Valuation Techniques and Metrics for Climate Change Impacts, Adaptation, and Mitigation Options:

Methodological Perspectives for the National Climate Assessment

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NCA Report Series, Volume 8

Valuation Techniques and Metrics for Climate Change Impacts, Adaptation, and Mitigation Options:

Methodological Perspectives for the National Climate Assessment

NCA Report Series

The National Climate Assessment (NCA) Report Series summarizes regional, sectoral, and process-related workshops and discussions being held as part of the third NCA process.

This workshop focused on techniques for quantitatively valuing climate impacts and adaptation in the context of the upcoming NCA. The workshop was held in Arlington, VA on January 12-13, 2011. Volume 8 of the NCA Report Series summarizes the discussions and outcomes of this workshop. A list of planned and completed reports in the NCA Report Series can be found online at http://assessment.globalchange.gov.

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EXECUTIVE SUMMARY

On January 12-13, 2011, the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) co-sponsored a workshop on valuation methods entitled, "Valuation Techniques and Metrics for Climate Change Impacts, Adaptation, and Mitigation Options." The principal goal of this workshop, which was convened on behalf of the Interagency National Climate Assessment (INCA) Task Force, was to provide a snapshot of the capabilities, readiness, and applicability of methodologies for quantitatively valuing climate impacts and adaptation in the context of the upcoming National Climate Assessment (NCA).The workshop was attended by about 70 representatives from federal agencies, non-governmental organizations, and research institutions. These representatives covered diverse disciplines, such as political science, public health, economics, climate modeling, and other social and physical sciences. Over the course of two days, these individuals participated in plenary sessions, discussions, and breakout groups exploring methodological perspectives on valuation in the context of the NCA. Background papers covering valuation techniques used for health, infrastructure, forestry, and other sectors were available prior to and distributed at the workshop.

Historically, valuation of impacts has not been a priority in the NCA. The first NCA, published in 2000, emphasized the use of models to evaluate the potential impact of changes in sectors and regions of the United States. The NCA released in 2009 drew from the findings of 21 Synthesis and Assessment Products (SAPs) produced by the U.S. Global Change Research Program (USGCRP) between 2004 and 2009. Neither NCA systematically focused on quantitative valuation of impacts, i.e., on translating impacts into metrics, such as damage to physical infrastructure, increased morbidity or mortality, or loss in ecosystem services. Such metrics supplement information on the pathways by which impacts occur and the likely direction of change. As a result, metrics can provide decision makers with an indication of the potential magnitude of changes to human and natural systems that might result from climate change.

Quantitative estimates of impacts frequently play a role in public and private sector decision making. At the national level, discussions about greenhouse gas (GHG) abatement policy frequently compare the cost of abatement—the cost of action—against impacts of climate change along the current trajectory—the cost of inaction. The depth and level of detail of available mitigation cost data is not, however, always matched by high quality data on impacts, hampering comparisons. Indeed, at all levels of government, the public sector faces decisions about what mitigation and adaptation options should be adopted and what investments (in mitigation or adaptation) should be made now. Many of these decisions have at least some quantitative (often financial or economic) component, and some depend heavily on information about costs and benefits of alternative options. Moreover, the private sector and business community require good information on the risks and opportunities presented by climate change, in order to make decisions for the future.

Although valuation has not historically been a significant component of the NCA, the academic and research community is gradually moving to fill the expressed need for quantitative estimates of impacts, and in turn building a growing (although somewhat desultory) body of literature. Economists have taken a leading role in producing this information, in part because of the types of policy questions being asked (many of which are economic in nature), and in part because of the existence of well-developed approaches within the profession that can be used to quantify and value. Economics has the additional advantage of providing a unifying framework and common metric (dollars) by which impacts in different sectors can be easily aggregated, allowing diverse impacts or values to be compared and combined. However, a number of non-economic methods for evaluating impacts also exist, and this workshop addressed both approaches to valuation.

The valuation workshop focused on identifying and exploring the range of methodological perspectives and issues surrounding valuation using the techniques of economics and other disciplines, in the context of the NCA. The workshop sought to build on existing practical experiences and applications of valuation approaches to both climate change and other environmental issues, and the use of both economics and alternative valuation metrics.

Key findings from the workshop are presented below, followed by a discussion of potential immediate next steps.

Valuation Workshop Findings and Insights

The presentations and discussions from the workshop clustered into four topic areas:

- meanings and uses of the concept of valuation and approaches to measurement
- methodological issues and challenges to (primarily quantitative) valuation in the context of the NCA
- types of economic valuation techniques and other metrics, current applications, and applying those techniques to climate impacts and adaptation
- the importance and potential for a consistent approach to valuation in the NCA going forward

Each of these areas is discussed below.

The Concept of Value and Approaches to Valuation

The concept of value is one that is not easily defined, and different disciplines define value differently. Figure ES-1 provides some examples of the concept of value as defined by different disciplines, along with the methods that are used, and the outcome or metrics that result. Although the Figure is based on material that was developed to explore the concept of value for ecosystems and so is far from comprehensive for our purposes, it illustrates the richness and variety in concepts of value and associated techniques, many of which could be relevant to the NCA. The figure should be considered illustrative of the range of available values and metrics, rather than as a definitive or consensus-based list.

In addition to the concepts and methods in the Figure, many other physical, social, health, and other measures and metrics exist that could be used to inform climate change decision making. Moreover, quantitative valuation, which entails the development of measures and metrics, is not the only mechanism by which values can be incorporated into decision making. As indicated in the Figure, some frameworks focus directly on understanding preferences and incorporating value—rather than valuation—into the decision-making process. Such approaches may be more appropriate for some decisions, or some decision-making groups.

Methodological Challenges to Valuation

Although valuation plays critical roles in many decision processes, it adds a layer of complexity to the already complex process of understanding impacts. Valuation is the final step in a series of steps that links emissions to changes in climate, to physical effects, and finally to the changes in human and natural systems that represent impacts. As such, valuation (whether quantitative or qualitative) is subject to the challenges and uncertainties endemic to impact assessment. In addition, the process of valuation faces some of its own unique challenges.

No single definition of the concept of value or universally accepted approach to valuation has been developed. Valuation is often interpreted as the process of placing a quantitative value—whether of dollars, physical measures, or another metric—on outcomes or consequences of an action or state of the world. Because different disciplines define the concept of value in different ways, they also frame the question of how or what to value in different ways, and so employ different methods.

Many public policy makers at all levels of government, as well as private decision makers, can benefit from valuation information on the impacts of climate change. Valuation information can be used to understand the impacts of alternative levels of greenhouse gas mitigation. Some concepts of value lend themselves to providing information that can be used to evaluate tradeoffs and set priorities across alternative adaptive actions. However, the information needs and capabilities of decision makers determine the type of data needed. In some cases, decision making may rely on qualitative or other types of information, rather than quantitative measures.

Climate change analysis poses challenges to valuation—whether in the development of quantitative valuation measures or the process of incorporating qualitative values into decision making. Challenges arise from the nature of climate change, the current state of knowledge about climate impacts, a lack of consistent and comprehensive data sources, and limitations in the available approaches.

Key challenges include

- ***Climate impacts are geographically dispersed and varied.*** Impacts encompass a wide range of categories, such as (at a minimum) ecological, health, infrastructure, and political effects. Assessment thus potentially requires a wide variety of types of information, at a detailed local level.

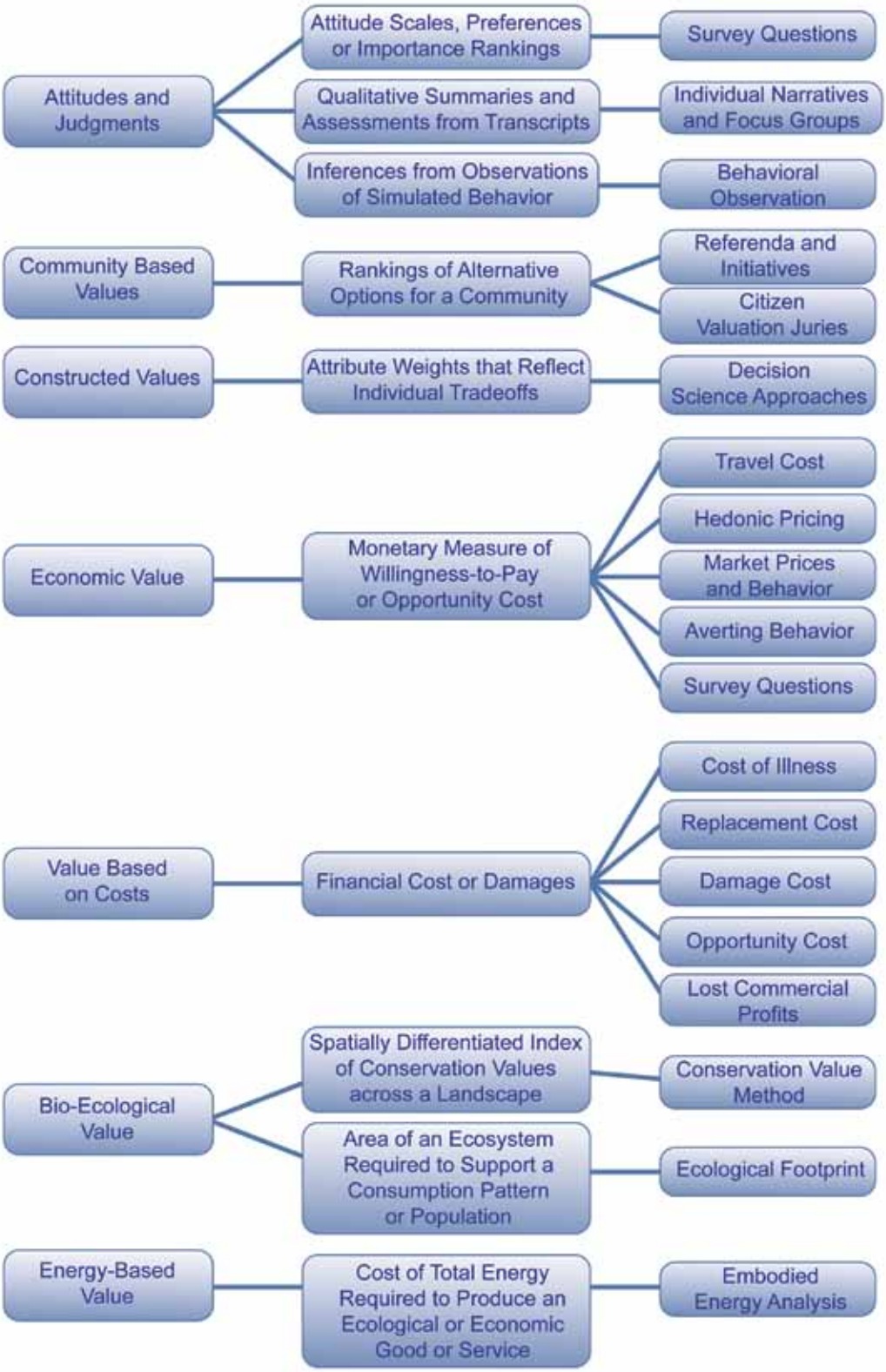


Figure ES-1. Flowchart relating concepts of value to methods and metrics. *Source*: Adapted from Table 3 of the EPA Science Advisory Board (2009) report, *Valuing the Protection of Ecological Systems and Services*.

- ***The intangibility of some climate impacts.*** Intangible impacts, such as changes in cultural icons or loss of trust in the government, can be very difficult to identify and more so to quantify.
- ***Impacts will be widespread and felt over long time frames.*** Valuation of impacts is difficult across generations and into the distant future. Valuation is further complicated by differences

in how regions, populations, and other subgroups are affected by climate change.

- ***Accounting for uncertainty, which is endemic to climate analysis.*** Uncertainties in the evolution of human systems, the mechanics of physical systems, the effects of a changing climate and the consequent human responses all contribute to the complexity of valuing climate change impacts.
- ***The interdependence of sector impacts.*** Economic sectors are so intertwined that it is impossible to fully understand the effects on one sector without taking into account impacts on other sectors. Similarly, adaptation and mitigation options go hand-in-hand – valuing one aspect without the other will result in inaccurate estimates.

Best practices and approaches exist to address many of these challenges, with the potential for greater or lesser degrees of success. For example, a robust and well-established literature (including the recent Synthesis and Assessment Product 5.2, *Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Decision Making*), describes methods for analyzing and expressing the uncertainty associated with climate change analysis. Analogously, economists have developed economy-wide models that can capture many of the inter-sectoral interactions.

Assessments should consider using a variety of measures, in order to present a nuanced view of value and to address the needs of decision makers. Different disciplines have developed a variety of measures that can be used to quantify impacts. For example, health impacts can be measured using the incidence of illness or mortality rates, cost of illness, willingness to pay to reduce health effects, measures of physical or mental health status, remaining years of life, and costs to the public health systems of reducing impacts.

Using a variety of measures will raise questions of which measures or metrics should be used, and how analyses can integrate diverse measures. It will also be important to understand when quantitative measures are relevant, and when qualitative impact assessments are appropriate.

An Exploration of Economic Valuation Methods

Economic valuation is one facet of the broader valuation landscape. The economic concept of value is grounded in welfare economics, which extracts value from the tradeoffs that people are willing to make, based on preferences (what they care about) and available resources (what they have available to trade). Market prices of commercially traded goods, replacement and restitution costs, damage costs, and costs of illnesses are all examples of measures that are commonly used to extract all—or in some cases only part—of the economic value of a good or service. Economic measures have both strengths and weaknesses when communicating the value of climate change impacts.

Economics has a well-developed set of techniques that has been widely applied in programmatic and policy situations. In water resources, for example, the U.S. Army Corps of Engineers applies a wide range of economic valuation measures. As another example, for regulations involving air pollution, the U.S. EPA routinely uses many measures of health impacts (including willingness to pay and cost of illness), as well as measures of impacts on materials and buildings.

Economic measures vary in data requirements, reliability, and acceptability. Economic valuation is most defensible when applied to tangible and measurable changes, for which market analogs exist. Other techniques associated with non-market goods, however, are also commonly used in policy and programmatic decision making.

The application of economic valuation to climate change impact measurement faces a number of conceptual, practical, and methodological considerations and, in some cases, challenges. As a consequence, economic values may not capture all aspects of value and so typically represent a lower bound estimate. Such challenges include

- ***Practical limitations.*** The varied types of impacts and the geographic and temporal scales of impacts generate significant data requirements which hinder the development of comprehensive measures of value. Gaps or uncertainties in our underlying data (or understanding) can limit our ability to measure and ultimately to place dollar values on a wide range of impact categories, as illustrated in Figure ES-2, which depicts one view of the process of developing economic values.

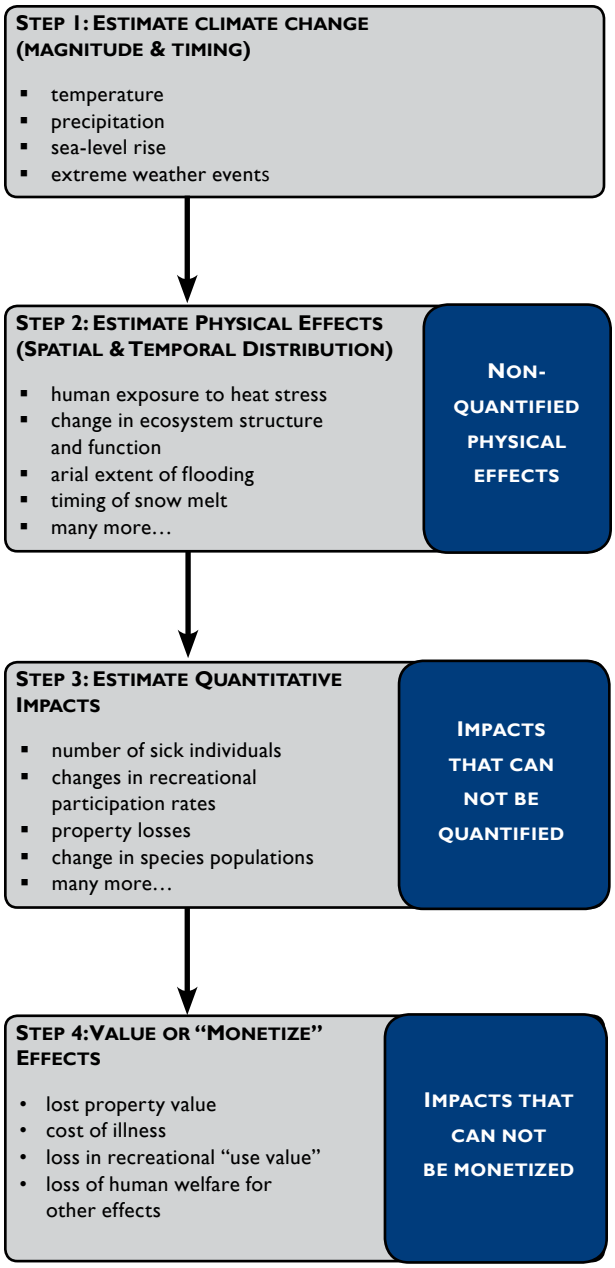


Figure ES-2. Estimating the monetized value of climate impacts. Reproduced from CCSP SAP 4.6 *Analysis of the Effects of Global Change on Human Health and Welfare and Human Systems*, 2008

- ***Controversial techniques and applications.*** A subset of economic valuation techniques, including some approaches to valuing human health and ecosystems services, are considered controversial, by some researchers.
- ***Theoretical assumptions and decision making.*** Welfare economics rests on a number of fundamental assumptions that are not always met by climate change (or other environmental problems). Characteristics of climate change, such as the magnitude of potential change or the long time frame of the analysis, challenge these assumptions and may raise questions about the applicability of economic valuation techniques, particularly if valuation is part of benefit-cost analysis as a decision-making tool.

In total, these challenges do not imply that the application of economic techniques to climate change is without merit. Rather, a key response to these challenges can be to take steps to ensure transparency, rigor, and completeness as much as possible in both the analysis and its presentation, and to clearly indicate underlying assumptions and limitations.

Consistency, Comparability, and Best Practices

Consistency across NCA "teams" in how they approach valuation is important to being able to aggregate, interpret, and use the results. The NCA will be conducted by teams operating across a range of economic sectors, impact categories, geographic regions, and cross-cutting topics. Comparing and in some cases aggregating the results of local and regional studies across sectors and regions will require some level of consistency and comparability in the way studies are conducted.

