Improving the Assessment and Valuation of Climate Change Impacts for Policy and Regulatory Analysis

Sponsored by United States Environmental Protection Agency; U.S. Department of Energy

Executive Summary:

Improving the Assessment and Valuation of Climate Change Impacts for Policy and Regulatory Analysis

Modeling Climate Change Impacts and Associated Economic Damages

and

Research on Climate Change Impacts and Associated Economic Damages

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I. Introduction

In 2009 and early 2010, the U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) joined other U.S. government agencies in conducting an analysis of the social cost of carbon (SCC). The interagency working group used the DICE, FUND, and PAGE integrated assessment models (IAM) to estimate a range of values for the SCC from 2010 to 2050 for use in U.S. government regulatory impact analyses. The U.S. government analysis concluded in February 2010 and the estimated SCC values were first used in March 2010 in the analysis of DOE's Energy Conservation Standard for Small Electric Motors. In preparation for future revisions to the U.S. government SCC analysis, EPA and DOE seek to improve the understanding of the natural scientific and economic impacts of climate change. This enhanced understanding is also intended to inform ongoing work of the U.S. government to improve regulatory assessment and policy analysis related to climate change.

To further these objectives, the EPA National Center for Environmental Economics and Climate Change Division and the DOE Office of Climate Change Policy and Technology sponsored a pair of invitational workshops on November 18-19, 2010 and January 27-28, 2011. The November workshop focused on conceptual and methodological issues related to modeling and valuing climate change impacts. It also addressed the implications of these estimates for policy analysis. The January workshop reviewed recent research on physical impacts and associated economic damages for nine impact categories (e.g., human health, agriculture, sea level), with a particular focus on knowledge that might be used to improve IAMs.

This workshop summary was prepared by ICF International on behalf of EPA and DOE. It does not represent the official position or views of the U.S. government or its agencies, including EPA and DOE, nor has it been reviewed by the workshop speakers and other participants. The potential improvements and key findings outlined below represent the perspectives of one or more participants, as expressed at the workshops and summarized by the planning committee. However, these summaries do not necessarily represent consensus views, since none was sought at these workshops. This Executive Summary is organized into six sections: Physical Impacts Assessment; Valuation of Damages; Representing Impacts and Damages in Models; Communication of Estimates; Research and Collaboration; and Specific Impacts Sectors.

II. Physical Impacts Assessment

Participants made comments and suggestions related to impacts assessment, including the following:

- **More fully incorporate uncertainty**. Natural and social scientists should attempt to more fully characterize the uncertainty in impacts assessments, including parametric, stochastic, and structural uncertainty at all stages in the modeling process. Many of the current IAM inputs and parameters represent too narrow a range of possibilities. Complex and non-linear processes at the high ends of the impacts probability distribution (i.e., "fat tails") should be better characterized.

- **Consider both top-down and bottom-up approaches.** Estimates from both top-down and bottom-up approaches can help to estimate and bound the range of climate change impacts. For bottom-up approaches, the appropriate scale and detail may be different for each sector.

- **Incorporate threshold effects of physical and biological impacts.** Mechanistic and process models relying on basic principles (e.g., conservations of energy, plant biophysiology, ocean biogeochemistry) should be used, when possible, to extrapolate responses to new conditions, since statistical methods may not capture non-linear threshold effects of unprecedented levels of change. When climate change impacts are expected to be within or close to the range of past variations, statistical models are appropriate.

- **Capture climate variables beyond global mean temperature.** A better characterization of multiple climate variables (e.g., precipitation, storms, seasonal and diurnal temperature variations, rate of temperature change) and threshold effects on a geographically disaggregated scale could improve model calibration and the accuracy of local damage projections.

- **Focus research efforts on sectors that could have the largest influence on overall damage estimates.** This will include research on impact categories that could comprise a large share of total damages but where relatively little information has been collected to date. Researchers should not simply focus on issues that are easiest to approach. Research priorities should be guided by the combination of potential consequences and uncertainty, not one or the other alone.

- **Increase focus on high-impact events, multi-century impacts.** Existing studies tend to examine the means of the impacts probability distribution, neglecting the low-probability, high impact tails of the distribution, which can have a significant influence on IAM results. Impact studies should address this gap, recognize the potential for unexpected and unpredictable events, and attempt to model very long-term impacts (e.g., beyond 2100), despite great associated uncertainty. To do this, modelers should develop more complete multi-century projections for socio-economic and climate inputs including estimates of socio-economic uncertainty.

- **Rigorously test, compare, and evaluate impact models**. Model intercomparison projects have helped to improve physical climate models and could be used to improve impact models.

III. Valuation of Damages

Comments and suggestions related to damage valuation included the following:

- **Consider alternate functional forms for damage functions.** Representation of damages could be improved by: evaluating the additive or multiplicative nature of impacts; better incorporating discontinuities; better capturing natural capital and its interactions with physical and social capital; and generally considering a broader set of functional forms. Alternate forms are particularly important given the challenges in extrapolating damage functions calibrated at 2-3°C warming to considerably higher global mean temperature increases.

