Response to Comments:
Social Cost of Carbon for Regulatory Impact Analysis
Under Executive Order 12866

Interagency Working Group on Social Cost of Carbon, United States Government

With participation by

Council of Economic Advisers
Council on Environmental Quality
Department of Agriculture
Department of Commerce
Department of Energy
Department of Transportation
Environmental Protection Agency
National Economic Council
Office of Management and Budget
Office of Science and Technology Policy
Department of the Treasury

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Social Cost of Carbon: Response to Comments

SUMMARY: On November 26, 2013, the Office of Management and Budget (OMB) published a Federal Register notice requesting comments on the Technical Support Document (TSD) entitled *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866*. The Social Cost of Carbon (SCC) is used to estimate the value to society of marginal reductions in carbon dioxide (CO_2) emissions. This TSD, issued in November, 2013, explained the derivation of the SCC estimates using three integrated assessment models (IAMs) regularly applied in the peer-reviewed scientific literature and provided updated values of the SCC that reflected minor technical corrections to the estimates released in May of that year.

OMB requested that comments be submitted electronically to OMB by January 27, 2014 through *www.regulations.gov*. On that date, OMB issued a subsequent notice extending the comment period until February 26, 2014.

This notice responds to the major comments received and discusses how the Interagency Working Group (IWG) that developed the SCC estimates will approach future updates to the estimates, based on comments received, developments in the academic literature, and advice from external experts.

SUPPLEMENTARY INFORMATION: Rigorous evaluation of benefits and costs is a core tenet of the rulemaking process.[1] It is particularly important in the area of climate change. The current estimate of the SCC has been developed over several years, using the best science available, and with input from the public.

In February 2010, after considering public comments on interim values that agencies used in a number of rules, an interagency working group of technical experts, coordinated by OMB and the Council of Economic Advisers (CEA), released updated SCC estimates. The IWG estimated the updated SCC values using the most widely cited climate economic impact models that are capable of estimating the SCC. Those climate impact models, known as IAMs, were developed by outside experts and published in the peer-reviewed literature. The TSD discusses in detail the models, inputs, and assumptions used in generating the SCC estimates, and the basis for their selection (2010 TSD). Recognizing that the models underlying the SCC estimates would evolve and improve over time as scientific and economic understanding increased, the IWG committed in the 2010 TSD to regular updates of these estimates.

In May of 2013, after all three of the underlying models had been updated and used in the peer-reviewed literature, and agencies had received public comments urging them to update their estimates, the IWG released revised SCC values. The May 2013 estimates are similar to those used by other governments, international institutions, and major corporations. Opportunity for public comment on those estimates

[1] Executive Order 12866 directs that its regulatory principles, which includes assessing the benefits and costs of intended regulations, should be adhered to by Federal agencies "to the extent permitted by law and where applicable." (http://www.archives.gov/federal-register/executive-orders/pdf/12866.pdf)

was previously provided in a number of proposed rulemakings, and any comments received through the rulemaking process were, or will be, addressed by the agencies in the normal course of finalizing those rules.

A slightly revised TSD with minor technical corrections was issued in November, 2013 (2013 TSD). The 2013 TSD was based on the best scientific information on the impacts of climate change available at that time. Consistent with the IWG's commitment to continued refinement of the SCC estimates to ensure agencies appropriately measure the social damages associated with CO_2 emissions as they evaluate the costs and benefits of rules, on November 26, 2013 OMB requested comments on all aspects of the TSD and its use of IAMs to estimate the SCC. OMB noted that it was particularly interested in comments on the following topics:

- the selection of the three IAMs for use in the analysis and the synthesis of the resulting SCC estimates, as outlined in the 2010 TSD;
- the model inputs used to develop the SCC estimates, including economic growth, emissions trajectories, climate sensitivity, and intergenerational discounting;
- how the distribution of SCC estimates should be represented in regulatory impact analyses; and
- the strengths and limitations of the overall approach.

OMB further clarified that it was not requesting comments on the three peer reviewed IAMs themselves; rather OMB was requesting comments on their use in developing the SCC estimates.

