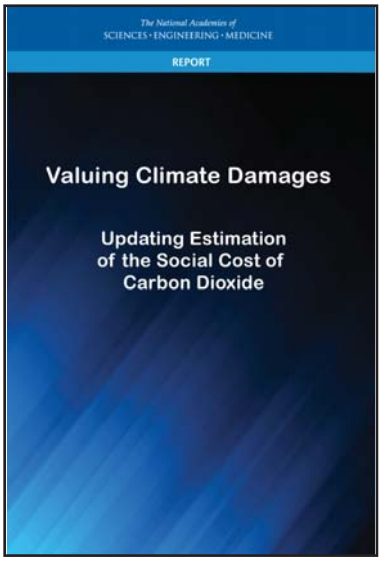
January 2017

Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide



When federal agencies are considering rules or regulations that affect carbon dioxide emissions (CO_2), they are required to analyze the emissions' impact on climate change and the resulting net damage or cost to society. Such analyses rely on a measure known as the social cost of carbon.

The federal Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) developed a method for estimating the social cost of carbon that has been used by agencies since 2010. The group asked the National Academies of Sciences, Engineering, and Medicine to recommend potential approaches for a comprehensive update to the methodology to ensure the estimates reflect the best available science.

The study committee's report, *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide* (2017), recommends both short-term and longer-term updates to the methodology to strengthen the scientific basis, provide greater transparency, and improve characterization of the uncertainties in the estimates.

WHAT IS THE SOCIAL COST OF CARBON?

The social cost of carbon ($SC\text{-}CO_2$) is an estimate, in dollars, of the net damage to society caused by a 1-metric ton increase in carbon dioxide emissions. Net damages equal the costs minus the benefits associated with climate change impacts, such as changes in agricultural productivity, risks to human health, and damage from floods.

Agencies use estimates of the social cost of carbon as they analyze the costs and benefits of potential rules and regulations that affect carbon emissions— for example, standards for automobile fuel economy or for air pollution from power plants.

The method for estimating the $SC\text{-}CO_2$ developed by the IWG has been used since 2010. The method uses three existing models to estimate the economic consequences of CO_2 emissions. First, a baseline level of CO_2 emissions is defined along with projections of underlying socioeconomic factors—global economic growth and population—decades into the future. Then, for each of the three models, an incremental increase in CO_2 emissions is added to the baseline,

which is translated into an increase in atmospheric CO_2 and a resulting increase in global mean temperature. These results are used to estimate potential net damages in dollars, using discounting to convert future damages into present dollars. The CO_2 values that result from running the three models using different socioeconomic scenarios and incorporating other uncertainties are averaged across model runs for each of three different discount rates.

The IWG's current estimate of the social cost of carbon in the year 2020 for a 3 percent discount rate is $42 per metric ton of CO_2 emissions in 2007 US dollars. If, for example, a particular regulation were projected to reduce CO_2 emissions by 1-million metric tons in 2020, the estimated value of those CO_2 emissions-reduction benefits would be $42 million.

RECOMMENDATIONS FOR UPDATING THE SC-CO_2

The report recommends a new framework that "unbundles" the steps in the IWG's current process into a series of modules that are integrated with one another. Under this approach, each step in estimating the SC-CO_2 is developed as a module that reflects the state of scientific knowledge in that portion of the analysis. Each module would be developed based on expertise within the disciplines relevant to that part of the analysis.

- **Socioeconomic module.** This module projects population and GDP, which in turn drive projections of CO_2 and other greenhouse gases that are input into the climate module. Population and GDP estimates are also input directly into the damages module and the discounting module.
- **Climate module.** This module takes the outputs of the socioeconomic module—particularly emissions of CO_2 and other greenhouse gases—and estimates their effects on the physical climate, such as on global mean surface temperature and sea level rise.
- **Damages module.** This module translates the outputs from the socioeconomic module (e.g., estimates of population and GDP) and the climate module (e.g., estimates of changes in temperature and sea level) into estimates of the net damages in dollar terms over time.
- **Discounting module.** Changes in CO_2 emissions today will affect economic outcomes for several centuries. Discounting determines how much dollar value to attach to net damages avoided in the future and translates that future value into present value.