Consistency does not require that all studies use the same assumptions or methodologies. Rather, guidelines can be developed based on existing studies. Such guidelines might include a range of methodologies, or might only involve similar processes, i.e., answering a consistent set of questions, or stating assumptions in a similar way.

Best Practices should be adopted to ensure comparability, confidence, and transparency in valuation in the NCA. The NCA teams should contain a core set of capabilities and expertise. Analyses should be grounded in peer-reviewed and trusted literature and techniques. The analyses should be structured from the outset keeping in mind the goal of valuation, and what data will be needed to support valuation. Limitations of the analysis and assessment should be stated clearly, and discussed explicitly to ensure transparency.

Immediate Steps Forward

Valuation of climate impacts, particularly quantitative measurement using economic and non-economic techniques, would heighten the ability of the NCA to inform ongoing policy and decision making at all levels of government and in the private sector. However, guidance on key issues for

the assessment teams is required in order to produce a consistent and comparable set of results.

Guidance might include

- a comprehensive typology of impacts and impact categories, so that omissions and limitations of analyses in terms of coverage are more readily apparent
- an expression of the range of value concepts and valuation techniques to be considered, and the sectors or impact categories that are most ready for quantitative valuation of some kind
- for those sectors where valuation is appropriate, categories of metrics that are sufficiently mature, and a set of disciplines that should be involved in valuation in those sectors
- guidelines for the treatment of difficult cross-cutting issues, such as the approach to (and reporting of) uncertainty, discounting for economic analyses, and incorporating intersectoral interactions
- suggestions for presenting information that can become lost in valuation studies, such as streams of impacts over time or the distribution of impacts across population groups or regions
- recommendations for best practices and consistency in the use of specific valuation techniques, such as those economic techniques that are more controversial
- defining processes or outcomes that represent appropriate methods to ensure transparency and clarity in the presentation of assumptions, results, and analytical limitations
- highlighting the ongoing NCA process and the potential importance of incorporating non-quantitative or process-oriented concepts of value, as needed by decision makers

In addition, because valuation would be a new component of the Assessment, educational material may be needed for members of the assessment team, particularly those unfamiliar with social science approaches to valuation. A wealth of information already exists in academic and gray literature. As part of the workshop, a series of background papers on issues relating to economic valuation in various sectors was prepared, drawing on this information. These papers could provide a starting point for educational materials.

Workshop participants also mentioned the value of holding one or more workshops to develop guidance on specific thorny issues, such as discounting, for the NCA.

I. THE NATIONAL CLIMATE ASSESSMENT AND THE WORKSHOP PROCESS

Established by the Global Change Research Act of 1990, the National Climate Assessment (NCA) is required periodically (at least every four years) to analyze and report the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and well-being, human social systems, and biological diversity. The NCA must integrate, evaluate, and interpret the findings of the U.S. Global Change Research Program (USGCRP) and discuss the scientific uncertainties underlying the USGCRP's findings. In addition, the NCA is required to analyze current and future trends in natural and human induced global change over the next 25 to 100 years.

The next report of the NCA is scheduled to be completed in 2013. Strategic planning for the NCA began in early 2010. An interim strategic plan has been developed by the Interagency National Climate Assessment (INCA) Task Force, which includes members from all 13 USGCRP agencies plus several others. The NCA will continually solicit input from a broad range of stakeholders, decision makers, and concerned citizens to ensure that its vision and implementation is responsive to their needs.

The 2013 NCA is envisioned somewhat differently from the climate assessments that were released in 2000 and 2009. The ultimate goal of the NCA will be to support ongoing decision making at multiple levels while improving the overall efficiency of producing the major NCA work products, such as the 2013 report. As a result, the NCA will be a continued, sustainable process that draws on the work of scientists and stakeholders across the country (see Figure 1). This NCA will focus not only on impacts but also on responses of human and natural systems, and on evaluating the Nation's progress in adaptation and mitigation. Crucial to this effort will be building long-term capacity to perform ongoing assessments of vulnerability, observing and projecting impacts of climate change, and developing consistent indicators of progress in reducing vulnerability and increasing resilience. The Assessment process will promote the development of multiple reports, web-based data and tools, and scientific networks and capacity for information exchange and synthesis.

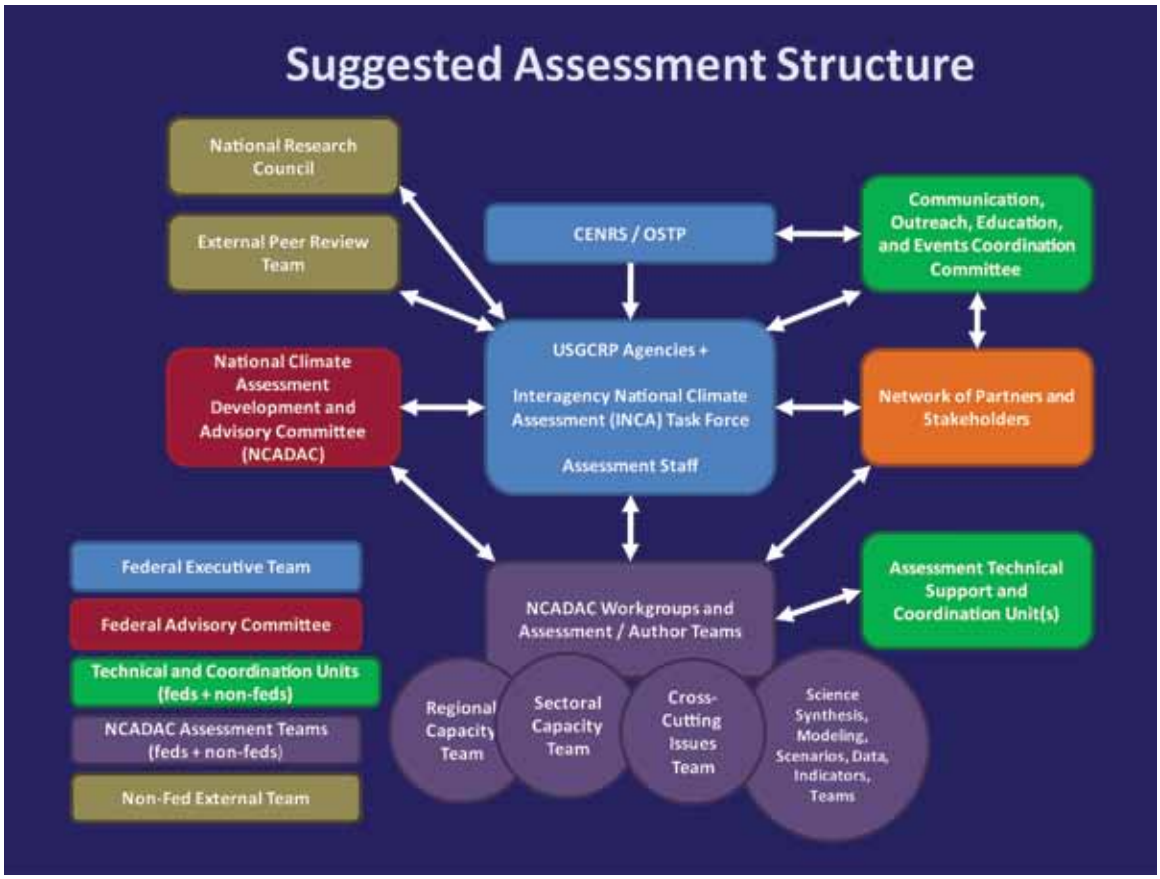


Figure 1. The suggested structure for ongoing and future National Climate Assessment processes. Provided by Katharine Jacobs, Director of the National Climate Assessment.

Some of the key objectives of the NCA include

- coordinating National Climate Assessment efforts across regions and sectors at multiple scales
- identifying gaps in knowledge, and providing information to help prioritize federal activities and science investments
- acknowledging the international context of climate trends and connections between climate risk and vulnerability in the U.S. and elsewhere

Members of the INCA Task Force have collaborated on a series of methodological and process workshops. These workshops, which have been funded by USGCRP agencies, have been designed to provide input to the 2013 Report as well as the ongoing Assessment effort. The workshops have convened a broad spectrum of individuals—including federal scientists and program managers, researchers, members of non-governmental organizations (NGOs), and representatives of state and local governments, utilities, and resource management agencies—in order to collect and integrate a range of expert opinions on ways forward for the NCA. The individual perspectives captured within the pages of the documents produced for and by these workshops provide a rich source of ideas for consideration by the architects of the NCA. In addition, these ideas and perspectives also help to inform the state of the science and build scientific capacity for more general use by the climate research community.

The workshops span a range of topics crucial to improving the methodologies used and the coverage of issues in the next NCA and the sustained Assessment process. The workshops have covered issues such as management of the multitude of data that will be generated by the various Assessment-related efforts; approaches to regional and sectoral assessments; the development of ecological indicators; and methodologies for scenario development.[1] This report focuses on outcomes from the workshop on "Valuation Techniques and Metrics for Climate Change Impacts, Adaptation,

[1] For more information on the National Climate Assessment, see http://globalchange.gov/what-we-do/assessment

and Mitigation Options: Methodological Perspectives for the National Climate Assessment" (referred to herein as the "Valuation Workshop"). This meeting covered techniques and issues related to the inclusion of economic and non-economic valuation approaches in the next NCA.

II. FORMAT OF THE VALUATION WORKSHOP AND THIS REPORT

The Valuation Workshop was planned by the Interagency National Climate Assessment (INCA) Task Force of the U.S. Global Change Research Program, in consultation with a group of researchers with expertise in aspects of valuing environmental, natural resource, health, and other impacts. Appendix A lists the individuals involved in planning the workshop. The workshop, which was held in Arlington, VA on January 12-13, 2011, was sponsored by the U.S. Environmental Protection Agency and the U.S. Department of Energy.

The principal goal of this workshop was to provide a snapshot of the capabilities, readiness, and applicability of methodologies for quantitatively valuing (i.e., placing a monetary or other type of value on) climate impacts and adaptation (and to a lesser degree, mitigation options). This snapshot will provide foundational insights that can help shape the subsequent recommendations and guidance to analysis teams engaged in the National Climate Assessment (NCA). The effort is intended to support both the 2013 NCA report and ongoing Assessment activities over the longer term.

Three primary topics were explored during the workshop:

- the current valuation landscape and the role of economic and non-economic techniques in that landscape
- general principles for applying valuation techniques for climate change analysis in a consistent and comparable manner
- the nature, applicability, and boundaries of economic techniques for valuation

These three topics were tackled over two days. The multifaceted nature of the workshop resulted in a wide variety of presentations that covered a range of topics and viewpoints. Each day contained two presentation sessions (each followed by question and answer periods) and a breakout session during which groups were charged to address specific guiding questions (see discussion below and Appendix B for a detailed workshop agenda and breakout charges).

The workshop convened about 70 representatives from federal agencies, non-governmental organizations (NGOs), and research institutions to discuss the current state of science, tools, and capabilities for quantitatively valuing climate change impacts, adaptation, and related mitigation options. In line with the inter-disciplinary spirit of the current NCA process, attendees included economists, social scientists, public health experts, climate scientists, ecologists, and engineers (Appendix C contains a complete list of participants).

Aware of the attendance of varied disciplinary experts, the workshop organizers prepared a series of background papers that served as introductory material to the tools and techniques of economic valuation, and were intended to stimulate discussion regarding their application to the NCA. The papers included overviews of economic valuation, economy-wide models, and integrated assessment models. Also included were summaries of valuation techniques used in specific sectors, including agriculture, health, commercial fisheries, land resources, the natural environment, transportation, water resources infrastructure, energy, air quality, and human social systems. These background papers, which were well-received by workshop participants and received several mentions during the presentations and discussions, will be published as a separate document.

Details on the Workshop Agenda

The first day of the workshop featured plenary talks discussing previous NCAs, identifying the need for a sustained and collaborative Assessment process capable of translating scientific information into the knowledge needed to support decision making, and assessing the need for inclusion of valuation techniques within the auspices of the NCA process. To complement the background papers, several presentations covered the current state of the valuation landscape. Other presentations addressed climate modeling tools and interactions with valuation techniques, presented a typology of climate impacts, described the use of valuation in adaptation policy and decision making, and assessed the possibilities of developing a national strategy for tracking climate change effects through valuation techniques.

In the first facilitated breakout session, groups were charged with creating guiding principles on the use of economic and other valuation techniques in the NCA, and determining a practical framework that could be used to implement these recommendations, while identifying the key gaps in the current state of knowledge to prioritize future research (see Appendix B for the agenda and detailed breakout charges). The breakout groups were assigned randomly, and contained representatives from different disciplines, which led to rich discussions that are expanded in later parts of this report. These groups were not required to reach consensus. Rather, participants were asked to provide individual opinions on the topics to provide input to the development of the NCA.

Day 2 focused on generalizing the lessons learned from the previous day. Presentations elicited the key issues in researching, designing and implementing valuation techniques: issues of uncertainty, cross-sectoral interactions, integrating and combining metrics of value, and discounting. The discussions from this session directly fed into the breakout group discussions on the second day, which focused on prioritizing issues and topics that should be included in the near-term NCA report. The expert groups were requested to think of possibilities for ensuring consistency and sustainability in the application of valuation techniques in these prioritized issues and sectors. Participants were also asked to provide input on the NCA process in general.

Over the two days, the participants were immersed in various discussions surrounding the fundamentals of valuation, its applicability to the NCA process and possible methods for its inclusion. The breakout groups provided an opportunity for participants from different disciplines to interact, discuss their varied approaches to the concept of valuation and its applicability in their respective fields, and provide feedback to the INCA Task Force and the Federal Advisory Committee on the role of valuation within the NCA. The lessons learned from the presentations, breakout groups, and discussion sessions are described in subsequent sections.

Structure of the Workshop Report

The remainder of this report is divided into three main sections. Section III addresses the state of valuation in previous NCA reports as well as the motivation and need for valuation in the next iteration. Section IV draws from the contents of the workshop and the background papers and is structured in three subsections that address the current state of the valuation landscape, the boundaries of economic valuation and lastly, issues that arise from the use of such methodology. Section V concludes with a discussion of next steps and ways to improve the inclusion of valuation techniques in the NCA. Sections VI and VII provide references and a glossary of economic terms. Several appendices provide additional information on the workshop.

III. VALUATION IN THE CONTEXT OF THE NATIONAL CLIMATE ASSESSMENT

Historically, the National Climate Assessments (NCAs) "have focused primarily on providing an overview of the impacts of climate change in the United States" (Report from NCA Strategic Planning Workshop, 2010). The first NCA, published in 2000, was built on a large stakeholder process, and included an extensive review of available literature and model output, to evaluate the potential impact of changes in sectors and regions of the United States. The second NCA in 2009 drew on the findings from 21 Synthesis and Assessment Products (SAPs) produced by the U.S. Global Change Research Program[2] (USGCRP) between 2004 and 2009, as well as other peer-reviewed scientific assessments and regional climate impact assessments.

The 2009 NCA identified a mix of socioeconomic, physical, and scientific dimensions of the impacts of climate change. Impacts are generally expressed in terms of potential or likely physical changes in human or natural systems, such as deterioration of roads and buildings due to extreme weather events, or impacts on industry and production. In only a few instances are climate change impacts and adaptive responses measured (i.e., valued). Almost no information is provided on economic damages or consequences; while the report includes some information on economic losses from current weather phenomena and on the value of what could be at risk, in very few instances are economic damages associated with projected climate change.

Science-based research provides a necessary foundation for understanding the impacts of climate change. Equally, measurement or valuation further

[2] USGCRP was formerly named the Climate Change Science Program (CCSP).

Box 1. The IPCC Fourth Assessment Report

Better valuation methods and quantification of current and future trends in climate and its related costs would make the case for informed action (or inaction). The Intergovernmental Panel on Climate Change (IPCC), in their Fourth Assessment Report, identified the need for quantitative evaluation of direct trade-offs using valuation techniques as a key research gap that has direct relevance to designing climate policy (IPCC, 2007a).

enables stakeholders to develop policy responses that reflect the relevant tradeoffs among impacts, mitigation actions, and adaptation options. In fact, the Intergovernmental Panel on Climate Change (IPCC), in its Fourth Assessment Report, has specifically highlighted the need for quantitative information to aid in designing climate policy (see Box 1).

Accurate, reliable, and consistent treatments of the implications of action and inaction are needed to ground national-, regional-, and local-level policymaking. In the policy and academic communities, economic valuation has received more attention than other valuation approaches. Economic valuation has the advantage of enabling stakeholders to compare the effects and consequences of alternative policies and decisions using a common metric—dollars. However, the peer-reviewed literature on the costs associated with impacts of climate change (i.e., the costs of inaction) and associated adaptation options is much less developed than the mitigation cost literature. Further, the literature on impacts and adaptation is very limited in both geographic scope and the impact categories considered. Consequently, information on values, including economic values and metrics, represents a critical missing piece of the puzzle for three distinct climate policy contexts.

First, considerable effort has gone into estimating the cost of mitigating greenhouse gas emissions at the national level. Analyses have explored a wide range of technologies that reduce emissions of greenhouse gases and a range of future socioeconomic conditions, types and rates of technological change, regulatory futures, and energy prices. Corresponding detail and depth on the impacts side—the so-called "costs of inaction"—is not, however, widely available and where it exists, it is spotty at best. Consequently, debates that seek to weigh the economic tradeoffs accompanying alternative levels of action to reduce greenhouse gas emissions (and slow the rate of climate change) face uneven information on which to base a decision. Improved depth and breadth of data on the economic measures of the consequences of climate change, including the uncertainty surrounding that information, can provide a counterpart to the wealth of data on the economic consequences of mitigation, and so facilitate informed national discussions. This does not mean, however, that the "costs of inaction" can or should all be presented in the form of economic values. Nonetheless, the generalization still holds that economic and other broad-based forms of quantification, such as risk-based measures, are generally lacking for valuing impacts.

Second, state, local, and tribal decision makers have a stake in how climate change will influence the future costs of protecting the public health, providing transportation services, and maintaining public infrastructure. These stakeholders face questions regarding climate change and what response options they should adopt, and what investments should be made now. Many—although not all—of these decisions have at least some economic component, and some depend heavily on information regarding the costs and effectiveness of alternative adaptation options. Indeed, the National Research Council's *America's Climate Choices* report (see Box 2) highlighted that "current efforts [to adapt] are hampered by a lack of solid information about the benefits, costs, and effectiveness of various adaptation options" (NRC, 2010). The NCA is in a unique position to influence how this information base continues to be developed and made available.