1 Introduction

Rigorous evaluation of benefits and costs is a core tenet of the rulemaking process. Since 1981 executive orders have required benefit cost analysis for all significant U.S. Federal regulations, to the extent permitted by law (EOs 12291 and 12866). Estimates of the SCC allow the effects of CO_2 emission changes on society to be counted in benefit cost analysis. Without estimates of the SCC the effect of a change in CO_2 emissions would be considered qualitatively, but could not be quantified in the bottom-line benefit cost estimates. In 2007 the Ninth Circuit Court remanded a fuel economy rule to DOT for failing to monetize the benefits of the CO_2 emissions reductions in its regulatory impact analysis, noting that "the value of carbon emissions reduction is certainly not zero."[2]

In 2009, the Administration launched a process to determine how best to monetize the net effects (comprising both positive and negative effects) of CO_2 emissions and sought to harmonize a range of different SCC estimates across multiple Federal agencies. This process was conducted by an interagency working group made up of Federal agencies likely to issue rules affecting CO_2 emissions and EOP offices that review such rules. The purpose of this process was to ensure that agencies were using the best available information and to promote consistency in the way agencies quantify the benefits of reducing CO_2 emissions, or costs from increasing emissions, in regulatory impact analyses. At the start of the 2009

[2] http://cdn.ca9.uscourts.gov/datastore/opinions/2007/11/14/0671891.pdf

effort, the IWG conducted a preliminary assessment of existing peer-reviewed literature to set interim SCC estimates while it worked on a more comprehensive analysis. When agencies began using these interim values in rulemakings, they solicited comments "on all of the scientific, economic, and ethical issues before establishing improved estimates for use in future rulemakings."[3]

In February 2010, after considering public comments on the interim values and conducting additional technical work, the IWG released improved SCC estimates. These improved SCC estimates were developed using the three most widely cited climate economic impact models. Those climate impact models were developed by outside experts and are the most widely used and widely cited models in the economics literature that link physical impacts to economic damages of CO_2 emissions. The National Academies of Science (NAS) identified these three models as "the most widely used impact assessment models" in a 2010 report (NAS, 2010).

With the release of the 2010 SCC estimates the IWG noted that there remained a number of limitations to the analysis and committed to updating the estimates as the science and economic understanding of climate change and its impacts on society improves over time. In particular, a goal was set to revisit the SCC estimates "within two years or at such time as substantially updated models become available." Subsequent to the release of the 2010 TSD, all three of the models used in the development of the SCC estimates were updated by their (academic) developers, in part, to reflect more recent information on the potential impacts of climate change. The three models remain the most widely cited models capable of estimating the SCC.

Since the publication of the interim estimates in 2009, the IWG's SCC estimates have been used in 34 proposed rulemakings that provided opportunity for public comment. Federal agencies and OMB have continued to review public comments on the SCC estimates that are received through the notice and comment rulemaking process. Public comments received on proposed rulemakings using the 2010 SCC estimates, among other comments, urged the IWG to update the SCC estimates to reflect the newest versions of the models being used in the peer-reviewed scientific literature.[4] In response to these comments and consistent with the 2010 commitment to periodically revise the SCC estimates, in 2013 the IWG released an update to the SCC estimates that maintained the same methodology underpinning the previous estimates, but applied the most current versions of the three IAMs.

That same year, in response to public and stakeholder interest in the SCC estimates, OMB announced it would provide an additional opportunity, in addition to those available in proposed rulemakings, for public comment on the SCC estimates. Over the 90-day comment period[5], OMB received 140 unique sets of comments and over 39,000 form letter submissions through two letter writing campaigns. The comments covered a wide range of topics including the technical details of the modeling, the aggregation and

[3] For example, the proposed rulemaking for Model Year 2012-2016 Light-Duty Vehicle Greenhouse Gas Emissions Standards. http://www.gpo.gov/fdsys/pkg/FR-2009-09-28/pdf/E9-22516.pdf.

[4] See Docket ID: EPA-HQ-OAR-2010-0660-10002 (p 4); EPA-HQ-OAR-2010-0660-10888 (p 26); EPA-HQ-OAR-2010-0799-9519 (p 10). Documents are available in www.regulations.gov.