- **Clearly incorporate human behavioral responses.** Adaptation and technological development should be more fully incorporated in estimates of climate change impacts, and the underlying assumptions associated with those factors should be clearly articulated.

- **Consider different ways of equity weighting when conducting social welfare analysis of climate policies.** Several workshop participants suggested considering different ways of incorporating equity weights into the SCC or IAMs more generally. For example, most IAMs use a utility function with a single parameter that controls preferences regarding intra-generational equity, inter-generational equity, and risk aversion. Future research should explore alternative functional forms that allow these effects to be disentangled.

- **Fully account for non-market impacts and non-use values.** This includes improving estimates of impacts currently included in some models (e.g., health impacts) and incorporating impacts currently missing from most models (e.g., ocean acidification, loss of cultural heritage). Revealed and stated preference estimates and benefit-transfer methods should be improved and estimated jointly to mitigate problems with each.

- **Consider "outer measures" of climate damages.** Developing a model for a highly simplified but inclusive "outer" measure of climate change damages may help provide an upper bound on SCC estimates. Current bottom-up models are "inner" measures that attempt to capture and sum the individual components of climate damages. Since it is challenging to capture all of the components and interactions between them, these models will tend toward underestimation.

IV. Representing Impacts and Damages in Models

Throughout both workshops, but especially during the first, participants made suggestions related to integrating impacts and damages in models. These comments included the following:

- **Improve both aggregated and disaggregated models while utilizing the strengths of each.** There are important roles for models across the spectrum of aggregation, as more or less aggregation may be appropriate for different applications. Model type and analysis time scale should be matched to analytical objective. Since aggregation can contribute to a bias in impact estimates, some models should be less aggregated spatially, temporally, and sectorally to more realistically represent impact mechanisms. Since disaggregated models can incorporate more realistic impact mechanisms and use empirical data to estimate model parameters, they can be used to calibrate components of more comprehensive aggregated models.

- **Incorporate more sectors.** IAMs should include a broader range of sectors. For example, no IAMs currently represent ocean acidification.

- **Incorporate interactions between sectors.** Interactions between sectors (and among climate and non-climate stressors) may be synergistic or antagonistic, additive, multiplicative, or subtractive, making cumulative impacts larger or smaller than the sum of the individual impacts. Double-counting should be avoided.

- **Use consistent scenarios.** Consistent socio-economic and climate scenarios should be used in impact and damage assessment to facilitate inter-comparison, integration, and combination of estimates.

- **Increase model flexibility to facilitate improvements.** IAMs should be (re)designed to facilitate updates to models or model components as new research develops. A more flexible or modular structure would allow components to be individually updated or replaced.

- **Conduct new empirical studies and better incorporate existing research.** IAMs need new primary impacts research from which to draw. Research needs include empirical studies on: physical impacts, monetization of damages, decision making under uncertainty, adaptation-related technological change, adaptive capacity, tipping points, and impacts beyond 2100. IAMs could also be improved by drawing more on the existing body of research.

V. Identify metrics for model validation. Metrics and methods of validation are needed to assess models and model results. Communication of Estimates

Participants, particularly at the first workshop, made comments and suggestions related to the communication of impacts and damages estimates. These comments included the following:

- **Increase transparency.** IAMs should be made more accessible and transparent, including their key assumptions, structural equations, parameter values, and underlying empirical studies.

- **Fully and clearly communicate uncertainty.** Communication should help decision makers and the public fully and clearly understand uncertainty and its implications. The full range of model outputs should be communicated and used, rather than focusing on one central value from a set of model runs.

- **Consider other metrics.** Multiple criteria, in addition to the SCC and cost-benefit analysis, should be used for climate-related regulatory analysis, including additional cost-effectiveness measures.

VI. Research and Collaboration

Comments and suggestions related to research and collaboration included the following:

- **Increase collaboration and communication between natural scientists, economists, and modelers.** Collaboration and communication should be increased between all parties involved in impacts assessment, damages valuation, and integrated assessment modeling. Impacts assessment and valuation efforts should be coordinated with existing efforts such as the National Climate Assessment and international impacts and valuation efforts. IAM data sources, damage functions, and outputs should be reviewed by relevant members of the Impacts, Adaptation, and Vulnerability (IAV) and economic valuation communities to ensure that IAMs reflect the current state of the primary literature for each of the impact categories.

- **Increase capacity to address challenges.** Additional funding and staff are needed to help address existing impacts and damages assessment challenges.

VII. Specific Impacts Sectors

The second workshop focused on the current state of research in nine impact categories. This section highlights key research findings and recommendations for future research for each of the categories.

Storms and Other Extreme Weather Events

- Fewer tropical storms are expected in the future, but average wind speeds and precipitation totals are expected to increase. The intensity of the strongest storms is expected to increase.