Box 2. A Need for Information

"Adaptation is a process that requires actions from many decision-makers in federal, state, tribal, and local governments, the private sector, non-governmental organizations, and community groups. However, current efforts are hampered by a lack of solid information about the benefits, costs, and effectiveness of various adaptation options, by uncertainty about future climate impacts at a scale necessary for decision-making, and by a lack of coordination."
--*Adapting to the Impacts of Climate Change*, America's Climate Choices Panel, National Research Council, 2010.

Last, the private sector and business community will also be key players in efforts to reduce emissions and adapt to the impacts of climate change. "Without economics and [financial costs] as part of the Assessment, it will be difficult to engage business and industry" (NCA Midwest Regional Workshop, 2010). The translation of the science of impacts into practical information and the availability of easily understood knowledge on current and future impacts will also provide businesses with data and knowledge upon which to build strategies for their respective operations.

Past NCAs have assessed the state of scientific knowledge on the impacts of climate change across sectors and regions. In this upcoming iteration, the aim is also to establish a sustainable process for ongoing improvement and expansion of the state of knowledge. The NCA can be a prime motivator for continued research into the valuation of climate impacts in order to adequately and accurately inform national, regional, and local public and private decision makers.

Box 3 summarizes key insights from Section III.

IV. ECONOMIC AND NON-ECONOMIC VALUATION: TOOLS, METRICS, METHODS, AND BOUNDARIES

Valuation can serve different purposes. As described in Section III above, the climate change policy context suggests that valuation can make an important contribution to decision making by the private sector and by various scales of government (e.g., national, state, and local). In this context, the purpose of incorporating valuation into research on climate change is to better understand the nature and magnitude of climate change impacts, the potential of adaptation to mitigate those impacts, and the tradeoffs inherent in different choices. Valuing current and future impacts and response options may inform decision makers and the public about economic and non-economic benefits and costs and potential tradeoffs.

How valuation can and should be incorporated into the National Climate Assessment will depend on a variety of factors. The policy context, the strengths and weaknesses of the various tools provided by relevant disciplines, and the nature of climate change impacts and available mitigation and adaptation options, will each have important implication for valuation. This section explores the perspectives that emerged at the workshop about the nature, purpose, and appropriate applications of valuation.

Box 3. Valuation in the Context of the National Climate Assessment: Key Insights

Past NCAs have not consistently included valuation techniques in their assessment of the current state of information on the impacts of climate change. Valuation, particularly economic valuation, will be useful in enabling stakeholders with a common metric – dollars – by which to compare the effects and consequences of alternative policies and decisions.

- Accurate, reliable, and consistent treatments of the costs of action and inaction are needed to ground national, regional, and local level policy making.
- Valuation will be useful in three distinct climate policy contexts:
  - providing information on the costs of the projected impacts of climate change to facilitate weighing the economic tradeoffs inherent in reducing greenhouse gas emissions and responding to the impacts of climate change
  - equipping state, local, and tribal decision makers with economic information on response options to support their decision-making processes
  - supporting the private sector and business community in their efforts to reduce emissions and adapt to the impacts of climate change

The perspectives expressed at the workshop are summarized in four sections[3]:

- The valuation landscape—the meaning and uses of the concept of valuation and applications to climate change decision making, and the strengths and weaknesses of quantitative valuation in that context
- Methodological consistency and comparability—discussion of methodological issues and challenges to both economic and non-economic valuation efforts in the context of climate change and the NCA
- Economic valuation techniques—a detailed look at available economic valuation techniques and the challenges that climate change poses to the application of these techniques
- Consistency and comparability—a discussion of the importance and potential for a consistent approach to valuation in the NCA going forward

Although valuation is critically important in decision processes, it adds another layer of complexity to the already complicated process of understanding the impacts of climate change. Participants emphasized that valuation techniques should be appropriately chosen to present a more nuanced and complete value of the issues at hand. Quantitatively estimating the impacts of (and responses to) climate change poses many challenges. These challenges include issues of uncertainty, inter- and intra-generational equity, discounting, and levels of aggregation/disaggregation.

Participants pointed toward existing best practices to address these methodological constraints and challenges. Consistency across NCA teams will be critical in interpreting, utilizing, comparing, and aggregating the results of valuation exercises. Further, ensuring transparency and rigor in the use of valuation techniques and the communication of results will be imperative in maintaining a robust, trusted, and sustainable Assessment process.

The Valuation Landscape

Loosely stated, valuation can be thought of as the process of placing a quantitative value—whether dollars, physical measures, or other metrics—on outcomes or consequences of an action or change in a state of the world. In this sense, valuation can refer to some sort of measurement, obtained by employing the tools of economics or alternative methods that rely on physical, socioeconomic, or psychological metrics to measure output or progress. However, the process of incorporating "value" into adaptive decision making for climate change can be interpreted in other ways as well. For example, the concept of incorporating value might encompass a process that integrates intrinsic and extrinsic value into decision making, but does not necessarily rely on quantifying specific metrics.

Different disciplines view "value" in different ways. Traditional economics, for example, views value in terms of how something contributes to the satisfaction of human wants and needs. A physical system approach, however, might view value in terms of how a component interacts with or contributes to the functioning of a system. The value placed on something by an individual will reflect the underlying philosophical perspectives and material circumstances of that individual. Consequently, there is no single, widely accepted definition of value or applicable tool for measuring value, i.e., for conducting valuation.

Different ways of approaching the concept of value have strengths and weaknesses that depend on the approach itself, on the characteristics of climate change impacts and adaptation options, and on the context within which decisions are made. Consequently, incorporating valuation into the NCA—whether using the tools of economic valuation, identifying economic, societal, ecological, physical and other indicators, or employing other means—will need to reflect the richness and complexity of the concepts and uses of value and clearly describe assumptions and methodologies.

Workshop participants made a number of important observations about how valuation can/should be incorporated into the NCA. This section presents alternative views of valuation that were brought out in the workshop. The first subsection discusses alternative concepts of value and methods for assessing value. The second discusses the purpose of valuation, and the final subsection focuses on valuation in the context of decision making. In contrast to the ideas presented in other sections of this workshop report, the discussions reported in this section were less focused on specific topics and outputs, but rather explored the multi-dimensional

[3] Section VII is a glossary of terms, and contains economic terms that are used in Section IV and may not be familiar to all readers of this report.

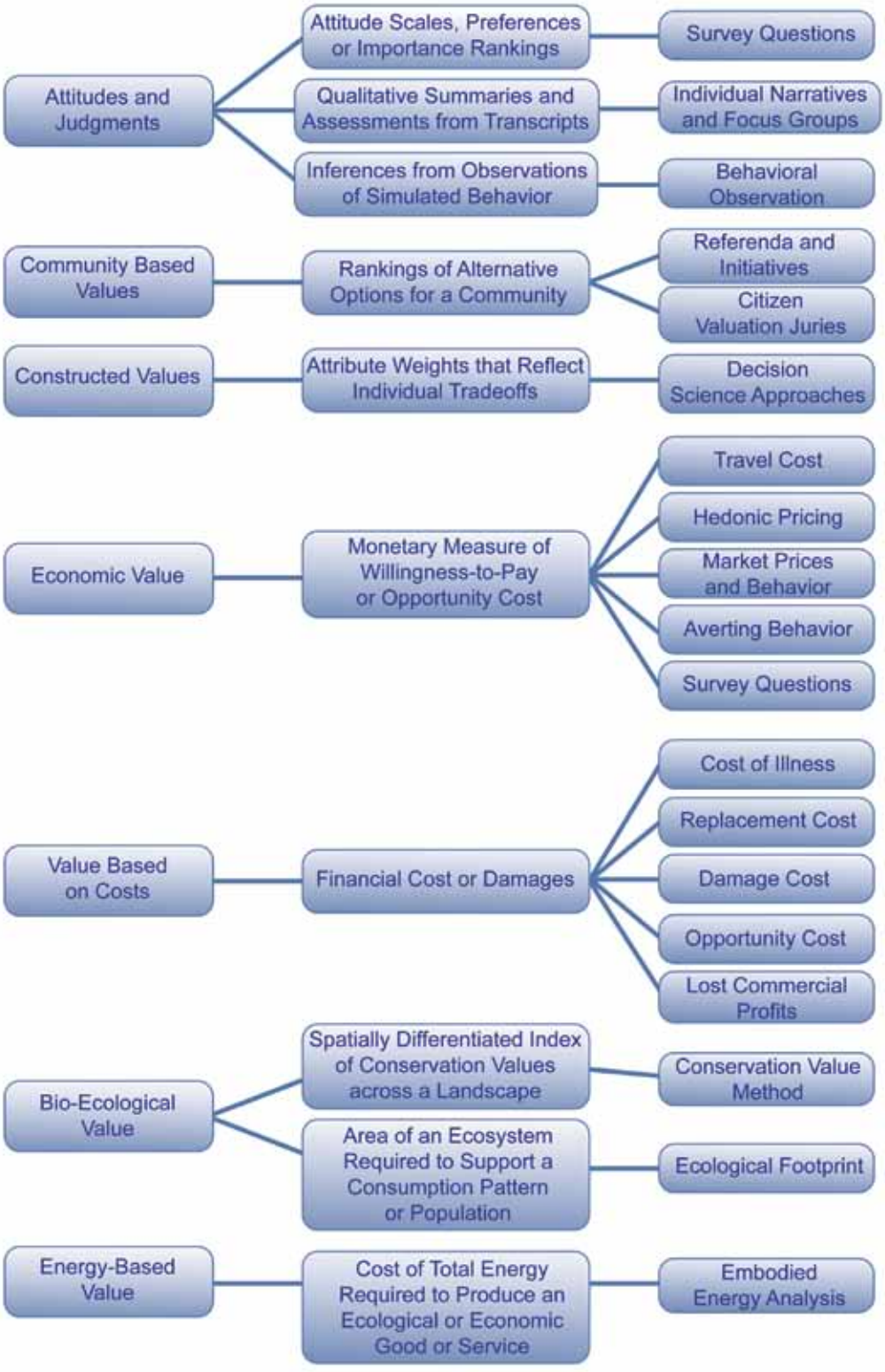


Figure 2. Flowchart relating concepts of value to methods and metrics. *Source:* Adapted from Table 3 of the EPA Science Advisory Board (2009) report, *Valuing the Protection of Ecological Systems and Services*.

nature of valuation. Box 7 at the end of this section summarizes key insights.

Methods for Assessing Value

Concepts of value vary along several dimensions, and no real agreement exists on how to define "value." For example, while an economic concept of value focuses on human preferences, other concepts of value may focus more on natural and ethical rights. And, even if human preferences are judged to be the basis of value, the question arises whether preferences should be those of individuals or of society, as well as how to treat the preferences of different generations or to aggregate preferences across individuals or different population groups. Consequently, no single, simple definition of value exists, and different disciplines view the concept differently.

The workshop highlighted the findings from a recent report prepared by the Science Advisory Board (SAB) of the U.S. Environmental Protection Agency, which grappled with the question of how to define and incorporate valuation in the context of ecological systems and services. The report was the result of a four-year effort that assembled a large, interdisciplinary committee to address the question of how to value the protection of ecological systems and services. The committee was charged with assessing the state of the art and science of valuing protection, and identifying key areas for improving knowledge, methodologies, practice, and research at EPA.

The SAB report points out that value is not a single concept. Rather,

> *People have material, moral, spiritual, aesthetic, and other interests, all of which can affect their thoughts, attitudes, and actions. . . Furthermore, experts trained in different disciplines (e.g., decision science, ecology, economics, philosophy, psychology) understand the concept of value in different ways. . .*

The report also points out that a fundamental distinction can be drawn between things that are valued as means (based on their usefulness in bringing about something else) or as goals (an end or outcome that is valued in its own right).

The diversity of the concepts of value and the tools that different disciplines bring to valuation is illustrated in Figure 2, which is adapted from Table 3 of the SAB report and informed by the background papers prepared for this workshop. This chart illustrates some of the methods that different disciplines offer for measuring different concepts of value, and the outputs or units that result. It should be considered illustrative of the range of available values and metrics, rather than definitive or a consensus-based list. The concepts of value include

- ***Attitudes or judgments.*** This concept of value acknowledges the individuals' priorities and preferences. The expression of these values is not constrained by income or prices. They are based on empirical evidence on individuals' attitudes, preferences, and behavior as captured by surveys, choices, or ratings.
- ***Economic values and other economic or financial measures.*** The economic approach to value specifically takes into account the tradeoffs that individuals are willing to make, given constraints of income and price. This concept of value assumes that actors are rational and are cognizant of, and stable in, their preferences and attitudes.
- ***Community-based values.*** In this approach toward value, individuals purposefully make choices that will benefit the broader public, versus serving their own interests and priorities. Alternatively, the individual expresses his or her value of goods in terms of the tradeoffs

Box 4. Recommendations from Valuing the Protection of Ecological Systems and Services

The large, interdisciplinary committee was charged with assessing the state of the art and science of valuing the protection of ecological systems and services and identifying the key areas for improving knowledge, methodologies, practice and research at the U.S. EPA. The committee had several key recommendations:

- Use an "expanded and integrated" approach to valuation–that is, they should
  - assess and quantify a broader range of impacts,
  - consider a larger suite of methods for valuation,
  - encourage interdisciplinary collaboration
- Prioritize valuation of impacts according to their importance to society versus easily valued impacts
- Encourage the prediction of impacts in terms that lend themselves to valuation
- Consider the use of a wider range of possible valuation methods

Source: U.S. EPA SAB, 2009

that he feels society should make to make the community better off.

- ***Constructed values.*** This concept begins from the premise that individuals do not have well-established preferences or values when confronted with unfamiliar situations. Constructed preferences are thus derived from deliberative processes that help individuals deduce their preferences and values in a particular situation.
- ***Bio-ecological values.*** This value depends on the relationships between the ecosystem conditions, functions, and a pre-determined biophysical goal or standard. Here, biophysical values refer to the contribution of ecological changes to a certain ecosystem-based goal or standard.
- ***Energy-based values.*** These values are not defined in terms of preference-based tradeoffs. Rather, they are defined in terms of the direct or indirect energy required to produce a good or service.

The SAB committee identified a number of over-arching and other key recommendations (see Box4) that recognize the complexity of the concept of valuation. The inherent challenges in valuing ecological protection are mirrored in those for many climate change impacts. Both are complex, stochastic, large-scale, and involve tipping points. Both include spatial and temporal heterogeneity and impacts that cut across geographic regions, sectors, and generations. Consequently, many of the recommendations of this report also resonate as recommendations for valuation in the context of climate change. However, the concepts and tools relevant to impacts of climate change transcend impacts on ecological systems and ecosystem services.

A large body of literature explores socioeconomic and other indicators of human well-being. CCSP Synthesis and Assessment Product (SAP) 4.6, *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems*, focused on impacts of climate change on three broad dimensions of the human condition: health, settlements, and welfare or well-being. As part of the discussion of welfare, the report looked at different approaches to identifying a range of metrics that capture quality of life and human welfare, broadly defined. One widely-applied use of metrics is the social indicators approach, in which location-specific measures of social, economic, and environmental conditions are assembled and used to indicate life quality. For example, pollution levels, availability of recreational opportunities, employment rates, and rates of volunteerism are all indicators of conditions that may influence quality of life in a given location. Table 1, reproduced from SAP 4.6, identifies oft-used categories or dimensions of place-specific quality of life or well-being. The Table explores each dimension in terms of its components, metrics that can be used to measure it, and how the category or dimension might be applicable to climate change.

The NCA process also recognizes the importance of these types of indicators, and is holding two topical workshops. The NCA hopes to identify a relatively small number of policy-relevant, integrated indicators, designed to provide a consistent, objective, and transparent overview of major trends and variations in climate impacts. These indicators are expected to include physical climate, ecological, and societal components.

While valuation is often conceived of as an effort to quantify or measure value (whether in dollar terms or via another metric), an alternative view is that value is something to be captured in decision making, but not necessarily quantified. In this view, value can be incorporated into a decision in different ways, for example, by making particular values explicit (e.g., following the precautionary principle), or following explicit decision rules for tradeoffs (e.g., minimizing likelihood or the magnitude of the worst cases).

Quantitative analysis and valuation can also be integrated into deliberative processes. For the remainder of this section on the valuation landscape, the term "valuation" is used relatively loosely, and may include qualitative statements of magnitude, as well as quantitative estimates (including monetary estimates as well as other indicators or measures).

Why Valuation Matters

Valuation can have different purposes and goals. A number of participants stressed that the type of valuation that is done—what methods are used, how the results are interpreted, and how relevant or robust quantitative methods of valuation are viewed as being—depends, at least in part, on the purposes for which valuation is being done.