[5] OMB originally provided a 60-day comment period but that was subsequently extended, in response to stakeholder requests, for an additional 30 days.

presentation of the results, and the process by which the SCC estimates were derived. The form letters contained a short paragraph supporting the 2013 update. The unique comment letters offered a wide range of perspectives on the process, methodology, and results, including both support and opposition. Commenters also provided constructive recommendations for potential opportunities to improve the SCC estimates in future updates. In this context, the IWG is reconfirming its commitment to periodic review and update of the methodology and estimates to ensure that they continue to reflect the best available science and economics.

The science underlying the assessment and valuation of climate change impacts is constantly evolving. Since the publication of the initial SCC estimates in 2010, the representation of the science and economic consequences of climate change in the three IAMs has improved. The 2013 SCC technical update allowed the SCC estimates to reflect these improvements. However, as explained in the 2013 TSD, this update was limited in scope to those improvements available in more recent versions of the IAMs. As such, there remain additional opportunities for technical improvements to the SCC estimates that should be considered for future updates.

As noted above, commenters provided a wide range of perspectives and technical input on how to further refine the SCC estimates. To help synthesize the technical information and input reflected in the comments, and to add additional rigor to the next update of the SCC, the IWG plans to seek independent expert advice on technical opportunities to improve the SCC estimates, including many of the approaches suggested by commenters and summarized in this document. Specifically, the IWG plans to ask the National Academies of Sciences, Engineering, and Medicine to examine the technical merits and challenges of potential approaches to improving the SCC estimates in future updates. Input from the Academies, informed by public comments and the peer-reviewed literature, will help to ensure that the SCC estimates used by the federal government continue to reflect the best available science and methodologies.

The Academies' review will take some time, during which Federal agencies will have a continued need for estimates of the SCC to use in benefit-cost analysis. After careful evaluation of the full range of comments and associated technical issues detailed below, the IWG continues to recommend the use of the current SCC estimates[6] in regulatory impact analysis until revisions based on the many thoughtful public comments we have received and the independent advice of the Academies can be incorporated into the estimates. We believe the current estimates continue to represent the best scientific information on the impacts of climate change available in a form appropriate for incorporating the damages from incremental CO_2 emissions changes into regulatory analyses.

[6] Concurrently with this document, the IWG is releasing a minor technical revision to the estimates, which is explained in a technical addendum below. The current SCC estimates are contained in the *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (Revised July 2015)* which is available at *http://whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf.*

The remainder of this Response to Comments document provides topic specific summaries of the comments received followed by a response. The comments have been categorized into the following topics, which are addressed in turn:

- Choice of Integrated Assessment Models and Damage Functions
- Climate Science
- Socio Economic and Emissions Scenarios
- Discount Rates
- Aggregation of Results and Selection of Final Estimates
- Consideration of Uncertainty
- Use of Global vs. Domestic SCC Estimates
- Other Technical Areas of Comment
- Process by which the SCC Estimates were Developed

These nine major topic sections are further divided into brief summaries of specific comment areas, each followed by a response. Subsequently, there is a brief technical addendum explaining two minor revisions to the TSD.

2 Choice of Integrated Assessment Models and Damage Functions

Many commenters addressed the IAMs used to estimate the SCC. Several commenters recommended improvements to the existing IAMs and their damage functions, which monetize the damages associated with the physical impacts of climate change. Finally, a few commenters discussed the value to society of the goods and services whose production is associated with CO_2 emissions.

(1) The IWG's choice of IAMs used to estimate the SCC

A number of commenters were generally supportive of the choice of the three IAMs used in developing the SCC. For example, a letter signed by several commenters noted that these IAMs are "reasonably based on current scientific and economic knowledge" and are "widely cited and accepted in the academic community." One commenter said the models reflect "the best available, peer-reviewed science to tally the benefits and costs of specific regulations with impacts on CO_2 emissions. The IAMs include benefits and costs that have been quantified to date."

Other commenters voiced concern that the economic damages estimated by the IAMs are too uncertain to be useful for policy analysis. Several of these commenters included quotations from Pindyck (2013) and argue that the current IAMs and their damage functions lack sufficient theoretical or empirical foundations. For example, one commenter stated that "… The loss functions in PAGE and FUND, the other two models used by the Interagency Working Group, are more complex but equally arbitrary ... there is no pretense that the equations are based on any theory." Another commenter wrote, "The outputs of the three integrated assessment models (IAMs) are dependent on arbitrary and subjective assumptions used for data inputs."