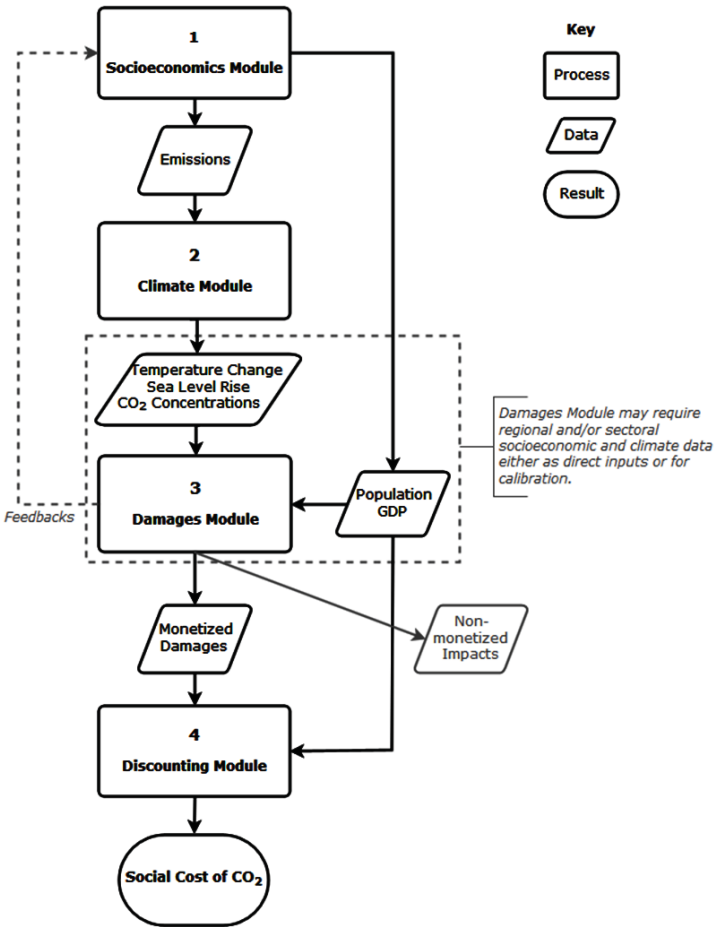


Figure 1 An integrated, modular framework for estimating the social cost of carbon (SC-CO_2).

Figure 1 illustrates how these modules are linked together in one framework. The report offers detailed recommendations about how the IWG should develop each of these modules and how the proposed framework could include feedbacks between and interactions within the modules.

NEAR-TERM AND LONGER-TERM UPDATES

The committee outlines a set of near-term recommendations that would be feasible to implement in the next 2 to 3 years and would improve each part of the analysis:

- The socioeconomic module should use statistical methods and expert elicitation for projecting distributions of economic activity, population growth, and emissions into the future.
- The climate module should employ a simple Earth system model that satisfies well-defined diagnostic tests to confirm that it properly captures the relationships over time between CO_2 emissions, atmospheric CO_2 concentrations, and global mean surface temperature change and sea level rise.

- The damages module should improve and update existing formulations of climate change damages; this update should draw on recent scientific literature related to both empirical estimation and process-based modeling of damages.
- The discounting module should incorporate the relationship between discount rates and economic growth to help account for uncertainty surrounding discount rates over long time periods.

The committee also outlines longer-term steps that should be taken to improve each module, including incorporating feedbacks across modules. These advances will require significant investments in both economic and climate modeling research, particularly related to the assessment of climate damages and to socioeconomic and emissions projections.

PROCESS FOR UPDATES

The committee recommends that the IWG use three primary criteria to evaluate the modules as they are considered for integration into the framework and for subsequent updates to the methodology:

- **Scientific basis:** Modules, their components, their interactions, and their implementation should be consistent with the state of scientific knowledge as reflected in the body of current, peer-reviewed literature.
- **Uncertainty:** Key uncertainties and sensitivities, including functional form, parameter assumptions, and data inputs should be adequately identified and represented in each module. Uncertainties that cannot be or have not been quantified should be identified.
- **Transparency:** Documentation and presentation of results should be adequate for the scientific community to understand and assess the modules. Documentation should explain and justify design choices. The extent to which features are evidence based or judgment based should be explicit. Model code should be available for review, use, and modification by researchers.

$SC\text{-}CO_2$ estimates should be updated using a three-step process at regular intervals of approximately 5 years, the report says. This process is illustrated in Figure 2 below. This timing would balance the benefit of incorporating evolving research against the need for a thorough and predictable process.