Table 1. The Relationship Between Categories Of Well-Being And Climate Impacts

Category of Well-being	Description and Rationale	Components / Indicators of Well-being	Illustrative Metrics / Measures of Well-being	Examples of Negative Climate Linkages
Economic conditions	The economy supports a mix of activities: opportunities for employment, a strong consumer market, funding for needed public services, and a high standard of living shared by citizens.	▪ Income and production ▪ Economic standard of living, e.g., wealth and income, cost of living, poverty ▪ Economic development, e.g., business and enterprise, employment ▪ Availability of affordable housing ▪ Equity in the distribution of income	▪ Gross Domestic Product (GDP) ▪ Wage rates (e.g., persons at minimum wage) ▪ Employment rates ▪ Business startups and job creation ▪ Housing prices ▪ Dependence on public assistance ▪ Families/children living in poverty ▪ Utility costs, gasoline prices, and other prices	Reduced job opportunities and wage rates in areas dependent on natural resources, such as agricultural production in a given region that faces increased drought. Higher electricity prices resulting from increased demand for Air Conditioning as average temperatures and frequency of heat waves rise.
Natural resources, environment, and amenities	Resources enhance the quality of life of citizens; pollution and other negative environmental effects are kept below levels harmful to ecosystems, human health, and other quality of life considerations; and natural beauty and aesthetics are enhanced.	▪ Air, water, and land pollution ▪ Recreational opportunities ▪ Water supply and quality ▪ Natural hazards and risks ▪ Ecosystem condition and services ▪ Biodiversity ▪ Direct climate amenity effects	▪ Air and water quality indices ▪ Waste recycling rates ▪ Acreage, visitation, funding of recreational and protected/preserved areas ▪ Water consumption and levels ▪ Deaths, injuries, and property loss due to natural hazards ▪ Endangered and threatened species	Sea Level rise could both inundate coastal wetland habitats (with negative effects on marsh and estuarine environments necessary to purify water cycle systems and support marine hatcheries) and erode recreational beaches.
Human health	Health care institutions provide medical and preventive health-care services with excellence, citizens have access to services regardless of financial means, and physical and mental health is generally high.	▪ Mortality risks ▪ Morbidity and risk of illness ▪ Quality and accessibility of health care ▪ Health status of vulnerable populations ▪ Prenatal and childhood health ▪ Psychological and emotional health	▪ Deaths from various causes (suicide, cancer, accidents, heart disease) ▪ Life expectancy at birth ▪ Health insurance coverage ▪ Hospital services and costs ▪ Infant mortality and care of elderly ▪ Subjective measures of health status	Increased frequency of heat waves in a larger geographical area will directly affect health, resulting in higher incidence of heat-related mortality and illness. Climate can also affect human health indirectly via effects on ecosystems and water supplies.
Public and private infrastructure	Transportation and communication infrastructure enable citizens to move around efficiently and communicate reliably.	▪ Affordable, and accessible public transit ▪ Adequate road, air, and rail infrastructure ▪ Reliable communication systems ▪ Waste management and sewerage ▪ Maintained and available public and private facilities ▪ Power generation	▪ Mass transit use and commute times ▪ Rail lines, and airport use and capacity ▪ Telephones, newspapers, and internet ▪ Waste tonnage and sewerage safety ▪ Congestion and commute to work ▪ Transportation accident rates ▪ Noise pollution	Melting permafrost due to warming in the arctic damages road transport, pipeline, and utility infrastructure, which in turn leads to disrupted product and personal movements, increased repair costs, and shorter time periods for capital replacement.
Government and public safety	Governments are led by competent and responsive officials, who provide public services effectively and equitably, such as order and public safety; citizens are well-informed and participate in civic activities.	▪ Electoral participation ▪ Civic engagement ▪ Equity and opportunity ▪ Municipal budgets and finance ▪ Public safety ▪ Emergency services	▪ Voter registration, turnout, approval ▪ Civic organizations membership rates ▪ Availability of public assistance programs ▪ Debt, deficits, taxation, and spending ▪ Crime rates and victimization ▪ Emergency first-responders per capita	Dislocations and pressures created by climate change stressors can place significant new burdens on police, fire and emergency services.
Social and cultural resources	Social institutions provide services to those in need, support philanthropy, volunteerism, patronage of arts and leisure activities, and social interactions characterized by equality of opportunity and social harmony.	▪ Volunteerism ▪ Culture, arts, entertainment, and leisure activities ▪ Education and human capital services ▪ Social harmony ▪ Family and friendship networks	▪ Donations of time, money, and effort ▪ Sports participation, library circulation, and support for the arts ▪ Graduation rates and school quality ▪ Hate, prejudice, and homelessness ▪ Divorce rates, social supports	Disruptions in economic and political life caused by climate change stressors or extreme weather events associated with climate change could create new conflicts and place greater pressure on social differences within communities.

Source: Reproduced from CCSP, 2008.

Box 5. Purposes of Valuation: One View

Valuation can be undertaken with different goals: demonstration, design, and deliberation. Qualitative and quantitative valuation methods have different strengths and weaknesses in contributing to these goals.

Demonstrating that Impacts Have a Given Magnitude. Valuation can be used to demonstrate that impacts have magnitudes of a given size. Quantitative measures (such as economic valuation) are strong in this regard, although they may not capture all aspects of value and so represent a lower bound. The process of quantitative valuation can also provide much-needed documentation on the projected impacts.

Quantitative measures may be misleading as measures of magnitude if they focus on quantifying impacts that are easiest to do first, rather than those that are most important. Moreover, impact estimates will depend critically on underlying assumptions, which may not always be transparent.

Designing Programs to Address Impacts. Both qualitative and quantitative measures of value, as well as multidisciplinary inputs, can assist in program design. In some cases, the magnitude of impacts may be less important than the knowledge of how to accomplish program goals, i.e., how to reduce impacts. In this case, valuation that highlights what is important may be more valuable than valuation that estimates a magnitude.

Deliberative Process. Valuation can help to identify that the things that we value, facilitate an informed discourse among stakeholders, and aid the development of solutions. Shared mutual understanding is critical in creating a sustainable, informed process. However, there is a danger that the process of valuation may receive more emphasis than the rigor of quantitative valuation, and that deliberation may take precedence over the development of an actual end goal.

Participants characterized the purposes to which valuation can be put in different ways. A common theme, however, was that valuation can be used both (1) to understand and characterize the world and (2) to assist in decision making. One paradigm that was presented described valuation goals by the extent to which the purposes of the valuation is descriptive or normative. For example, valuation can be used to describe what is, e.g., to provide information to decision makers on the magnitude of impacts, or simply to educate stakeholders. Normatively, valuation can be used to rank or prioritize alternative outcomes or actions, or in other ways act as a decision aid. Participants also discussed how valuation can be used to motivate action, e.g., by indicating the magnitude of climate impacts or providing a comparison between the costs of action (e.g., to reduce greenhouse gas emissions) and the cost of inaction (e.g., if climate change continues unabated).

Participants discussed the advantages and disadvantages of different types of quantitative measures of value, including not only economic measures of value but also societal, physical, ecological, and other indicators (described in more detail above and revisited in the section on *"Economic Valuation: Methods, Applications, and Strengths and Weaknesses"*). In the field of health, for example, measures of mortality are available, as well as life-years remaining (LYs) and quality adjusted life-years remaining (QALYs). These and other quantitative measures have the general advantages of being explicit, quantitative, and replicable, and so are useful for cost-effectiveness analyses, where alternative options to reach similar goals are compared using cost (and other characteristics). Monetary measures of value (e.g., applying a dollar value to a change in mortality or risk or incidence of illness) have the additional advantage of being easily aggregated, allowing diverse impacts or values to be compared and combined. Quantitative measures, including monetary measures, have the disadvantage of being somewhat rigid; quantitative values have an appearance of rigor that may not be warranted, if uncertainty is high, key impacts are omitted, or values cannot easily be adapted to reflect the preferences of different users of the information.

The purpose of the valuation affects what type of valuation should be used, the degree of precision or quantification needed, and the most appropriate measure. For example, valuation information that is used to judge the need for immediate action can be based on the potential scope of the benefits and/or damages and may not need to be precise. The application of valuation techniques can deepen our current understanding of adaptation, resilience, and adaptive capacity. One participant pointed out that the process of valuation should be accessible and framed in such a manner that it can be used to

engage and educate stakeholders and help them understand the impacts and options available for response.

Measures that are used to support decision making in specific sectors may need different characteristics and meet different criteria. For example, if the purpose is to assist in setting priorities across adaptation options, then measures that are comparable across adaptation options are needed, but the measures do not necessarily need to be in dollar terms. It was also noted that in the context of making decisions in complex, multi-dimensional systems the process of valuation can be as important as the outcome. These issues are discussed in the context of decision making below.

One paradigm presented at the workshop clustered the potential purposes of valuation into three categories: demonstration, design, or deliberation (see Box 5). Each of these purposes will suggest more or less quantitative measures and the relative strengths and weaknesses of alternative approaches to valuation in comparison with each other and with various decision processes, as described in the text box.

Valuation in the Context of Decision Making

One of the potential uses of valuation information is to contribute to decision making about climate change. Such decisions could include weighing costs of action and inaction in order to inform emissions abatement policies, comparing climate change impacts across impact categories to inform priorities for planning and actions to address impacts, and analyzing adaptation options. Several participants pointed out that valuation is contextual; users of information, their information needs, and the types of decisions being made may together determine the types of valuation that is appropriate (see Box 6).

Not only the types of decisions, but the way in which the decision is made and by whom (and the information needs and capabilities of the decision makers) influences the type of data that is needed, and whether qualitative information, quantified measure of value, or monetized estimates are appropriate and helpful. Participants made a number of observations:

- Comparisons of adaptation options do not necessarily require monetized estimates of effectiveness but do require measures that are comparable across the options being evaluated.
- Different decision (ranking) rules require different types of valuation information.
- Decision makers do not always use economic data but make decisions based on other criteria and considerations.
- A well thought out process, as well as tools, is important for bringing values into decision-making processes.
- Consistency and transparency are critical in ensuring comparability of replicable and robust estimates.

Box 6. Information Needs in Tribal and Indigenous Decision Making

One presentation focused on adaptive decision making in a variety of circumstances. The presentation pointed out that some indigenous communities have their own long-standing methods of valuing cultural practices and other climate impacts, and systems for collecting information on climatic and ecosystem trends relevant to their livelihoods and way of life. Metrics and values assembled for other, more general purposes may not provide the types of information needed for decision making in these communities.

Participants noted that valuation can contribute to a range of decision-making approaches and analytical frameworks. Such approaches and frameworks include benefit-cost analysis, more complex risk and resource management approaches, multi-criterion analysis, and triaging. Some participants pointed out the benefits of using bounding analysis to understand the range of likely futures; this approach identifies all the contingencies that could lead to low and high values of impacts.

Climate Change and Valuation: Methodological Considerations

Efforts to value climate change impacts—whether using quantitative measures or a more qualitative approach—face a number of challenges. These challenges arise, in part, because of the nature of climate change, and in part because of the current state of science regarding impacts and adaptation. In turn, integrating valuation into the Assessment will require making practical decisions about a wide range of methodological issues. Given the nature of the challenges in conducting valuation in the context of climate change, it may be desirable for valuation studies conducted for the Assessment to maintain some measure of consistency in

Box 7. The Valuation Landscape: Key Insights

- Valuation can be thought of as the process of placing a quantitative estimate—whether dollars, physical measures, or other metric—on outcomes or consequences of an action or state of the world.
- The concept of value is not easily defined, and different disciplines define value differently. In turn, different concepts of value will suggest different metrics and methods of measurement.
- Whether one uses alternative valuation techniques or those provided by economics, the incorporation of valuation into the NCA will have to reflect the richness and complexity of the concepts and uses of value and clearly describe assumptions and methodologies.
- Valuation can be used in understanding and characterizing the state of the world, and to assist decision making. The information needs and capabilities of decision makers determine the data that are needed, and whether qualitative information, quantified measure of value, or monetized estimates are appropriate and helpful.
- It is important to realize that the use of valuation information, such as that provided by economists, does not necessitate a benefit-cost approach, but can be part of other decision-making approaches, including more complex risk and resource management approaches, multi-criterion analysis, and triaging.

treatment of key issues. At a minimum, high-quality analyses will need to maintain certain standards, to the degree possible, across regional and sectoral analyses.

Participants explored the dimensions and importance of these issues. The following sections first discuss some of the general challenges that climate change poses to the valuation of impacts, and then focus on five specific issues that were discussed in detail at the workshop. These issues are introduced along with discussion of major themes on each that emerged at the workshop. Box 10 at the end of this section summarizes key insights.

General Challenges: The Nature of Climate Change and Climate Change Research

Climate change conjures up a long list of difficult conceptual issues for valuation—the varied and widespread nature of impacts, the intangible nature of some impacts (such as culture), and the uncertainty surrounding impacts and effects such as thresholds or tipping points. All these characteristics make it difficult to quantitatively value, or in some cases make decisions about, climate change impacts. Understanding these issues and, where possible, providing for consistent treatment across analyses, will improve the quality of assessments as well as facilitate comparing NCA results across sectoral and regional analyses. A few of these aspects of climate change were touched on at the workshop, and so are summarized briefly below.

Although some impacts of climate change are already occurring, the magnitude of impacts is expected to increase over coming decades and, likely, centuries. The long time frame is one of the most difficult aspects of climate change to address in an assessment. Any quantitative valuation effort will need to provide values for a time far into the future—an effort made difficult by the uncertainty surrounding future changes in climate and in human and natural systems (as discussed below in the section on uncertainty). In addition, valuation efforts that rely on preferences will need to make assumptions about the stability or changes in those preferences over time. Valuation approaches that aggregate quantitative estimates over time (such as the discounting approach employed by economists (described in Box 14, in the section on *Economic Valuation: Methods, Applications, and Strengths and Weaknesses*)) will need to determine whether and how to weigh future impacts relative to current impacts.

Distributional effects will be important not only over time, but across populations and regions, and within a generation (as well as between generations). The treatment of values for different populations, or populations that are affected disproportionately by climate change, will be an important issue for valuation efforts to address. The concept of "winners and losers" is an important consideration for decision makers, since the consequences of a decision may favor one location or population over another. Failures to acknowledge who pays the costs and who receives the benefits can have major implications for decisions makers.

Scientists warn of large-scale changes, thresholds, tipping points, and other dramatic changes in both climate and the responses of human and natural

systems to climate change. Placing a value on large-scale changes, such as the loss of whole ecosystems, relies on different information than valuing a series of incremental changes, such as the incremental loss of wetlands. Such changes can be difficult to value quantitatively or qualitatively, because of their magnitude and the significant disruptions that might occur, as well as scientific uncertainty surrounding the likelihood of such threshold changes and the nature of resulting climate impacts.

The extent to which impacts and options can be valued depends, in part, on the availability of robust and complete data. Data gaps and incomplete information can complicate the process of valuation and exacerbate the level of uncertainty associated with such analyses. The next section delves into further detail about the sources of uncertainty and possible methods of management.

Further, certain changes are generally difficult to value. For example, cultural practices and traditions are subjective in nature, and their values depend on how their importance is viewed by individuals and society. This subjectivity further challenges the application of valuation techniques.

Uncertainty in Valuation

Uncertainty is endemic to climate impact analysis, beginning with climate predictions (see Box 8). Uncertainty exists about the evolution of the human systems that might lead to greenhouse gas emissions, the physical systems that govern the fate of these gases and their influence on the global climate, the effects of a changing climate on human and natural systems, and finally the human response to a changing climate. While acknowledging this challenge, participants pointed to a robust and well-established literature describing methods for analyzing and expressing the uncertainty associated with climate change analysis. For example, a recent CCSP report (see Box 9) explicitly addressed the methods available for addressing and expressing uncertainty in the context of climate change.

Participants also explored two approaches that focused on outcomes in more detail, and therefore are particularly relevant to impact assessment: constructing scenarios to bound the outcome space, and focusing on outcomes of concern and working backward to determine potential causes (rather than the typical "forward looking" approach to analysis).

The first approach that participants explored, involved the use of scenario-based approaches and their usefulness in global change impacts and valuation assessments. Scenarios are a common way to understand complex systems in the context of uncertainty. They have been used extensively in climate change analysis to explore mitigation, impacts, and adaptation. The most commonly articulated benefit of scenarios is that they provide a systematic way for a group to explore a small number of distinct but plausible storylines by

Box 8. One Presentation's View on the Contribution of Climate Predictions to Uncertainty

Climate model development efforts are about a lot more than just increasing a model's spatial resolution. Ongoing efforts also continue to improve and add increasingly sophisticated, physically-based parameterizations that seek to represent the effects of a wide range of climate-relevant processes not explicitly resolved by the models' grids. Also, entirely new model components can be added.

So how does one judge what makes a "better" model? Is it one that yields a climate simulation that more closely resembles the observed physical climate? Is it one with higher spatial resolution? Or is the better model one that strives to represent a wider range of the physical, chemical, and biological processes that together determine the way the global climate system "works"?

Different modelers put different weights on these factors. The weights one gives to the different factors can depend on whether the model is viewed as a research tool or as an operational prediction model.

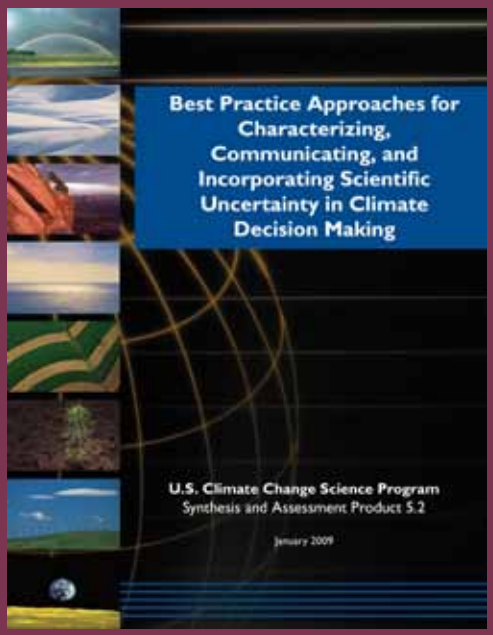
Model "Comprehensiveness"

Increased comprehensiveness increases the degrees of freedom and does not guarantee convergence to observations …quite possibly the opposite.

IPCC-class global climate models are developed primarily as GLOBAL climate research tools…not North American water cycle prediction models.

CCSP Synthesis and Assessment Product 5.2:
Box 9. "Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Climate Decision Making"

In January 2009, the U.S. Climate Change Science Program (CCSP) issued an assessment product presenting a summary of methods and strategies to characterize and analyze uncertainty as it relates to climate change and its effects. The report was written to serve the needs of climate scientists, experts assessing the likely impacts and consequences of climate change, and technical staff supporting policy makers. The report explores sources and types of uncertainty, the importance of correctly quantifying those issues, the ability to make decisions in an uncertain environment, and how to effectively communicate this information to the public. While acknowledging the considerable uncertainty associated with climate change and its effects, the report identifies and discusses a range of well-established tools and methods that are available to address uncertainty and to help inform decisions today.



One of the conclusions from the CCSP report is that the process of analyzing uncertainty is not formulaic. Rather, throughout the analysis, researchers should ask themselves questions such as

- Are factors being excluded that are equally or more important than the factors being considered?
- Are key correlation structures in the problem being ignored?
- Are normative assumptions and judgments explicitly addressed?
- Is information about the uncertainties related to research results and potential policies being communicated clearly and consistently?

deliberating on the forces and interactions that might influence the future. This can often lead to a broadening of thinking about future conditions and planning responses in anticipation of those conditions.

Participants also pointed out the drawbacks of using scenarios. One view is that they lead to overconfidence by restricting people's perceptions of the possible outcome space, via a number of well-understood cognitive biases. For example, the degree of uncertainty associated with climate impacts is high enough that any set of scenarios will represent only a small fraction of possible futures, but when people interpret scenarios they may tend to believe that they represent all possibilities. Overconfidence is particularly likely without the explicit assignment of uncertainty to specific scenarios. However, the assignment of probabilities to scenarios has itself also been subject to debate, and such assignments have historically met with substantial resistance. These and other issues were considered more extensively in a related workshop on scenarios for the NCA.