Some commenters suggested that one or more of the models should be rejected. For example, some cited Dayaratna and Kreutzer (2013) in arguing that the DICE model is "flawed beyond use for policymaking." Others argued that both PAGE and DICE should be omitted because both include "little-to-no CO_2 fertilization benefit" in estimating agricultural damages. Another commenter suggested all three models be rejected because "… DICE and PAGE are too aggregated to represent research on climate impacts in any detail; they offer only their developers' guesses about how to reduce the vast, multi-dimensional array of climate damages to a few summary, monetized impacts", and "FUND … attempts a higher level of disaggregation, but produces damage results that are too low to be consistent with current climate science."

Finally, a few commenters suggested that other IAMs should be considered for any future SCC updates. Sometimes this was a generic suggestion such as "updates to the SCC should also consider other models that are similarly peer reviewed and based on the state of the art of climate-economic modeling." A model that was mentioned by a few commenters was the World Bank's Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) Model. One commenter suggested the use of the model, Climate and Regional Economics of Development (CRED).

A few commenters criticized the TSD for failing to adequately explain or justify the choice of models and/or inputs used to run the models. For example, one commenter wrote, "… adequate justification is not currently provided for some aspects of the modeling. … For example, justification is lacking for ... use of an average 550 ppm scenario, constant discount rates, EMF-22 versus other published scenarios, FUND and PAGE probabilistic modeling, and a variety of 2013 revisions to the individual models …" Another commenter cited a 1981 D.C. Circuit U.S. Court of Appeals decision that an agency "must provide a complete analytic defense of its model [and] respond to each objection with a reasoned presentation" and must demonstrate "rational connections between factual inputs, modeling assumptions, modeling results and conclusions drawn from those results." A third commenter cited the Administrative Procedure Act (APA), arguing that the "use of the SCC estimates in rulemaking will not meet the requirements of the APA as interpreted by the courts because the IWG and OMB have not provided a rational connection or sufficient justification for the models, data inputs and assumptions used to create the SCC estimates."

Response

The IWG agrees with those commenters who believe the choice of the three IAMs—DICE, FUND, and PAGE—was the most appropriate for the purpose of estimating the SCC. The IWG made this determination when it began developing the SCC estimates in 2009-2010. DICE, FUND, and PAGE are the most widely used and widely cited models in the economic literature that link physical impacts to economic damages for the purposes of estimating the SCC. As stated in the 2010 TSD:

> These models are frequently cited in the peer-reviewed literature and used in the IPCC assessment. … These models are useful because they combine climate processes, economic growth, and feedbacks between the climate and the global economy into a single modeling framework. … Other IAMs may better reflect the complexity of the science in their modeling frameworks but do not link physical impacts to economic damages.

In addition, the National Academies of Science (NAS) identified these three models as "the most widely used impact assessment models" in a 2010 report (NAS, 2010). Furthermore, in a comprehensive literature review and meta-analysis conducted in 2008, the vast majority of the independent impact estimates that appeared in the peer-reviewed literature were derived from FUND, DICE, or PAGE (Tol, 2008).

While the development of the DICE, FUND and PAGE models necessarily involved assumptions and judgments on the part of the modelers, the damage functions are not simply arbitrary representations of the modelers' opinions about climate damages. Rather they are based on a review by the modelers of the currently available literature on the effects of climate change on society. The conclusions that the modelers draw from the literature, and the bases for these conclusions are documented, and all three models are continually updated as new information becomes available. While we recognize that there are limitations with these models, including some of those discussed in Pindyck (2013), nonetheless IAMs provide valuable information for regulatory impact analysis. In a recent article in the peer-reviewed literature, Weyant (2014) addressed this issue as follows:

> While Pindyck's observations about the empirical weaknesses of IAMs or calculations of the SCC are worthy of careful study, the conclusion that IAMs are therefore useless fundamentally misconceives the enterprise. IAMs and the SCC are conceptual frameworks for dealing with highly complex, non-linear, dynamic, and uncertain systems. The human mind is incapable of solving all the equations simultaneously, and modeling allows making "If…, then…" analyses of the impacts of different factors. The models have provided important insights into many aspects of climate-change policy.