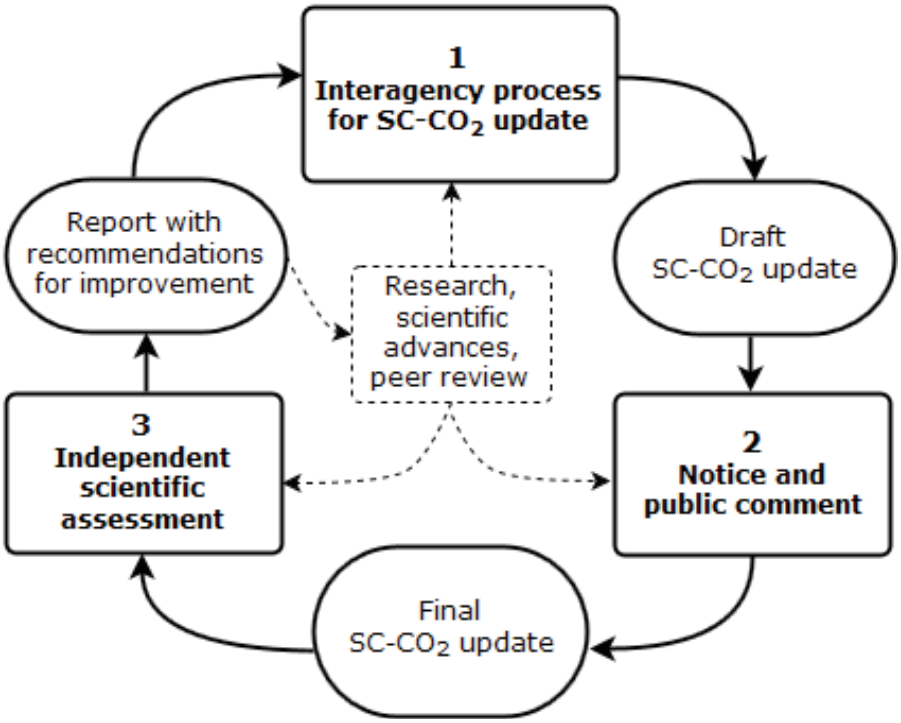


Figure 2 Regularized process for $SC\text{-}CO_2$ updates.

COMMITTEE ON ASSESSING APPROACHES TO UPDATING THE SOCIAL COST OF CARBON

MAUREEN L. CROPPER (*Cochair*), Department of Economics, University of Maryland; **RICHARD G. NEWELL** (*Cochair*), Resources for the Future, Washington, D.C.; **MYLES ALLEN,** Climate Dynamics Group, Department of Physics, University of Oxford, England; **MAXIMILIAN AUFFHAMMER,** Department of Agricultural & Resource Economics, University of California, Berkeley; **CHRIS E. FOREST,** Departments of Meteorology and Atmospheric Science & Geosciences, Earth and Environmental Systems Institute, Pennsylvania State University; **INEZ Y. FUNG,** Department of Earth & Planetary Science and Department of Environmental Science, Policy and Management, University of California, Berkeley; **JAMES K. HAMMITT,** Department of Health Policy and Management, T.H. Chan School of Public Health, Harvard University; **HENRY D. JACOBY,** Sloan School of Management (emeritus), Massachusetts Institute of Technology; **ROBERT E. KOPP,** Rutgers Energy Institute and Department of Earth and Planetary Sciences, Rutgers University; **WILLIAM PIZER,** Sanford School of Public Policy, Duke University, North Carolina; **STEVEN K. ROSE,** Energy and Environmental Analysis Research Group, Electric Power Research Institute, Washington, D.C.; **RICHARD SCHMALENSEE,** Sloan School of Management (emeritus), Massachusetts Institute of Technology; **JOHN P. WEYANT,** Department of Management Science and Engineering, Stanford University; **JENNIFER HEIMBERG,** *Study Director*; **CASEY J. WICHMAN,** *Technical Consultant, Resources for the Future, Washington, D.C.;* **MARY GHITELMAN,** *Senior Program Assistant.*

For More Information . . . This report highlights was prepared by the Board on Environmental Change and Society (BECS) based on the report *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon* (2017). The study was sponsored by the members of the Interagency Working Group on the Social Cost of Carbon, including the U.S. Department of Commerce, U.S. Department of Energy, U.S. Department of the Interior, U.S. Department of Transportation, and the Environmental Protection Agency. This Report Highlights was made possible through a grant from the Alfred P. Sloan Foundation. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the report are available from the National Academies Press, (800) 624-6242; http://www.nap.edu or via the BECS page at http://nas.edu/valuing-climate-damages.

Division of Behavioral and Social Sciences and Education

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

The nation turns to the National Academies of Sciences, Engineering, and Medicine for independent, objective advice on issues that affect people's lives worldwide.
www.national-academies.org