A second approach that participants discussed was whether to work the impact assessment "forward" or "backward." A common approach to the treatment of uncertainty is to operate "forward" along a linear path from greenhouse gas emissions to atmospheric concentrations to regional climate projections and associated impacts, and so forth toward assessments of outcomes, including valuation. A subset of this kind of typical, "forward"-oriented framework was referred to in the workshop as the "predict then act" approach. In this approach, the basic goal is to identify the most likely future, and design responses that are optimized for it. The basic question that underlies this framework is, "What will happen?" Participants noted that one drawback of this kind of approach is the potential for propagating and widening uncertainty through each analysis step.

In contrast, working the problem "backward" involves identifying the greatest vulnerabilities across a full range of plausible futures, as a function of the sensitivity of particular places, ecosystems, and socioeconomic sectors to external drivers of change. The researcher then identifies a suite of responses that are robust across this range. This approach is often best pursued in the context of specific decisions that need to be made. It can be used to articulate what would have to happen to lead to outcomes of particular concern.

Fundamentally, this approach asks the question, "How does my system work?" One participant noted that working the problem forward focuses on maximizing expected utility, whereas working the problem backward focuses on minimizing regret.

Participants also raised other general considerations that might fall into the category of "best practices." For example, participants noted that a range of values is likely to be more useful than a point value. That is, analyses should focus more on clarifying the range of uncertainty than on best estimates. Participants also noted the need to recognize and characterize different sources of uncertainty, as well as the fact that analyses in the different domains may require different techniques. For example, methods for characterizing uncertainty in climate models may be different than means for characterizing uncertainty with respect to human development or human responses to climate change.

Inter-sectoral Interactions and Valuation of Climate Impacts

Particularly in a modern economy, economic sectors are so intertwined that it is impossible to understand fully the effects of a change in one sector without taking into account changes in other sectors. These interactions will be important whether the approach to valuation is economic in nature or relies on other methods and metrics. As described at the workshop, sectoral interactions can take a number of different forms.

- A sector affected by climate change may use inputs from other sectors also affected by climate. For example, the livestock sector uses crops to feed livestock, and crops use water for irrigation.
- Multiple sectors may also compete for a common input. For example, hydropower, irrigation, industrial/household, and instream demand all compete for water.
- The incidence of impacts may also matter. For example, changes may differentially affect producers and consumers, or poorer households and wealthier households, or various demographic groups.
- Climate impacts may also interact with pre-existing economic distortions in an economy. For example, existing agricultural subsidies, tariffs, and taxes, can all distort how markets work and affect the economic outcome resulting from climate change.
- Impacts have an inter-temporal character in the sense that economic damage in one period reduces overall real income, and may redirect savings toward investments that make up for damage or protect from increased threat.

A commonly shared viewpoint expressed at the workshop was the NCA needs to account for these broader interactions, while not losing the focus on decisions in a local context. For example, because of competition for common inputs, evaluating sectors in isolation could result in underestimating the impacts of climate change. One viewpoint expressed at the workshop is that impacts are also likely to be underestimated if the NCA misses cumulative effects on saving/investments and crowding out of other productive investments. More broadly, a failure to account for changes in the global prices of commodities may miss a major channel for domestic impacts. Options to address these concerns, such as economy-wide or integrated assessment models, were not discussed at length in the workshop, but were noted as a topic of interest.

Adaptation and Mitigation

In many analyses, mitigation is treated as distinct and independent of impacts and adaptation. Indeed, separate research communities have grown up around the analysis of mitigation, on the one hand, and analysis of impacts, adaptation, and vulnerability on the other. In reality, however, these topics cannot be fully separated. Two particular classes of interactions were raised at the workshop.

First, actions taken to mitigate emissions can influence sectors that also experience impacts from climate change. One prominent example cited at the workshop is the role of changes in land use in reducing atmospheric carbon dioxide (CO_2) concentrations through bioenergy production and efforts to increase terrestrial carbon sequestration. These mitigation efforts will clearly interact with the impacts of a changing climate on carbon storage in terrestrial systems and agricultural and bioenergy yields. Indeed, studies have indicated that these mitigation efforts may exert a larger long-term influence on agricultural systems than the direct impact of climate change itself. Other examples can be found in the energy sector. The changing climate may affect energy use, for example, by altering building energy demands. Energy production may also depend on a resource that is influenced by climate, such as water used for hydropower.

The second category of interaction raised at the workshop was the interaction between impacts and adaptation. One viewpoint expressed at the workshop is that impact studies that fail to address adaptation produce unrealistic estimates of impacts. For example, calculating impacts without adaptation in the agricultural sector assumes that farmers will continue to plant the same crop on the same day with the same uses of fertilizer and irrigation, regardless of changes in the climate. The reality is that agriculture producers routinely adapt their crop choices and farming practices in response to changing market and weather conditions. At the same time, it is important to acknowledge that some estimates of climate damages in the literature also include some adaptation costs. For example, some studies of climate change and cooling demand explicitly assume that consumers will adapt to climate change by using more air conditioning.

Scale and End-to-End Analysis

Understanding climate change drivers and responses requires "end-to-end" analysis, with an assessment of the drivers of greenhouse gas emissions and the physical climate system at one "end", and vulnerabilities, impacts, and human responses at the other. Workshop participants noted that connections must be made between different steps in the analysis and between the different disciplines needed to achieve a full "end-to-end" assessment. The challenges of conducting "end-to-end" assessment raise several conceptual and methodological issues. A number of these issues speak to the important question: at which "end" of the impacts analysis should the NCA start, and what implications does this have for valuation?

As discussed above in the section on "Uncertainty in Valuation," an important consideration is whether to work the problem "forward" or "backward." Here, questions related to the (perhaps largely irreducible) uncertainties in predictions of multi-decadal climate change and the value added by (and limitations of) downscaling approaches become particularly relevant. Working the problem backward offers the potential to minimize, or manage, some of the challenges associated with these issues.

Another set of issues surrounds the use of potentially complicated and highly technical scientific information to support decision making. A large body of literature seeks to understand and describe how decisions are actually made, and this literature makes clear that scientific knowledge, including data and research products, is only one part of a much broader system of study and practice. In this context, successful decision support tends to occur as a result of sustained, close collaboration between producers and users of scientific information around a highly specific set of decisions. An approach to impact assessment that starts with particular sectors or regions and, therefore, a particular collection of stakeholders, may lend itself more easily to these types of decision support best practices.

One viewpoint that emerges as a result of these various difficulties in working from climate to impacts is that "working the problem backward," as discussed above, may be a more appropriate approach for impacts analysis than working through the causal chain to find most likely or representative outcomes. If so, this would clearly have implications for how valuation should be carried out, i.e., in a more region- and sector-focused way rather than using top-down, general equilibrium approaches. It was also clear from the workshop discussion, however, that the appropriate paradigm for structuring assessments is still very much an open question.

Using an Array of Values and Metrics

Valuation covers a broad range of metrics that recognize and can be used to evaluate tradeoffs. Valuation metrics that might be used to consider tradeoffs associated with climate impacts and response strategies span a large range. At one end of the valuation spectrum are economic approaches that focus on monetizing impacts. These rely on concepts like willingness to pay and opportunity cost and on commonly used metrics of aggregate economic welfare such as Gross Domestic Product (GDP) or consumption expenditures. Other economic metrics that are commonly used include measures of jobs, the production of particular goods (e.g., domestic food production), or reliance on imports (e.g., oil). And beyond these explicitly economic metrics are a host of physical, ecological, human health, and other metrics that can also be used to evaluate impacts and response strategies. Some of these could be amenable to monetization with modest transformations (e.g., applying a value to human life). Some, however, will be exceptionally difficult to monetize, such as loss of biodiversity. Still others will be difficult to define and quantify using any metric (such as loss in many ecosystem services or cultural traditions), much less a monetized measure.

Given the diversity of economic and non-economic measures and metrics that indicate value, the question arises of how to decide which metrics to use, how to integrate these metrics in a given analysis, and when to aggregate. While these issues were not explored in depth during the workshop, some themes emerged. One theme was the importance of retaining disaggregated data. Impacts aggregated within or across regions or states can obscure the unique character of local value. For example, the impacts of a devastating flood in one portion of a state may have little effect outside the state, and so average or aggregated impacts may not adequately capture and represent these effects. Models that estimate economy-wide impacts are able to integrate sectoral interactions, but may sometimes obscure these local effects.

Second, as indicated in the discussion below on *Economic Valuation: Methods, Applications, and Strengths and Weaknesses*, a number of participants were critical of some valuation techniques, such as those that use survey rather than market data. Participants generally advocated using a variety of metrics to present a rich view of value and address the needs of diverse decision makers. Some also stressed the need for multi-disciplinary teams in the NCA, in order to ensure that the Assessment captures the viewpoints of different disciplines—ecology, sociology, psychology, etc.—on the range of impacts important to value. Participants were generally unwilling, however, to identify overarching principles governing the types of circumstances under which impacts should be monetized, and when other economic and non-economic metrics should be used.

Economic Valuation: Methods, Applications, and Strengths and Weaknesses

Economic valuation is one facet of a broader valuation landscape. As described during the workshop, the economic concept of value begins from a theoretically consistent foundation in welfare economics. In welfare economics, value is based on tradeoffs that people are willing to make. In turn, these tradeoffs reflect both what people care about (preferences over goods and services and states of

Box 10. Methodological Challenges, Consistency, and Comparability: Key Insights

- Climate change poses challenges to both quantitative and qualitative valuation. Given these challenges, it may be desirable for valuation studies conducted for the Assessment to maintain some measure of consistency in treatment of key issues.
- Climate impacts are geographically dispersed, widespread and pervasive throughout population groups and regions, and occur over the long term. Considerable information at the local level, and projected into the far future, may be required to estimate impacts.
- Impacts can be both tangible (impacts on infrastructure) and less tangible (impacts on culture). Techniques to place a value (whether quantitative or qualitative) on less tangible impacts are not well-developed.
- The question of the fairness of the distribution of climate change impacts across and within generations plays an important role in the context of climate change. Valuation techniques will have to account for both inter- and intra-generational considerations.
- Integrated, combined uncertainty is hard to quantify due to the multiple sources of uncertainties. However, there exists robust and well-established literature on methods and tools for dealing with uncertainty in climate impacts specifically. An important example of this body of literature can be found in Climate Change Synthesis Product 5.2: Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Understanding in Climate Decision Making.
- The use of a range of values is more useful than a point value. It provides stakeholders the ability to focus on a spread of possible estimates, rather than on a best estimate.
- Economic sectors, adaptation and mitigation options, and impacts and adaptation are so intertwined that it is impossible to fully understand the effects of a change to one without taking into account changes to the others. Without accounting for these interactions, impacts and possible responses are likely to be underestimated.
- A diverse set of economic and non-economic measures and metrics, both qualitative and quantitative, may together present a richer view of value. Moreover, different measurement approaches may be appropriate in different circumstances of for different decision makers. This diversity raises questions about the use of appropriate metrics, the methods necessary for integrating these metrics, and the instances where aggregation/disaggregation might be possible and appropriate.

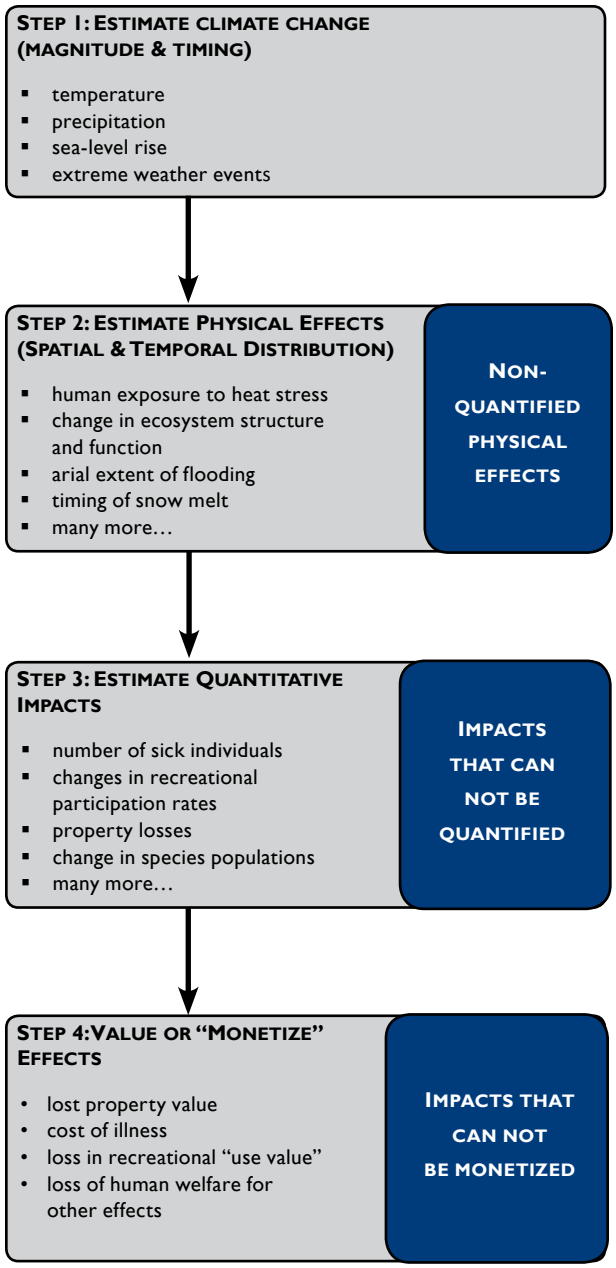


Figure 3. Estimating the monetized value of climate change impacts. Reproduced from CCSP SAP 4.6 *Analysis of the Effects of Global Change on Human Health and Welfare and Human Systems*, 2008

the world) and how much they have available to trade (reflecting scarcity and resource constraints). Other concepts of value exist (as described earlier in Section IV), such as measures of importance that do not depend on resource constraints, or values that are based on physical or other metrics, and not human preferences.

Economic valuation is, almost by definition, a human-centric activity. Seen through the lens of economics, valuing climate impacts requires identifying and measuring changes in human and natural systems in terms that capture what humans value and then applying the techniques of economics to estimate that value. Economic valuation, thus, is the end of a chain that begins with projecting changes in climate, moves through identifying the physical effects of climate change (such as changes in ecosystems or disease vectors) and interpreting these changes in terms of changes in valued endpoints in human and natural systems, to finally valuing these changes in endpoints in dollar terms.

Each point in the chain of economic valuation, as illustrated in Figure 3 (reproduced from SAP 4.6 and included in the background papers), is subject to small or large gaps in data or in available techniques and methodologies.[4] As a consequence, economic measures may not capture all aspects of value and so typically represent a lower bound estimate. These gaps may arise from our fundamental ability (or inability) to project relevant climatic changes, or to link those changes to changes in goods and services, in human health, and in ecological, social, or economic conditions that humans care about. Gaps may also arise due to limitations in our ability to apply available economic techniques to the task of valuing those changes. Thus, our ability to develop economic values for climate change impacts depends on outputs from multiple disciplines—climatology, ecology, engineering, and epidemiology, as well as economics. Ethics may also play into the determination of a valid approach to valuation, and the implications of that approach for decision making and other applications.

Economics has an evolved theory of valuation. Numerous tools have been developed, and applied in the context of both project assessment and policy analysis, that allow economists to value changes in a wide range of types of goods and services, environmental conditions, and states of the world. Understanding the boundaries of economic valuation requires understanding what economics does well and does not do well, as well as the nature and quality of the data and inputs that other disciplines contribute to the process of valuation. It also requires recognizing the uses to which the

[4] Economic valuation is not always a linear process, as described in Figure 3. Moreover, it is possible to estimate value—even dollar values—without undertaking all steps in the chain. For example, a survey could ask how much individuals are willing to pay to avoid projected impacts of climate change, without indicating specific impacts of concern.

data will be put. While economic valuation can be incredibly powerful, as with all sciences its application has both best practices and best uses. Consequently, economic methods will have both strengths and weaknesses in the context of valuing the impacts of climate change and possible human responses. The workshop (as well as the background papers) explored all these ideas, as discussed below. Box 15 at the end of this section summarizes key insights.

An Available Suite of Economic Valuation Tools

Economists understand value in terms of tradeoffs. Consider the value to society of achieving a specific outcome, whether a change in the level of a good or service, or of an environmental condition or state of the world. To value this outcome, economists ask what the outcome is worth to society, given the available alternatives and what must be foregone to achieve the outcome. How much do we have to give up to get the outcome? What inputs or resources are used to produce it, and which could have been otherwise used to produce something else? What are we willing to pay for the outcome? What will we choose not to buy, so that we can instead achieve this outcome?

When estimating value, economists begin by identifying whether the outcome being valued involves goods and services that are bought and sold in markets, or not. For goods and services that are bought and sold, market activities provide suitable information from which economic value can be derived. For non-market goods and services, economists often look at markets for goods that are complementary to the good being valued, or at goods that are substitutes for those goods. Economists can also look at goods that are composites of other goods, and how the price of a good—such as house or a car—reflects implicit prices for the characteristics of the good (e.g., a house's location or square footage). Failing a market analog of some sort, economists construct questionnaires and surveys to elicit values.

The appropriate valuation method will depend on the type of good or service to be valued, and whether it is a "market" or "non-market" good. Most methods fit into the following broad categories:

- Changes in producer and consumer surpluses (derived from market behavior) which measure the resources consumers and producers are willing (or need to) give up in order to obtain or produce goods and services in the marketplace
- Measuring financial damages directly, e.g., the costs of medical treatment, or damage to transportation infrastructure.
- Looking at related market behavior, e.g., the amount spent to travel to recreational areas, the premiums paid to workers in risky occupations, or expenditures to increase safety
- Simulating market behavior to determine how much individuals are willing to pay for a change, by means of questionnaires or experiments.

As measures of the economic value of a good or service, each of these tools can be evaluated in terms of the breadth of costs and benefits that they capture. Some are only partial measures, and so represent a lower bound on the "true" economic value. For example, a cost-of-illness (COI) measure does not include the cost of pain and suffering, or declines in quality of life associated with disease, even though these effects are important to individuals and society, and contribute to our desire to avoid a disease outcome. Increased maintenance and repair costs for transportation infrastructure do not include the aggravation and lost time for commuters or travelers, or lost profits for business. On the other hand, willingness to pay measures generally include both psychic and physical costs borne by the individual, but may not capture all the social costs and benefits.