The IWG thus believes that it was appropriate to base the SCC estimates on the DICE, FUND and PAGE models. Moving forward, the IWG will continue to follow and evaluate the latest peer reviewed literature applying IAMs. The IWG will seek external expert advice on the technical merits and challenges of using additional models (e.g., CRED, ENVISAGE) to estimate the SCC and/or removing existing models from the ensemble (DICE, FUND, and PAGE) used to estimate the SCC.

Finally, the IWG disagrees with the comment that insufficient justification has been provided for the models, data inputs, and assumptions used to estimate the SCC. The IWG has regularly and repeatedly provided detailed explanations and justifications for the data, assumptions, and models used to estimate the SCC. The 2010 TSD thoroughly detailed each of these aspects, justified their use, and elucidated their limitations. The 2013 TSD provided a detailed explanation of updates and revisions made to the SCC. The additional OMB public comment solicitation provided a further opportunity for the public to comment on the data, assumptions, and models used in developing the SCC estimates; in this Response to Comment the IWG is responding to those comments received. Thus, the IWG has provided clear, transparent analytic defenses of its estimates, explained the rational connections that underlie these estimates, and responded to public comments.

The 2010 TSD provides a complete explanation of the entire modeling exercise, including a description of the chosen integrated assessment models (IAMs) and why they were selected, how the harmonized

modeling decisions were developed, how the sources of the data inputs were selected, and how the model results were aggregated to the final four point estimates that are used in regulatory analysis. For example, Section III A. of the TSD describes, in detail, the structure and connections within the IAMs (DICE, FUND, and PAGE), and the features that make them relevant and appropriate for estimating the SCC. As described in the 2010 TSD, after critical evaluation the IWG concluded that it is reasonable to use these three models from the peer-reviewed literature for the purpose of estimating the SCC. Section III of the 2010 TSD also describes, in detail, other relevant modeling inputs adopted by the IWG, the basis for the specific inputs used, and how these inputs are connected to the modeling and estimates of the SCC. For example, see Section III D. of the 2010 TSD for discussion about the IWG's analysis, development, and application of the distribution for the equilibrium climate sensitivity parameter; Section III E. for discussion about the IWG's analysis, selection, and, application of socioeconomic and emissions scenarios; and Section III F. for discussion about the IWG's literature search, analysis, and selection of discount rates. In addition, in Section V of the 2010 TSD the IWG described potential limitations of the analysis and made clear the resulting implications for the SCC estimates, based on the IWG's critical examination of the models and their underlying assumptions.

(2) Recommendations for improving the current IAMs or damage functions

Many commenters suggested improvements to one or more of the models before future SCC updates. Many of these commenters believe that the current SCC estimates underestimate the damages induced by climate change because of incomplete or missing treatment of a number of damage categories. Suggestions for additional damage categories include: ocean acidification, spillover effects from displaced persons, increased variability in weather patterns, wildfires, "catastrophic" damages stemming from exceedance of various "tipping points," loss of species and habitat diversity, cultural impacts, health effects from increased air pollution, and impacts on global security, among others. Commenters also questioned whether the models adequately addressed linkages between the damage categories. One Commenter suggested the use of the aggregate damage function introduced by Weitzman (2010) as an alternative specification relating mean temperature change and GDP loss.

Commenters disagreed about whether the IAMs overestimate or underestimate CO_2 fertilization effects in the agriculture and forestry sectors. For example, one commenter wrote "only one of the three IAMs used by the IWG has any substantial impact from CO_2 fertilization, and the one that does, underestimates the effect by approximately 2-3 times," referencing Idso (2013). However another commenter argued that "the models do not reflect recent research on agricultural changes, which suggests that CO_2 fertilization is overestimated, particularly in the FUND model, and that much, if not all, of the fertilization benefits may be cancelled out by negative impacts on agriculture."