- Estimates in the literature for increases in cyclone property damages due to climate change range from 0.002 to 0.006% of global GDP. Increases in property damages from all extreme events (including cyclones) due to climate change under an A1B scenario, according to one study, range from $47-$100 billion (2008 dollars) per year, or 0.008-0.018% of GDP, by 2100.

- Fatalities may increase or decrease due to climate change impacts on extreme events, as deaths from tropical cyclones may decrease more than deaths from other extreme events (e.g., heat waves) increase. Tropical cyclones are expected to continue to be the dominant cause of extreme event-related damages.

Water Resources

- Water demand, supply, and management should be modeled on a river basin scale to effectively estimate climate change impacts.

- National estimates from the literature of climate change damages to water resources range from $12-$60 billion (2009 dollars) per year for the United States according to analyses in a range of studies.

- Coupling approaches that model changes using regional hydrologic models and those using regional economic models could help bridge some gaps in water resources damage estimation.

Human Health

- The majority of climate change health effects result from diarrhea, malnutrition, and malaria. The World Health Organization estimates that the costs to treat climate change-related cases of diarrhea, malnutrition, and malaria in 2030 would be $4 to $13 billion under a scenario in which CO_2 is stabilized at 750ppm by 2210. The study predicts a 3%, 10%, and 5% increase in cases of diarrhea, malnutrition, and malaria, respectively.

- Health impact valuation depends largely on mortality valuation, particularly in developing countries and particularly among children. Adjusting the value of a statistical life for income is critical for accurate valuation.

Agriculture

- Estimates in the literature project the global range of yield changes in the 2050s to be approximately -30 to +20% under a 2.3°C mean global temperature increase (relative to 1961-1990).

- Average global effects of climate change on agriculture are expected to be positive in the short term and negative in the long term. The location of the inflection points is unknown.

    - CO_2 fertilization from increasing CO_2 concentrations will benefit some plants (C_3 plants) more than others (C_4 plants). Elevated CO_2 concentrations especially benefit weeds.

- Agriculture contributes only 2-3% of U.S. GDP, but the highly inelastic nature of agricultural demand means that even a small reduction in agricultural production from climate change could result in large price changes and large welfare losses.

- Adaptation and technological change can help to mitigate the impacts of climate change on agriculture. A key challenge will be producing heat and drought tolerant plants with high yields.

Sea Level Rise

- Climate-induced sea level rise will be compounded by both natural and human-induced subsidence in many densely-populated coastal areas.

- Emissions abatement may stabilize the rate and ultimate total amount (in 100s of years) of sea level rise, but not reduce the current significant commitment to sea level rise.

- The valuation of sea level rise damages depends heavily on wetland values and adaptation.

Marine Ecosystems and Resources

- Increasing atmospheric CO_2 concentrations cause ocean CO_2 concentrations to increase, decreasing ocean pH, and decreasing saturation states for calcite and aragonite, which are used by marine animals to produce calcareous parts (e.g., shells).

- Damages from decreased mollusk harvest revenues due to a 0.1-0.2 ocean pH decrease are estimated at $1.7 to $10 billion in net present (2007) value losses through 2060. Under the A1FI scenario pH decreases of 0.1 and 0.2 are expected by approximately 2040 and 2060, respectively.

- Assessments using bio-climate envelopes, minimum realistic models, and ecosystem and food web models would be beneficial to estimate marine impacts.

- A wide variety of studies to estimate damages is needed, using both revealed and stated preferences, to estimate total economic value of marine ecosystems and resources. Analyzing the results available from multiple existing studies could be used in a benefit transfer study to estimate economic value by transferring available information into the appropriate context.

Terrestrial Ecosystems and Forestry

- Three major types of terrestrial ecosystem impacts are expected: changes in vegetation distribution and dynamics, wildfire dynamics, and species extinction risks. For example, predicted global vertebrate extinctions due to land use and climate change range from over 30% to nearly 60% for >2 degree warming.

- Understanding changes in pest outbreaks, interior wetlands, and snow pack are important gaps.

- Natural scientists and economists need to work together to identify biophysical impacts assessment endpoints best suited for use in revealed and stated preference valuation studies.

Energy Production and Consumption

- Energy impacts may be beneficial for small to modest climate change, due primarily to decreases in heating requirements for buildings, but are expected to be dominated by negative impacts in the long-run and at higher levels of temperature change.

- More data and research are needed to evaluate the effects from wildfire and sea level rise on power sector infrastructure, and temperature impacts on electricity production, transmission, and distribution.

Socio-economic and Geopolitical Impacts

- Climate change-induced natural disasters, migration caused by sea level rise and other climate factors, and increasing resource scarcity may promote conflict; however, the policy debate regarding socio-economic and geopolitical impacts from climate change is well ahead of its academic foundation, and sometimes even contrary to the best evidence.