Measures also differ in ease of use and in the degree of acceptability (or controversy) surrounding their application. Economic welfare measures, while conceptually more robust measures of how much individuals are willing to pay (than, for example, damage estimates), may require considerable data to develop. In the case of methods that estimate value by simulating markets, questions may be raised regarding the reliability of the method, and how close to actual preferences and willingness to pay the results can be.

Several presentations at the workshop gave examples of how the techniques of economic valuation are applied to both climate change and other project and policy analysis, addressing both market and non-market impacts. For example, in water resources management, the U.S. Army Corps of Engineers (USACE) uses economic valuation as part of its normal decision process, and is incorporating climate change impacts into that

Box 11. The Use of Economic Valuation by the U.S. Army Corps of Engineers in Water Resource Management

The USACE conducts valuation of climate change impacts as part of its normal decision processes. Values must conform to "Economic and Environmental Principles and Guidelines for Water and Related Implementation Studies," issued by the U.S. Water Resources Council, 1983 (being revised). These guidelines are permissive in terms of the techniques used to estimate value, but identify "willingness to pay" as the measurement standard.

Categories for which economic values are estimated include

- Urban flood damage reduction
- Agricultural floodwater, erosion, and sedimentation reduction
- Inland transportation
- Deep draft navigation
- Municipal and industrial water supply
- Hydropower
- Agricultural drainage
- Agricultural irrigation
- Recreation
- Commercial fishing
- Hurricane and storm damage reduction

Techniques to measure the value of reductions in impacts range from avoided losses (as in urban flood damage or hurricane and storm damage reduction) to the cost differentials of the most likely alternative (as in the case of hydropower reductions or water supply impacts).

process. The USACE typically considered a fairly wide range of impacts (see Box 11), and uses the economic concept of "willingness to pay" as the standard against which valuation techniques are evaluated. The techniques used may include those based on actual or simulated markets, changes in net income, the cost of the most likely alternative, and administratively established values, based on the economics literature.

Other presentations addressed aspects of human health impacts valuation, in the context of both analyses to support air quality regulations and climate change. Valuation of health impacts generally involves complementary use of *both* economic (monetized) and non-economic metrics. Monetized measures include cost of illness (which may include both medical care cost and opportunity costs, such as lost income), and willingness to pay measures that include both COI and pain and suffering. These latter estimates are derived from both market information (in the form of revealed preference/salary studies) and stated preference methods. Non-monetized approaches include estimating the incidence of illness (e.g., the number of new cases in a given time period (per population)), non-financial measures of the burden of disease (such as estimates of morbidity or mortality), and estimates of the years of life lost (YLLs) or disability-adjusted life-years (DALYs) (see Box 12). Monetized measures have the advantage of being internally consistent and employing standardized methods that can be compared across types of health impacts as well as temporal and regional scales. However, some forms of valuation, such as monetizing a percentage change in mortality risk (effectively, placing a value on a statistical life), are considered controversial by some.

Managed forests and ecosystems, as described in presentations at the workshop, provide examples of both market and non-market goods and valuation techniques. Participants identified a range of techniques for valuing ecosystems. These techniques include methods for valuing ecosystem services using traditional economic techniques (including surveys and replacement costs). Techniques also include focusing on physical dimensions, such as acres of wetlands, rather than economic valuation, and then relying on cost-effectiveness/incremental cost analysis, rather than comparing benefits and costs. From the perspective of climate change, most of the work thus far has focused on timber impacts—changes in net primary productivity, species changes due to temperature and precipitation change, etc. Consequently, many of the most critical issues—responses to variability rather than average climate change, understanding how future forests ecosystems may contain novel plant and animal assemblages, and linking changes in forests to the services provided—have not been well-addressed from an impacts perspective. Taking the next step of valuing these impacts is, thus, hampered by data limitations, even before the issue of available valuation techniques arises.

Box 12. Definitions of Health-Related Terms

Disability-adjusted life year (DALY): The disability-adjusted life year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill health, disability or early death. One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.

Quality-adjusted life year (QALY): The quality-adjusted life year (QALY) is a measure of disease burden, including both the quality and the quantity of life lived. The QALY combines length of life with health-related quality of life in one single metric. Quality of life is represented by an index, which is assumed to represent the expected "utility" of a given health state and can vary between 1 for "perfect health" and 0 for "dead". Years lived in less-than-perfect health are assigned a value of between 0 and 1.

Value of statistical life (VSL): The value of life is an economic value assigned to life in general. The economic approach to valuing risks to life focuses on risk–money trade-offs for very small risks of death, or the value of statistical life (VSL). The key question is how much people are willing to pay to prevent a small risk of death. For small changes in risk, this amount will be approximately the same as the amount of money that they should be compensated to incur such a small risk.

Years of potential life lost (YPLL): The concept of years of potential life lost (YPLL) involves estimating the average time a person would have lived had he or she not died prematurely. It is, therefore, a measure of premature mortality. YPLL inherently incorporates age at death, and its calculation mathematically weights the total deaths by applying values to death at each age.

Sources: WHO (2010), Viscusi (2008), Gardner and Sanborn (1990), and Schlander (2010).

As illustrated in workshop presentations, economics has a well-developed set of techniques that are applied in informing public and private decision making. Economic valuation is at its best when applied to tangible and measurable changes, for which market analogs exist. However, the valuation techniques associated with non-market goods and services, such as ecosystems services and human health, are also commonly used in policy and programmatic decision making. Economic valuation measures can be arrayed alongside other economic and non-economic metrics (such as physical measures) to provide a richly dimensional view of impacts.

Strengths and Weaknesses of Economic Valuation Methods in the Context of Climate Change Impacts and Decision Making

As described above, the economics profession has well-developed and appropriate techniques for valuing many kinds of impacts. Moreover, these techniques have a history of deployment in programmatic and policy evaluation and decision making using benefit-cost analysis and other criteria. Many valuation techniques have also been used successfully to estimate climate impacts in selected sectors, such as water resources and coastal protection. Despite economists' experience in various applications and the evident strengths of valuation, these techniques are not widely applied to valuing climate change impacts.

Workshop participants indicated a number of conceptual, practical, and methodological considerations—in some cases challenges—to the application of valuation to climate change impact measurement. Some considerations create challenges not only for economic valuation but for any quantitative valuation. As discussed earlier in this report, such challenges include the widespread and sometimes intangible character of climate impacts, the large-scale changes that may result from climate change, or the paucity of data in some areas. In other cases, such as the theory underlying economic valuation, not only climate change but other environmental problems pose challenges that economists have successfully met in other circumstances, and so may meet again. Still other considerations are specific to climate change.

In total, these challenges do not imply that the application of economic techniques to climate

change—or indeed any other problem where some of these conditions exist—is without merit. Rather, many workshop participants indicated that a key response to these challenges should be to take steps to ensure transparency, rigor, and completeness as much as possible in both the analysis and its presentation, and to clearly indicate its underlying assumptions and limitations.

Considerations and challenges that workshop participants highlighted as being particularly important for economic valuation are described below, with discussion of how economists deal with these issues. Workshop participants identified the three types of challenges:

- ***Practical limitations.*** The range of types of impacts and the geographic and temporal scales of impacts have significant data requirements for any attempt to develop valuation measures or indicators.
- ***Controversial techniques.*** Some economic valuation techniques, including some approaches to valuing human health and ecosystem services, are considered controversial by some researchers.
- ***Theoretical assumptions and decision making.*** The development and application of economic valuation techniques rests on a theoretical foundation that includes a set of assumptions that are not easily met by climate change. In addition, economic valuation estimates are often—but not always—used in benefit-cost analyses. The application of this decision aid to climate change issues faces some of its own challenges.

The discussion below focuses on these challenges and explores participants' viewpoints on the assumptions, data requirements, and ethical issues surrounding valuation.

Practical Limitations to Economic Valuation

Participants identified a wide and varied range of types of climate impacts. In addition to tangible changes that can be measured, such as property damage or changes in the productivity of forests or fisheries, impacts of climate change include effects that can be very difficult to define, much less measure quantitatively. Among the more elusive impacts are changes in the services provided by ecological systems, cultural changes as ways of life are altered for indigenous communities, and changes in safety or security due to extreme events. A participant pointed out that researchers do not even have a good and comprehensive list of all the types of impacts of concern, and that generating such a list should be high priority.

As discussed above and summarized in Figure 3, economic valuation requires a series of steps that takes the researcher from climate changes, through physical changes in human and natural systems, to translating those changes into measures or metrics of endpoints that are valued. In the case of economic valuation, the final step is valuing those changes in dollar terms.[5] Each step requires sufficient data to produce a valid result and ultimately, a valid estimate of value.

Gaps or uncertainties in data, therefore, can limit our ability to measure and ultimately to comprehensively monetize or value the variety of impacts occurring over a long time frame and across the varied and large geographic regions comprising the United States. As pointed out by one participant, even before valuation, a critical science need in the arena of health impacts is for attributed risk and dose-response relationships for a variety of health outcomes. Valuation efforts can also be hampered by issues with the scale at which data can be provided, and whether it is appropriate for valuation. For example, many climate models are generated at large scales, and so local valuation requires statistical or dynamical downscaling, introducing additional uncertainty. While climate models are one source of uncertainty (as discussed above in Box 8), demographic trends and other socioeconomic projections are also important sources of uncertainty. As a result, the process of valuation requires understanding the means by which information is generated, and recognizing the uncertainty and quality of underlying data.

In many cases, as described above, the limitation on valuation arises not from the economic technique, but the limited ability of researchers to provide quantitative information on appropriate endpoints. Placing a value on large-scale changes (for example, the loss of whole ecosystems) requires different information than valuing a series of incremental changes (for example, the incremental loss of wetlands). Valuation also faces data limitations, particularly given the wide variety of impacts, over the range of geographic areas and time periods

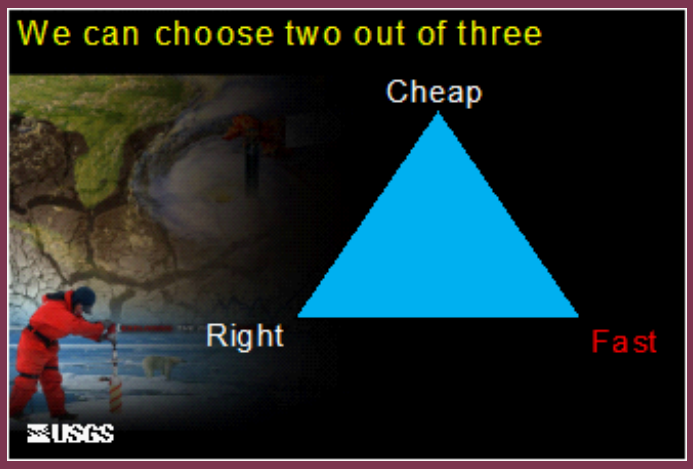
[5] Economic values are not always in dollar terms. The trad-eoffs can be expressed in terms of any two goods. Dollars are often convenient and the most commonly used metric, but they are not the only metric for economic valuation.

during which impacts may occur. Valuation, like other steps in the chain from climate to estimation, is not costless, and so economists rely on methods such as benefits transfer that can apply the results of one valuation study to a similar situation.

Deciding which effects to measure and potentially value, and how to generate the necessary data, requires setting priorities for the use of resources at all stages of valuation (see Box 13, for one perspective on these practical limitations). In turn, setting priorities will require sifting through some difficult issues, such as: which questions does the NCA need to answer first, what measurements are the highest priorities, and how much uncertainty is acceptable?

Box 13. A Perspective on Addressing a Typology of Climate Impacts

Ideally, valuation should be cheap, right, and fast. In reality, researchers are forced to choose, and so an analysis can at best meet two out of three criteria. The critical question is how to choose.



One of the difficulties in valuation is determining the highest priority impacts for the investigation. Impact assessments generally (and economic valuation in particular) are sometimes faulted for focusing on impacts that are easiest to assess and monetize, rather than focusing on those that are considered most important.

Controversial Techniques and Applications

The background papers and workshop participants highlighted important considerations in using valuation methods for certain sectors. For example in the health sector, many find the notion of placing a dollar value on changes in mortality risk and mortality rates to be suspect as an input to policy making. Even among those who do not criticize the method, there is disagreement over how to deal with mortality values across populations of different ages and health status.

Also controversial are the alternative valuation techniques used in cases where data needed for traditional valuation techniques are missing or incomplete, as in the case of what are termed "non-market" goods, such as ecosystems services. These techniques include the use of contingent valuation surveys, a method economists use to elicit an individual's preferences in preserving a service or benefit or avoiding discomfort or a specific impact. These surveys rely on individuals having an accurate understanding of themselves and their preferences and, thus, an accurate reading on what their willingness to pay would be.

Discounting future values, whether for mortality or other impacts, is an issue surrounded by considerable controversy. The long-time frame under which climate impacts are generally estimated makes it important to deal with future impacts in some way, yet non-zero discount rates quickly reduce impacts in the more distant future to zero. Workshop participants highlighted the lack of consensus on how to address inter-generational equity issues (as well as intra-generational equity) when quantifying the impacts of climate change (see Box 14). Not only are these fundamental difficulties in applying economic valuation, but they also pose ethical problems if the effects on future generations and less economically advantaged people are not taken into account.

Assumptions Underlying the Theory of Valuation and Benefit-Cost Analysis

Economic valuation depends on a complete and complex theory under which valuation techniques yield an "economically correct" measure of value. For many projects and programmatic analyses that involve valuation, the assumptions underlying the development of these measures are largely met. For climate change, however, some of these

Box 14. Discounting and Equity in Climate Change Economics

In economics, "equity" refers to the distribution, and the "fairness" of the distribution, of costs and benefits among different people, or across population groups. In the context of climate change impacts, equity should be viewed as having two dimensions: an inter-temporal or inter-generational dimension that focuses on the distribution of costs and benefits over time; and an intra-generational dimension that explores the distribution of costs and benefits at a single point in time; for example, across income groups or populations with different levels of vulnerability.

The inter-temporal dimension of equity is particularly important in the context of climate change, because the impacts of emissions today may not be felt in their greatest severity for many decades or centuries into the future, while the costs of investing in mitigation occurs in the near term. Economists typically use discounting to represent the relationship between costs and benefits that occur at different points in time. Discounting adjusts dollar values that occur in the future, turning them into "present values" that can be compared to dollar costs and benefits occurring today. Conceptually, discounting is the inverse of the process by which an investment today grows at a rate of interest. If the discount rate is positive, a dollar in the future is worth less than a dollar today.

When dealing with purely financial investments, a positive discount rate reflects the fact that investments made today typically have a positive return. Business or individuals (or even society) should therefore be willing to postpone or give up a dollar today only if it is being exchanged for more than a dollar in the future. Moreover, for many public sector projects and policies, a positive discount rate can be justified on similar grounds, i.e., that the project should represent a reasonable return to the investor, and a good use of public and private funds, based on the streams of benefits and costs that result from the project, and prevailing interest rates.

Unlike most projects, the stream of costs and benefits associated with climate change policy is not confined to periods on the order of months or years or even a decade or two. Rather, climate change will play out over many decades and centuries. Consequently, the question of inter-generational equity—how to treat fairly the impacts of both current and future generations—raises very real concerns. With a modest discount rate of 3%, the value of future impacts rapidly approaches zero in a matter of decades, and even with a tiny discount rate, future values are eroded in a century or two. The question of what discount rate to use for future impacts has significant ramifications for how large those impacts will be, when viewed today. Thus the question of how to discount the very long term is not simply a question of how to rationally make investments, but an ethical question of how to treat future generations.

To examine this question more closely, economists generally decompose the discount rate that should be applied to future streams of consumption or income (or in this case monetized impacts) into two components. One component is called the "rate of pure time preference"—the rate at which we devalue the future, simply because it is the future. Economists have posited a number of reasons why this rate might be positive, such as the affinity we feel for generations that are closer to us in time. For many, however, it seems unethical to value the welfare of future generations at less than we value the welfare of current generations, and so many economists believe that the appropriate rate for inter-generational discounting is zero. The other component reflects what will happen with consumption over time. If we believe that future generations will be richer than we are, then it makes sense to discount their consumption, since additional consumption in the present will add more to current well-being than future consumption will add to future well-being. If, however, we believe that climate change impacts will be severe enough to reduce future consumption, then this second component might be negative, i.e., we might want to value an increment to future consumption at more than we value current consumption.

Box 14. Discounting and Equity in Climate Change Economics (Continued)

There is little agreement among economists over the appropriate discount rate to use, particularly in the case of climate change. Many argue that a discount rate above a tiny positive number is unethical, and represents a disservice to the future. While few—if any—economists argue that climate change should be treated the same as any other investment or public project, the question of what discount rate to use is not easily resolved. Economists have devised a variety of approaches that are an alternative to choosing a single discounting rate, such as discount rates that rise or fall over time. Because of the difficulty of resolving the ethical questions surround discounting and climate change, some economists argue that for the very long time frames involved in climate change, presenting streams of impacts may be preferred to aggregating these streams into one number using a discount rate.

The distribution of impacts at a single point in time is also important in the context of climate change. At any point in time, climate impacts will be felt more severely by some people, or groups of people, than others. For example, communities living in low-lying coastal areas will be more susceptible to sea-level rise than those living inland. Unfortunately, many of the models and analyses that are used to quantify impacts are weak at capturing equity effects. Indeed, equity is often disregarded in many analyses of both mitigation and impacts, and some workshop participants voiced concern about the ability of the types of aggregate economic models that are commonly used in climate impact assessment to produce meaningful results for an equity analysis. Participants also pointed out that aggregation of economic impacts requires making assumptions about the weights placed on impacts to different groups. In economic parlance, aggregation requires an implicit or explicit social welfare function. Since the form of this function is not dictated by economic logic but by philosophical and ethical considerations, reaching agreement on the appropriate method of aggregation is not a simple task. Consequently, some argue that impacts may be better communicated by presenting them in a disaggregated rather than aggregated form.

Sources: Heal (2009), Scheraga and Sussman (1998), Frederick et al. (2002), Schelling (1995), and workshop presentations and discussions.

assumptions are not met, which both complicates the application of valuation tools and reduces the relevance of these techniques to climate change impact analysis.