Response

To date, the IWG has accepted the models as currently constituted, and omitted any damages or beneficial effects that the model developers themselves do not include. The IWG recognizes that none of the three IAMs fully incorporates all climate change impacts, either positive or negative. Some of the effects referenced by commenters (e.g., "catastrophic" effects, disease, and CO_2 fertilization) are explicitly

modeled in the damage functions of one or more of the current models (although the treatment may not be complete), and the model developers continue to update their models as new research becomes available. In fact, the IWG undertook the 2013 revision because of updates to the models, which include new or enhanced representation of certain impacts, such as sea level rise damages. In addition, some of the categories mentioned by commenters are currently speculative or cannot be incorporated into the damage function for lack of appropriate data. Using an ensemble of three different models was intended to, at least partially, address the fact that no single model includes all of the impacts. We recognize that there may be effects that none of the three selected models addresses (e.g., impacts from ocean acidification) or that are likely not fully captured (e.g. catastrophic effects).

The IWG also recognizes that the impacts of climate change on agriculture is an area of active research and that methodological and data challenges persist. As a result there is uncertainty as to the magnitude of these impacts and the role of interactions between changes in the climate and other factors, such as CO_2 fertilization, temperature, precipitation, ozone, pests, etc. Additionally, these effects are likely to vary widely across regions and crops. However, with high confidence the IPCC (2013) stated in its Fifth Assessment Report (AR5) that "[b]ased on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts." As noted above, the IWG's approach to date has been to rely on the damage functions included in the three IAMs by their developers.

The IWG agrees that it is important to update the SCC periodically to incorporate improvements in the understanding of greenhouse gas emissions impacts and will continue to follow and evaluate the latest science on impact categories that are omitted or not fully addressed in the IAMs. Also, the IWG will seek external expert advice on the technical merits and challenges of potential approaches to update the damage functions in future revisions to the SCC estimates.

(3) Value of goods and services whose production is associated with CO_2 emissions

Some commenters felt that the SCC estimates should include the value to society of the goods and services whose production is associated with CO_2 emissions. Many of these commenters mentioned goods produced using fossil fuels, such as "plastics, chemicals, nitrogen fertilizer, steel, aluminum, synthetic rubber for tires, glass, pharmaceuticals, and paper." One commenter argued for including the benefits to "regions that depend on employment from energy intensive industry, regions dependent on fossil fuels for heating, cooling, food production and other components associated with preserving their standard of living and regions that are in need of low cost fossil fuels to enable the economic development improving their standard of living." Similarly, other commenters focused on the negative consequences of regulating CO_2 emissions, such as the potential effect on energy prices, economic growth, or international competitiveness. One commenter suggested the inclusion of "… the social costs and economic dislocations that could result from carbon reduction policies that would eliminate fuel options such as coal, the social costs associated with higher electricity prices, and the economic and security risks associated with electric reliability problems."

Response

Rigorous evaluation of benefits and costs is a core tenet of the rulemaking process. The IWG agrees that these are important issues that may be relevant to assessing the impacts of policies that reduce CO_2 emissions. However, these issues are not relevant to the SCC itself. The SCC is an estimate of the net economic damages resulting from CO_2 emissions, and therefore is used to estimate the benefit of reducing those emissions.

A rule that affects CO_2 emissions may also affect the production or consumption of goods and services, in which case it could create costs and benefits for businesses and households that either produce or use those goods and services. These costs and benefits are important to include in an analysis of the rule's impacts, but are not a result of changes in CO_2 emissions. The SCC is not a measure of social welfare from the consumption of goods and services whose production results in CO_2 emissions, or other positive or negative externalities associated with the production of those goods and services.[7] In other words, the SCC is just one component of a larger analysis that includes consideration of many other potential impacts, including labor market changes, energy security, electricity reliability, and changes in emissions of other pollutants, among others.

3 Climate Science

Comments on the climate science components of the modeling fall into three broad areas: the specification of the equilibrium climate sensitivity parameter, the formulation and parameterization of other physical science components in the IAMs, and uncertainty in climate science and climate modeling. In addition, a number of the commenters generally encouraged continued updating of the SCC to maintain the best scientific understanding of the relevant earth system processes as new findings emerge.