- ***Impacts represent marginal changes.*** Valuation techniques are intended to be applied at the margin. That is, economic tools and techniques are best applied to incremental changes (whether positive or negative) from the status quo. The types of large-scale impacts that are projected to result from climate change—such as large-scale loss of ecosystems, catastrophic impacts of extreme events, and displacement of indigenous cultures—contradict this assumption.
- ***Stability of preferences over time.*** Economists generally assume that preferences are stable over time, so that the values elicited today—whether by examining market behavior or conducting surveys—are equally appropriate in the future. Given the time frame and potentially dramatic changes that may accompany climate change, it is unlikely that preferences will remain unchanged.
- ***Non-linearity and threshold effects.*** Valuation techniques assume that the effects they are studying are continuous–that is, systems change smoothly over a given time period. In the case of climate change, many have raised concerns that climate change will be discontinuous, and that natural or human systems may experience threshold effects or sudden changes. Such changes are difficult to value using any technique.
- ***Uncertainty is well-characterized.*** As discussed above, uncertainty is a challenge for climate change analysis generally, and for valuation efforts in particular. Expected utility and other forms of assessing benefits and costs in the presence of uncertainty are not well-designed to deal with uncertainty that is unknown and potentially unknowable.

Moving Forward with Economic Valuation

Many participants indicated an urgent need to include economic valuation in the NCA. Economic

techniques were identified as being particularly appropriate for certain sectors where market goods or physical infrastructure is involved, such as agriculture and water resources. Other participants expressed reservations regarding the extent to which economic valuation could be used to capture some categories of impacts, such as ecosystem services or cultural changes. Throughout, participants stressed the need for a transparent process and methodology, and suggested that the NCA consider the application of different valuation techniques for varied end users, to accommodate the diverse needs of these users. Participants also indicated that an array of economic and non-economic valuation techniques could be applied to different sectors or topic areas within the NCA. However, participants also noted that it may not be appropriate to aggregate economic values and/or other types of metrics.

Discussants from the breakout groups suggested that even if there were instances where quantification and/or monetization was not appropriate, economics might still play a useful role in capturing tradeoffs and opportunity costs. They further pointed out that the application of economics could help in embedding multi-sectoral and inter-regional approaches within the NCA.

As with any valuation effort, economic valuation faces significant challenges. All valuation efforts—whether quantitative or qualitative—face difficulties in dealing with uncertainty, valuing non-marginal or in some cases potentially catastrophic events, trading off near-term and long-term impacts, capturing sectoral interactions, lack of detailed and comprehensive data, and other challenges discussed in the sections above. Economics has evolved a set of approaches to dealing with many of these issues. However, many of these approaches—such as discounting, expected utility, and contingent valuation methods—are not fully satisfactory, in the face of the extreme challenges posed by climate change.

Participants were optimistic about addressing some of these challenges, both by using a range of valuation techniques and by using different methods of analyzing, interpreting, and presenting valuation data. Some suggestions included the use of in-depth analyses and case studies to support local decision making, the inclusion of non-economic metrics in the valuation of climate impacts, and involving stakeholders in the process of creating valuation metrics and indicators. Participants also proposed a number of ways in which high-quality, consistent, and comparable analyses could be conducted, as discussed in the next section.

Box 15. Economic Valuation: Methods, Applications, and Strengths and Weaknesses: Key Insights

- The economic concept of value is grounded in welfare economics. Value is based on tradeoffs that people are willing to make, which reflects both what they care about (preferences over goods and services and states of the world) and how much they have available to trade (reflecting scarcity and resource constraints).
- Economics has a well-developed set of techniques that has been widely applied to public programs and in policy settings. Different techniques have been developed for goods or services that are market goods (are bought and sold) vs. those that are non-market goods (less tangible and not directly bought and sold).
- Economic welfare measures, while conceptually more robust estimates of how much individuals are willing to pay, may require considerable data to develop and so researchers often resort to more limited "cost" measures, which do not always capture full value.
- The application of economic techniques to climate change faces several types of challenges, including
  - Appropriate data may not be available to quantify the range of impacts explored, especially at different temporal and geographical scales.
  - The use of non-market valuation techniques to measure some impacts (such as changes in health status or changes in ecosystem services) is considered by some to be controversial.
  - These challenges to the use of economic valuation techniques to measure climate change impacts suggests that researchers in the NCA may need to take steps to ensure transparency, rigor, and completeness as much as possible in both analysis and its presentation, including clearly indicating underlying assumptions and limitations.

Consistency and Best Practices: A Range of Viewpoints

The NCA will be conducted by teams operating across a range of economic sectors, impact categories, geographic regions, and cross-cutting topics. Some measure of consistency across valuation approaches taken by these teams will be essential if the results of local and regional studies are to be arrayed, compared, and in some cases aggregated within and across sectors and regions. Workshop participants explored the issues of consistency and comparability from several perspectives: the interpretation of consistency in general, the potential for consistency in specific topics, and standards that studies and teams should meet methods (including sources of guidance to achieve consistency). Each of these is discussed below. Box 17 at the end of this section summarizes key insights.

General Interpretation of Consistency

Consistency in the application of valuation concepts to the NCA can be interpreted in different ways. Participants suggested that "consistent" can refer to the broad framework for valuation, including whether impacts are monetized or not, to the consistent use of scenarios (should scenarios provide the basis for analysis) across regions and sectors, or to the time frame of the analysis. Another application of consistency could encompass how dollar values are presented in cases where impacts are monetized, i.e., whether values are presented as aggregated values (typically discounted present value), or as streams over time. Some participants pointed out that a consistent treatment of uncertainty depends on context, and requires a thoughtful approach (as illustrated in Box 9 in SAP 5.2).

Participants stressed that consistency does not mean that all studies make the same assumptions or use the same methodologies. Rather, it may be sufficient if different teams choose parameters values or methodological approaches from among a range of values or clearly identified set of approaches. Guidance could be given for when different valuation techniques are most appropriate (i.e., for which impact categories). Consistency may also relate to how results are presented, or how assumptions are characterized. More generally, guidance could also be promulgated in the form of best practice. For example, best practice might involve transparency or the use of gray literature. Finally, one interesting suggestion for consideration was to gather a small working group or hold a workshop with the specific charge of defining guidance on valuation methods across sectors and regions.

Box 16. Discounting: One Breakout Group's Viewpoint

One of the breakout groups on the second day explored in more detail what guidance and consistency might mean for a few issues. The group identified the following potential principles for discounting, reflecting both the issues and the range of viewpoints on the issue:

- Explicitly recognize that consensus does not exist in the literature or research community and that the issue has an ethical as well as economic component
- Allow multiple approaches and wide range of assumptions, including the possibility of not discounting
- Do not use just one discount rate, but present results for several different rates, and for variable as well as fixed rates over time
- Present time series as well as present discounted values
- Recognize the limitations of discounting with regard to long-term decision making
- Be explicit about underlying assumptions affecting aggregated present values
- Use graphs and other methods of displaying information

Participants also acknowledged that guidelines might not be able to take the form of specific methodological steps or specific numbers to be used for parameters, such as the discount rate. Instead, guidelines might focus on process. For example, one participant suggested that valuation teams be required to step through a consistent series of questions to identify the economic tools or metrics to be used, and that all teams be required to spell out their assumptions in a similar way. Under this paradigm, consistency would be mean that all the teams will have gone through a similar thought process to choose their approach.

The Potential for Consistency on Specific Issues

Although participants offered different perspectives on how to define consistency, a common

viewpoint was that some form of guideline or guidance was important to develop for key issues, such as discounting or uncertainty. However, it was not possible within the scope of the workshop to develop detailed recommendations regarding the means to achieve consistency on specific issues. Instead, participants provided examples at different points in the discussion and in the breakout groups. Discounting, in particular, received substantial discussion in plenary and in breakouts (see Box 16).

The treatment of multiple metrics also received some consideration in discussions. One valuable suggestion in this regard was that metrics should, to the degree possible, be consistent across sectors and regions. For example, if morbidity and mortality are used to address disease vectors, these two metrics should also be used to assess the effects on, for example, nutrition.

Best Practices and Standards in Valuation

One of the important themes to emerge regarding consistency was that consistency is not simply about consistent analytical methodologies. As discussed above, consistency can take many different forms. For example, it can be expressed in terms of consistent process. Again, the workshop did not endeavor to develop consensus on best practices to achieve consistency, but it did solicit a range of suggestions from participants. Several of the most prominent of these are listed below.

- ***Set standards for use of supporting literature.*** It was suggested that there be a standard for the use of literature in the NCA, just as the IPCC maintains standards for literature included in its assessment products. At one end of the spectrum, one suggestion was to use only peer-reviewed literature. However, this might limit the potential to use government reports and other, valuable gray literature.
- ***Set standards for the makeup of NCA teams.*** One suggestion raised by several participants was to ensure that a core set of capabilities and backgrounds is represented on each NCA team. A common refrain was that an economist should be included on each team from the beginning.
- ***Ensure transparency of results.*** Participants repeatedly stressed the need for documentation that makes the results both transparent and reproducible. A common set of guidelines regarding what must be provided by the NCA teams to ensure transparency would be helpful.
- ***State limitations.*** Similar to the suggestion to ensure transparency of results, participants suggested that explicit discussion of limitations should be part of every NCA analysis. For example, each study should state what was—and was not—valued in the study.
- ***Communicate uncertainty.*** Following on the need to be transparent about analysis and results, many participants emphasized the need to explicitly articulate uncertainty in the results. A common approach for communicating uncertainty would be helpful.
- ***Disseminate existing materials to NCA teams.*** As noted above, a number of participants pointed to a range of existing materials that could provide a partial basis for guidance in selected areas, such as the reports on uncertainty and the EPA SAB report discussed above. A number of additional documents were suggested. Participants suggested that these documents be disseminated to all the NCA teams.

V. NEXT STEPS: MOVING FORWARD

Valuation of climate impacts—particularly quantitative measurement using economic and non-economic techniques and metrics—would heighten the ability of the NCA to inform ongoing policy and decision making at all levels of government and in the private sector. Producing a consistent and comparable set of results across assessment teams will require guidance on key issues for the assessment teams.

Guidance might include

- A comprehensive typology of impacts and impact categories, so that omissions and limitations of analyses in terms of coverage are more readily apparent
- An expression of the range of value concepts and valuation techniques, coupled with an indication of which sectors or impact categories are most ready for quantitative valuation of some kind
- For those sectors where valuation is appropriate, categories of metrics that are sufficiently mature and a set of disciplines that should be used for valuation in those sectors
- Guidelines for the treatment of difficult, recurring cross-cutting issues, such as the approach to and reporting of uncertainty, discounting for economic analyses, and incorporating intersectoral interactions

- Suggestions for presenting information that can become lost in valuation studies, such as streams of impacts over time, or the distribution of impacts across population groups or regions
- Recommendations for best practices and consistency in the use of specific valuation techniques, such as the more controversial economic techniques
- Defining processes or outcomes that help to ensure transparency and clarity in the presentation of assumptions, results, and analytical limitations
- Highlighting the potential importance as the NCA moves forward of non-quantitative or process-oriented concepts of value, as needed by decision makers

In addition, because valuation would be a new component of the Assessment, educational material may be needed for members of the assessment team, particularly those unfamiliar with social science approaches to valuation. A wealth of information already exists in academic and gray literature. As part of the workshop, a series of background papers on issues relating to economic valuation in various sectors was prepared, drawing on this information. These papers could be peer-reviewed and provide a starting point for educational materials.

Workshop participants also mentioned the value of one or more workshops to develop guidance on specific thorny issues, such as discounting, for the NCA.

Box 17. A Range of Viewpoints on Consistency and Best Practices: Key Insights

- Consistency across valuation approaches taken by NCA teams will be important in arraying, comparing, and in some circumstances aggregating the results of local and regional studies within and across sectors and regions.
- Consistency could require that all the NCA contributing teams go through a similar thought process to choose their approach.
- A common viewpoint among participants was that guidelines could be promulgated with respect to key methodological issues, such as the treatment of discounting and intergenerational equity.
- Several best practices were outlined to ensure appropriate inclusion of valuation in the NCA. To ensure transparency and reproducibility, standards should be set for the use of supporting literature, the communication of results and limitations, documentation of methodology, and the analysis and presentation of uncertainty.
- NCA teams should have a core set of capabilities and backgrounds and should have access to the established set of literature and relevant and related materials, such as the USEPA SAB report (USEPA 2009) and the CCSP SAP report on Uncertainty (CCSP 2009).

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VII. GLOSSARY OF ECONOMIC TERMS

Some words and phrases used in the economic valuation field may have different meanings from their general usage. This section defines many of the economic terms used in this report.

Benefits: Any gain, to any individual in society at any time, stemming from an action or activity. A benefit may actually be positive or negative. In the context of climate change, benefits are generally characterized as the avoided impacts if action is taken to reduce greenhouse gas emissions and so slow climate change.

Benefits transfer: A practice used to estimate benefits by transferring information available from one study or analysis to a different setting, often in a geographic area other than the one in which the original study was performed.

Complementary goods: A good that tends to be purchased when another good is purchased. A rise in the price of one good decreases the demand for the other. Examples of complements include (for consumers) cups and saucers or frankfurters and hot dog buns. Contrast these with **substitute goods**, which are used instead of each other, such as butter and margarine. When the price of one good rises, the demand for substitutes also rises. (To some extent, all goods are substitutes for each other.)

Consumer surplus: A monetary measure of the benefit to the consumer, net of the sacrifice he has to make, from being able to buy a commodity at a particular price. The surplus is a monetary representation of the utility the consumer receives from being able to purchase a product for a price that is less than the highest price the consumer would be willing to pay for that product.

Contingent valuation method (CVM): an approach to quantitatively assess values assigned by people in monetary (willingness to pay) and non monetary (willingness to contribute with time, resources, etc.) terms. It is a direct method to estimate economic values for ecosystem and environmental services. A survey is used to ask people their willingness to pay for access to, or their willingness to accept compensation for removal of, a specific environmental service, based on a hypothetical scenario and description of the environmental service.

Cost-benefit analysis: A conceptual framework for the evaluation of projects, programs or policies. Ideally, the evaluation should include all of the social and financial costs and benefits to all parties over time. However, not all benefits can be easily monetized. Difficulties also arise because market prices may be distorted. The results of the monetary portion of a cost-benefit analysis can be expressed as a net benefit or cost (the difference between total costs and benefits), or as a ratio of one to the other, indicating whether or not the project, option, or action should be pursued on a cost-benefit rationale.

Cost-effectiveness analysis: A technique that is closely related to cost-benefit analysis, but asks a different question: given a particular objective, what is the least-cost way of achieving it? This framework aids in choosing the means to achieve a given objective, but cannot answer the question of whether or not the objective is worth pursuing.

Damages: The negative effects stemming from an activity, such as pollution. Valuing damages can be relatively straightforward, as in the loss of commercial fisheries due, for example, to oil pollution. However, it can be quite difficult in the case of loss of wilderness or wildlife. In the context of climate change, damages could encompass both human systems and ecosystems.

Discounting: A mathematical operation making monetary (or other) amounts received or expended at different points in time (years) comparable across time. The operator uses a fixed or possibly time-varying discount rate from year to year that translates future values into a present value. With a positive discount rate, a dollar in the future will be worth less than a dollar today.

Economic efficiency (Pareto efficiency): A situation in which nobody can be made better off without making somebody else worse off. If an economy's resources are being used inefficiently, it means that it is possible to make somebody better off without anybody else becoming worse off. In reality, change often produces losers as well as winners. Pareto efficiency does not help judge whether this sort of change is economically good or bad.

Equity: The concept of distributive justice used in Welfare Economics. Equity as "fairness" has several possible meanings, not all of which are consistent. For example, it could refer to equality, or it could refer to the coincidence between what is deserved and rewards.

Expected Utility: A measure of welfare accruing to a consumer from an asset or future stream of consumption, when the flow of future benefits is uncertain. Expected utility is defined as the probability-weighted average of utility levels from possible future outcomes. The empirical validity of the construct as a predictor of how decisions are actually made has been strongly challenged in recent years, resulting in alternative frameworks.

Implicit price (hedonic price): The hedonic price model views products as bundles of characteristics or attributes. Thus, the market prices paid for differentiated products will reflect the degree to which they posses these specific characteristics. Using econometric techniques, the observed price paid for these products can be decomposed into implicit (or hedonic) prices of the individual attributes of the products.

Incremental cost analysis: An analysis that estimates the additional private or public costs incurred in moving from a baseline situation to a project, outcome, or state of the world. In a policy context, the analysis may estimate the additional costs of moving from a no-policy baseline to a policy, or the difference in costs between successively more stringent policies.

Life cycle cost analysis: Life cycle costing evaluates all the costs and revenues associated with acquisition, construction and operation of a project or action over its lifetime. These values are totaled by year and discounted back to time zero at some interest rate to arrive at a net present value.

Market and non-market goods: As described in this report, market goods are goods that are traded in markets. For these goods market activities provide good information from which value can be derived. In contrast, non-market-goods do not have observable market prices. These include most environmental goods, such as clean air and water, and healthy fish and wildlife populations. To derive the value of non-market goods and services, economists often look at markets for goods that are complementary to the good being valued, or at goods that are substitutes for those goods.

Normative economics: Economics analysis that provides prescriptions or statements about what "should be" rather than what is. This type of economics is contrasted with **positive** economics, which is concerned with describing and analyzing the economy as it is.

Producer surplus: A concept similar to consumer surplus, but from the perspective of the producer. It represents the revenues that the seller receives from supplying a commodity over and above the least that they would be willing to sell for (based on costs of production).

Social cost: Includes all the costs of an activity, output, or transaction, including private costs to all households and business and external costs (also called externalities), which represent effects of the activity that are not taken into account in the market, and for which no compensation is paid (the costs imposed by pollution, for example). For government programs, it also includes programmatic costs.

Social Well-being or Welfare: The total well-being of society. Economists debate what social welfare means, i.e., how to measure the concept of welfare (which is laden with value judgments) and how to aggregate welfare across members of society. Economists sometimes distinguish a narrower concept, **economic welfare**. Economic welfare is an efficiency concept, i.e., it is based solely on social surplus measures of changes in both market and non-market goods. More rarely, economists conduct analysis based on a social welfare function, which incorporates both efficiency (social surplus) and distribution (the allocation of that surplus), which is that part of human welfare that results from consumption (represented by social surpluses). In turn, **welfare economics** is the study of the way in which different resource allocations affect the economic welfare of members of society. It includes a number of concepts that are important for this report, including criteria for economic efficiency and how to conduct cost-benefit analysis of environmental issues, such as climate change. While some economists argue that economic welfare can be assessed in a value-free manner, others dispute this.

Substitute goods: see **complementary goods**.

Utility: A synonym for individual welfare. It is the pleasure or satisfaction derived by an individual from being in a particular situation or from consuming a given bundle of goods or services. Utility is not directly measurable. However individuals reveal by their choices of combinations of available commodities and actions what it is that generates utility for them.

Welfare economics: see **social welfare.**

References used in developing glossary:

Bannock et al. (1987), Black (1997), King et al. (2000), Pearce (1992), IPCC (2007b), WHO (2010), *The Economist* (2011), Higbee (1998), and Rosen (1974).

APPENDIX A. COMMITTEES

The organization of the workshop was guided by a steering and planning committee. The committees shared some members, and thus ensured collaboration and continuity in the pre-, during, and post-workshop phases. The Steering Committee comprised a range of experts from federal agencies and research institutions and guided the overall direction and content of the workshop. The Planning Committee managed the logistical details of the workshop, invited participants and was responsible for this report, and providing information and perspectives received at the workshop for the consideration of the National Climate Assessment Development and Advisory Committee.

Federal Coordinating Committee

Anne Grambsch, Acting Staff Director, Global Change Research Program, *U.S. Environmental Protection Agency National Center for Environmental Assessment*

Bob Vallario, Program Manager, Integrated Assessment Research Program, Climate Change Research Division, *U.S. Department of Energy Office of Science*

Linda Langner, National Program Leader, Resources Planning Act Assessment, *USDA Forest Service*

Kathy Jacobs, Director, National Climate Assessment; Assistant Director for Climate Assessments and Adaptation, *White House Office of Science and Technology Policy*

Sheila O'Brien, Coordinator, National Climate Assessment, *U.S. Global Change Research Program*

Leon Clarke, Senior Research Economist, Integrated Modeling and Energy Group Leader, Joint Global Change Research Institute, *Pacific Northwest National Laboratory*

Fran Sussman, Senior Economist, *ICF International*

Research Community Steering Committee

Fran Sussman (Co-Chair), Senior Economist, *ICF International*

Leon Clarke (Co-Chair), Senior Research Economist, Integrated Modeling and Energy Group Leader, Joint Global Change Research Institute, *Pacific Northwest National Laboratory*

Trudy Cameron, Raymond F. Mikesell Professor of Environmental and Resource Economics, Department of Economics, *University of Oregon*

Tom Dietz, Professor of Sociology and Environmental Science and Policy, Assistant Vice President for Environmental Research, *Michigan State University*

Tom Holmes, Research Forest Economist, Southern Research Station, *USDA Forest Service*

David Moser, Chief Economist, *U.S. Army Corps of Engineers*

John Weyant, Professor, Department of Management Science and Engineering, *Stanford University*

APPENDIX B. WORKSHOP MATERIALS

AGENDA

Valuation Techniques and Metrics for Climate Change Impacts, Adaptation, and Mitigation Options: Methodological Perspectives for the National Climate Assessment

Hyatt Arlington, 1325 Wilson Boulevard, Arlington, Virginia
January 12-13, 2011

Overview And Objectives

The principal goal of this workshop is to inform understanding of the current state of science, tools, and capabilities for quantitatively evaluating and valuing climate change impacts, adaptation, and related mitigation options, including scientific perspectives on the strengths, weaknesses, and applicability of different techniques, metrics, and toolsets. A snapshot in time on methodological capabilities, readiness, and applicability will provide foundational insights that can help shape subsequent recommendations and guidance to analysis teams engaged in the National Climate Assessment. This effort is intended to support both the 2013 NCA report–particularly with respect to the need to prioritize NCA efforts in the short-term within the context of a risk-based framework–and ongoing Assessment activities over the longer term. The participants at this workshop will be charged with providing individual input to the National Climate Assessment (NCA) Interagency Task Force and the NCA Federal Advisory Committee.

The workshop will take on three primary issues:

- The workshop will survey the valuation landscape, addressing such foundational questions as what techniques are available for valuation, what needs to be valued, and what is meant by value.
- The workshop will conduct a deep dive into the applicability of economic techniques for valuation, attempting to develop insights into which areas are most appropriate for economic techniques, what are the boundaries of economic valuation tools, and where will other techniques be more appropriate.
- The workshop will attempt to gain insights into general principles for applying valuation techniques to climate change impact analysis (both economic and non-economic as appropriate), with an eye toward important conceptual issues such as uncertainty, using an array of metrics, and distributional effects.

DAY 1: JANUARY 12, 2011

INTRODUCTION TO THE MEETING

8:30 – 8:40 **Welcome, Introduction, and Charge:** Anne Grambsch, EPA, Bob Vallario, DOE

8:40 to 8:50 **Plan for the Workshop:** Leon Clarke, JGCRI/PNNL, Fran Sussman, ICF

8:50 to 9:15 **Overview of the National Climate Assessment:** Kathy Jacobs, OSTP

SESSION 1: A SURVEY OF THE VALUATION LANDSCAPE

This session is intended to provide a high level overview of the valuation landscape, addressing foundational issues such as: what do different communities mean by value; what are the different approaches to economic and non-economic tools; what are productive examples of some of these tools; and what are some of the general issues surrounding the use of these different tools?

Moderator: Charlie Kolstad, UCSB

9:15 – 9:40 **Keynote address: An Overview of Valuation Issues, Concepts, and Challenges:** Baruch Fischhoff, CMU

9:40 – 10:05	**Keynote address: Valuation in an Adaptation Context:** Maria Blair, Rockefeller
10:05 – 10:25	**Presentation: Modeling tools: An Introduction for Social Scientists:** Keith Dixon, GFDL
10:25 – 10:40	**Break**
10:40 – 10:55	**Presentation: A Typology of Climate Impacts:** Tom Armstrong, DOI
10:55 – 11:10	**Presentation: Perspectives on Valuation in the Context of Developing National Strategy for Detecting and Tracking Climate Change Effects:** Peter Murdoch, USGS
11:10 – 11:25	**Presentation: Private Sector Perspectives on Valuation:** Paul Reinke, Ellen Post, Abt Associates
11:25 – 12:00	**Discussion**
12:00 – 1:00	**Lunch**

SESSION 2: THE ROLE AND BOUNDARIES OF ECONOMIC VALUATION TECHNIQUES

The purpose of this session is to explore the appropriate role of economic tools in climate impact assessment. Economic tools are interpreted broadly to include both valuation measures and other economic metrics (such as employment, jobs, income). The session will look at the range of available tools, and identify the types of impacts for which economic tools (particularly those of valuation) have particular strengths, and impacts that are not amenable to economic tools and that might be better addressed using non-economic approaches, such as non-economic metrics or risk-based approaches. Drawing from specific sectoral examples, the session will move in the breakout groups to identify guiding principles and a framework for apply economic tools to the NCA.

1:00 – 2:30	**Panel: Examples of Sectoral Valuation Efforts.** [Four 15 minute talks (including clarifying questions) followed by group discussion] **Moderator:** Kevin Boyle, Virginia Tech
1:00 – 1:15	**Panelist–Overview:** Kathleen Segerson, University of Connecticut
1:15 – 1:30	**Panelist–Health:** John Balbus, NIEHS
1:30 – 1:45	**Panelist–Water Resources:** David Moser, Institute of Water Resources, USACE
1:45 – 2:00	**Panelist–Forestry:** Tom Holmes, USDA
2:00 – 2:30	**Break**
2:45 – 4:15	**Breakout Session: The Role of Economic Valuation.** **Breakout Leads, Group 1:** Anne Grambsch and Leland Deck **Breakout Leads, Group 2:** Fran Sussman and Rosimeiry Portela **Breakout Leads, Group 3:** Stephanie Waldhoff and Lisa Robinson
4:15 – 5:30	**Reports from Breakout Groups and Discussion:** **Moderator:** Carol Jones, USDA

DAY 2: JANUARY 13, 2011

WRAP UP FROM DAY 1

8:30 – 8:45 **Presentation: Plans for Day 2**

SESSION 3: PRINCIPLES FOR ECONOMIC AND NON-ECONOMIC VALUATION

This session will explore key methodological issues regarding valuation and cost methodologies (both economic and non-economic as appropriate) in the NCA. What are the key issues? What is the range of options/views on these issues? Is there potential for "best practices" and/or consistency across assessment teams and analyses? How critical is it to establish this consistency at this early stage? The session will begin with examples of particularly important issues and then move to breakout groups.

8:45 – 11:15 **Presentations: Key Issues in Valuation** [six 15 minute presentations (including clarifying questions) followed by group discussion]
Moderator: Bob Vallario, DOE

8:45 – 9:10 **Presentation: Uncertainty in Valuation:** Granger Morgan, CMU

9:10 – 9:25 **Presentation: Interactions between Sectors:** John Reilly, MIT

9:25 – 9:40 **Presentation: Adaptation and Mitigation:** Kate Calvin, JGCRI/PNNL

9:40 – 9:55 **Presentation: Scale–End to End Analysis:** Chris Weaver, EPA

9:55 – 10:10 **Presentation: Integrating and Combining Metrics:** Paul Stern, NAS (presented by Baruch Fischhoff, CMU)

10:10 – 10:25 **Presentation: Discounting and Intergenerational Equity & Distributional Issues:** Geoffrey Heal, Columbia

10:20 – 11:00 **Discussion**

11:00 – 11:30 **Break**

11:30 – 1:30 **Breakout Sessions> Guiding Priniciples for Valuation.** (Work through lunch)
Breakout Leads, Group 1: Baruch Fischhoff and Kathy Segerson
Breakout Leads, Group 2: David Letson and Linda Langner
Breakout Leads, Group 3: Anne Wolverton and T.C. Richmond

1:30 – 3:10 **Reports from Breakout Groups and Discussion**
Moderator

3:10 – 3:30 **Break**

SESSION 4: THE PATH FORWARD

3:30 – 3:45 **Thoughts on the Meeting: Kathy Jacobs, OSTP**

3:45 – 5:00 **Panel discussion:** Panelists will discuss the implications of the workshop for key messages, next steps in the context of the NCA, and the longer term research agenda. [Five ten-minute presentations followed by discussion]
Moderator: Anne Grambsch, EPA
Panelist: David Montgomery, CRA
Panelist: Pete Wilcoxen, Syracuse

Panelist: Stephanie Waldhoff, EPA
Panelist: Bob O'Conner, NSF

5:00 – 5:15 **Wrap Up:** Leon Clarke, JGCRI/PNNL, Fran Sussman, ICF

BREAKOUT CHARGES

SESSION 2 BREAKOUT:
WEDNESDAY, JANUARY 12, 2:45 TO 4:15 PM

The Role of Economic Valuation

Context: The National Climate Assessment (NCA) requires a report to the President and the Congress every four years, with the next one due in 2013. The Global Change Research Act of 1990 specifies a number of "sectors" including the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and well-being, human social systems, and biological diversity. In addition to a national picture, previous Assessments have provided information at a sub-national (or regional) level. Finally, there is growing recognition that climate impacts in one sector may interact with other sectors (e.g., climate impacts on energy and water resources), exacerbating or ameliorating these impacts. The 2013 NCA Report will therefore include multiple sectors, regions and cross-cutting themes, and analyses conducted at different scales—often at the local level.

Valuation techniques have not thus far been applied to the Assessment. While many of these techniques are well-developed in economics and other fields, some are more controversial, difficult to interpret, or face practical limitations because of the data that will be available as a result of the Assessment. In this breakout, workshop participants are asked to identify the range of views and potential general principles for how economic valuation should be applied in the upcoming Assessment, and how non-economic valuation techniques can contribute.

Questions: With this framing in mind, the charge to the group has three parts:

1. What type of guidance can/should be given to the Assessment regarding the use of economic and other valuation tools in the NCA. In thinking about this guidance, consider:
    a. Are there general guiding principles for using economic valuation tools in the NCA? What are these guiding principles?
    b. What are the general or common boundaries/limitations in conducting economic valuation for these sectors in the NCA context? That is, in what contexts are economic valuation methods appropriate and in which contexts are they not appropriate?
    c. Given these boundaries, what are some of the alternative approaches and metrics that could be used, especially when economic valuation techniques may not be appropriate or applicable?

2. Develop a framework for implementing these principles, i.e., for conducting valuation and determining when (for what sectors, scales, impacts) different valuation techniques should be used, given these principles and the structure of the Assessment (e.g., scales, regions, sectors). (For framework, think: table, flow chart, org chart, Venn diagram, pyramid, etc.)

3. What are the key gaps in our knowledge where longer term research is needed to advance our ability to value climate impacts?

SESSION 3 BREAKOUT:
THURSDAY, JANUARY 13, 11:30 AM TO 1:30 PM

Guiding Principles for Valuation

Context: The National Climate Assessment (NCA) requires a report to the President and the Congress every four years, with the next one due in 2013. The Global Change Research Act of 1990 specifies a number of "sectors" including the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and well-being, human social systems, and biological diversity. In addition to a national picture, previous Assessments have provided information at a sub-national (or regional) level. Finally, there is growing recognition that climate impacts in one sector may interact with other sectors (e.g., climate impacts on energy and water resources), exacerbating or ameliorating these impacts.

The 2013 NCA Report will include multiple sectors, regions, and cross-cutting themes, posing valuation challenges to assessment teams. With the introduction of valuation techniques—particularly economic valuation—into the Assessment for the first time, assessment teams will be confronted with a range of decisions about both methods and parameters. Session 3 raised a number of these issues and highlighted some of the decisions that can and may need to be made about how to conduct economic analysis in the Assessment. However, these presentations were not intended to be comprehensive or even necessarily to identify the highest priority issues.

In this breakout, workshop participants are asked to identify the highest priority methodological issues associated with valuation that will be faced in the upcoming Assessment. We want to explore the potential for consistent guidance that can be used by the assessment teams in incorporating valuation into their analyses.

Questions: With this context in mind, each parallel breakout group should address the following three questions:

1. What are the highest priority issues or topics in the sense that if guidance were provided by USGCRP in the near-term, this guidance could significantly improve the quality, consistency, and efficiency of valuation in the assessments? *What rationale and/or criteria did you use to generate this list?*
2. For each of these topics, describe a path forward that considers the following questions:
    a. What is the range of alternatives or viewpoints on this issue? Is there already some consistency in the literature on how to address this issue?
    b. What would consistency across analyses mean for this topic and is consistency necessary, desirable, or possible, given the topic and practical limitations?
    c. Is there a path forward in the form of common assumptions, data sets, quantitative tools and techniques, qualitative tools and techniques, combining and integration methods, limitations, other?
3. In the context of a long-term, sustainable process (beyond the 2013 report) what are the *critical few*, potentially high yield topics for which research and/or development is needed to and could significantly transform valuation methods for the NCA?

APPENDIX C. LIST OF PARTICIPANTS

Robert Abt, North Carolina State University

Tom Armstrong, U.S. Department of the Interior

John Balbus, National Institute of Environmental Health Sciences (NIEHS)

Maria Blair, Rockefeller Foundation

Kevin Boyle, Virginia Tech

Jim Buizer, Arizona State University

Kate Calvin, Joint Global Change Research Institute, Pacific Northwest National Laboratory

Frank Casey, U.S. Geological Survey

David Chapman, Stratus Consulting

Linda Chappell, U.S. Environmental Protection Agency

Leon Clarke, Joint Global Change Research Institute, Pacific Northwest National Laboratory

Emily Cloyd, U.S. Global Change Research Program

Joe Cordes, George Washington University

Leland Deck, Stratus Consulting

Mark Dickie, University of Central Florida

Keith Dixon, NOAA/Geophysical Fluid Dynamics Laboratory Baruch Fischhoff, Carnegie Mellon University

Jaimie Galayda, University of Arizona

Shelby Gerking, University of Central Florida

Elisabeth Gilmore, U.S. Environmental Protection Agency

Bryce Golden-Chen, U.S. Global Change Research Program

Anne Grambsch, U.S. Environmental Protection Agency

Charles Griffiths, U.S. Environmental Protection Agency

Howard Gruenspecht, U.S. Energy Information Administration

Michael Hanemann, University of California – Berkeley

Geoff Heal, Columbia University Business School

Tom Holmes, USDA Forest Service

Kathy Jacobs, White House Office of Science and Technology Policy (OSTP)

Carol Jones, USDA

Melissa Kenney, NOAA

Charles Kolstad, University of California–Santa Barbara

Elizabeth Kopits, U.S. Environmental Protection Agency

Ray Kopp, Resources for the Future

Robert Kopp, U.S. Department of Energy

Carolyn Kousky, Resources for the Future

Nisha Krishnan, ICF International

Charlotte Landis, National Institute of Environmental Health Sciences

Linda Langner, USDA Forest Service

David Letson, University of Miami

Maxine Levin, U.S. Global Change Research Program

Fred Lipschultz, U.S. Global Change Research Program

Molly Macauley, Resources for the Future

Julie Maldonado, U.S. Global Change Research Program

Jeremy Martinich, U.S. Environmental Protection Agency

Albert McGartland, U.S. Environmental Protection Agency

Russell Meyer, Pew Center on Global Climate Change

John Mitchiner, Sandia National Laboratories

David Montgomery, Charles River Associates

Granger Morgan, Carnegie Mellon University

David Moser, Institute of Water Resources

Peter Murdoch, U.S. Geological Survey

Steven Newbold, U.S. Environmental Protection Agency

Richard Newell, U.S. Energy Information Administration

Sheila O'Brien, U.S. Global Change Research Program

Robert O' Connor, National Science Foundation

Thomas Parris, ISciences, L.L.C

Laura Petes, NOAA

Rosimeiry Portela, Conservation International

Ellen Post, Abt Associates

John Powers, U.S. Environmental Protection Agency

Jeffrey Prestemon, USDA Forest Service

John Reilly, Massachusetts Institute of Technology

Paul Reinke, Abt Associates

T.C. Richmond, GordonDerr, L.L.P.

Lisa Robinson, Independent Consultant

Steven Rose, Electric Power Research Institute

Alan Sanstad, Lawrence Berkeley National Laboratory (LBNL)

Tom Schelling, University of Maryland

Joel Scheraga, U.S. Environmental Protection Agency

Kathleen Segerson, University of Connecticut

Fran Sussman, ICF International

Robert Vallario, U.S. Department of Energy

Stephanie Waldhoff, U.S. Environmental Protection Agency

Chris Weaver, U.S. Environmental Protection Agency

Jack Wells, U.S. Department of Transportation

Pete Wilcoxen, Syracuse University

Ann Wolverton, U.S. Environmental Protection Agency

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