(1) Climate Sensitivity

The equilibrium climate sensitivity (ECS) parameter is a measure of the climate's responsiveness to increased concentrations of greenhouse gases in the atmosphere. Specifically, the ECS is the long-term increase in the annual global-average surface temperature from a sustained doubling of the atmospheric CO_2 concentration relative to pre-industrial levels. Several commenters supported the IWG approach of calibrating the distribution of Roe and Baker (2007) to the IPCC (2007) Fourth Assessment Report (AR4) consensus statement on the ECS. However, many commenters, including many of those that approve of the IWG's basic approach, suggest updating this modeling input. The majority of these commenters suggest incorporating new research published since the 2010 TSD was released. Some commenters noted that in its Fifth Assessment Report the IPCC has revised its discussion of the likely range of climate sensitivity compared to AR4 (IPC 2013). Other commenters pointed to individual papers, such as Otto et al. (2013), which present lower and more constrained probability density functions (pdfs) than either the AR4 or AR5 consensus statements, in support of the commenters' suggestion that the pdf used by the IWG was biased high. Some commenters suggested that certain recent papers (e.g., Loehle, 2014; Otto et

[7] Similarly, the SCC does not capture benefits to society from goods and services that reduce CO_2 emissions, or other co-benefits from reducing emissions such as reduced particulate matter pollution. Those benefits are treated elsewhere in a benefit cost analysis.

al., 2013; Aldrin et al., 2012) may be especially informative because they rely on recent historical temperature measurements. A couple of commenters suggested that the mean of the climate sensitivity pdf used by the IWG was too low, because the climate models do not take into account poorly understood climate system feedbacks and tipping points.

Response

The IWG is aware that this is an active area of research and remains committed to updating the SCC estimates to incorporate new scientific information and accurately reflect the current state of scientific uncertainty regarding the ECS. While we agree with commenters that the ECS distribution, along with other climate modeling inputs to the SCC calculation, should be updated periodically to reflect the latest scientific consensus, care must be exercised in selecting an appropriate range of estimates for this important parameter. Many studies estimating climate sensitivity have been published, based on a variety of approaches (instrumental record, paleoclimate observations, models, etc.). These individual studies report differing values and provide different information. Picking a single study from the high or low end of the range, or even in the middle, will exclude relevant information. A valid representation of uncertainty regarding climate sensitivity should be obtained from a synthesis exercise such as that done by the IPCC that considers the full range of relevant studies.

At the time the 2013 SCC update was released, the most authoritative statement about ECS appeared in the IPCC's AR4. Since that time, as several commenters noted, the IPCC issued a Fifth Assessment Report that updated its discussion of the likely range of climate sensitivity compared to AR4. The new assessment reduced the low end of the assessed likely range (high confidence) from 2°C to 1.5°C, but retained the high end of the range at 4.5°C. Unlike in AR4, the new assessment refrained from indicating a central estimate of ECS. This assessment is based on a comprehensive review of the scientific literature and reflects improved understanding, the extended temperature record for the atmosphere and oceans, and new estimates of radiative forcing.

Several of the post-AR4 studies highlighted by some commenters were cited in the AR5 assessment. In particular, both Aldrin et al. (2012) and Otto et al. (2013) were cited in both Chapter 10 and Chapter 12 of the AR5 Working Group I assessment. Eight of the authors of Otto et al. (2013), including the lead author, were authors of Chapter 12 for AR5's Working Group I and one was a lead author for the chapter. Hence it is clear that the IPCC considered Otto et al. (2013) in its synthesis of literature on the ECS. More broadly, the AR5 climate sensitivity distribution likely incorporates much of the literature identified by the commenters. The IWG will continue to follow and evaluate the latest science on the equilibrium climate sensitivity and seek external expert advice on the technical merits and challenges of potential approaches prior to updating the ECS distribution in future revisions to the SCC estimates, including (but not limited to) using the AR5 climate sensitivity distribution for the next update of the SCC.

(2) Other Physical Science Components of the Integrated Assessment Models

We define the physical science components of the models to include the modeling of physical impacts, such as changes in mean global temperature or sea level rise. This definition excludes the functions in the models that translate those physical endpoints into economic damages, which is addressed above in the

discussion of damage functions. Some commenters expressed approval of the physical science components of the models but others criticized specific components as being overly simplified or incomplete. For example, some commenters suggested that IAMs under-represent the potential for future damages by concentrating on changes in annual and global mean climate indicators, when changes in variability, or interactions between changes in the mean and natural variability, could be key components in determining future damages. Others noted the need for more explicit representation of the potential for low-probability, high impact "catastrophes," with one commenter calling for better modeling of multiple "tipping points" at the climatic thresholds indicated by the most recent scientific literature. Another commenter suggested that the IAMs assign too high a probability to "catastrophic" and extreme events, such as "ocean circulation shutdown, catastrophic sea level rise, and runaway climate change."

The comments regarding the representation of the carbon cycle were mixed. One commenter suggested that the highly simplified carbon cycles in the IAMs may lead to an underestimation of atmospheric CO_2 concentrations over time because they do not adequately capture the feedback of climate change on the strength of carbon sinks, citing Kopp and Mignone (2012). Other commenters suggested that the ocean uptake of CO_2 has actually been greater than predicted and thus the models may be overestimating atmospheric CO_2 concentrations.

A few commenters suggested that changes in the temperature response functions across model versions are unsupported by evidence or research.[8] For example, two commenters suggested that a change in the triangular probability distribution of the transient climate response function in PAGE was largely subjective and lacked adequate supporting citations. Another noted that, in the FUND model, the increased rate of temperature change for any given climate sensitivity was inconsistent with recent observations, which the commenter suggests show the rate of warming to be slower than predicted. One commenter suggested that the version of the DICE model used may overestimate sea level rise relative to AR5 projections or estimates projected by the MAGICC climate model because of DICE's reliance on an outdated semi-empirical methodology that uses models of reduced complexity in conjunction with statistical relationships between sea level and climate forcing.[9] Finally, one commenter suggested that the entire physical climate and greenhouse gas concentration functions in the IAMs should be replaced by functions from other models. The commenter mentions the more detailed representations such as MAGICC, SNEASY, or BEAM, which would have simultaneous implications for the carbon cycle, sea level rise, and/or temperature response rates.[10]

Response

[8] While the ECS determines the long-term magnitude of the climate's response to changes in atmospheric concentrations of GHGs, the IAM's temperature response functions model the near-term dynamics of how the climate responds to increasing atmospheric concentrations.

[9] MAGICC is the Model for the Assessment of Greenhouse Gas Induced Climate Change. For more information see Meinshausen et al. (2011).

[10] For more information on the SNEASY model see Urban and Keller (2010). For more information on the BEAM model see Glotter et al. (2014).

A key objective of the IWG was to draw from the insights of the three models while respecting the different approaches to linking GHG emissions and monetized damages taken by modelers in the published literature. After conducting an extensive literature review, the interagency group selected three sets of input parameters (climate sensitivity, socioeconomic and emissions trajectories, and discount rates) to use consistently in each model. All other model features were left unchanged, relying on the model developers' best estimates and judgments, as informed by the then-current literature. While the IAMs are periodically updated, the rapid pace of research in the area of climate science means that at any given time there may be new research that has not yet been incorporated into one or more models. Thus, while a given model may not always reflect the most recent research regarding any given climate subsystem, the IWG concluded that, at the time, the IAMs collectively represented the state of the science by bringing all these systems together into a single framework.

A benefit of using an ensemble of three models is that they cover a range of potential outcomes as expressed in the literature. For example the three models used collectively span a range of carbon cycle and climate change responsiveness that reflects the uncertainty in the literature.

With regards to comments on the temperature response function, the past 15 years of observed atmospheric temperatures cannot be compared directly to climate model simulations because (1) observed temperatures were influenced by volcanic eruptions that were not included in simulations because the timing and spatial distribution of eruptions are not known in advance; and (2) the last 15 years of atmospheric temperatures have been strongly influenced by natural climate variability due to oceanic fluctuations, such as the El Niño Southern-Oscillation; models include this variability, but no attempt is made to synchronize the models' timing of this variability with observed variability. In other words, while the models incorporate variability around a trend over time, they cannot predict how that variability affects measured temperatures in a specific year.

Regarding the criticisms by commenters of the sea level rise projections in DICE, the IWG recognizes that sea level rise projections are also an area of ongoing research. One key issue involves projections of melt from the Greenland and West Antarctic ice sheets. The IPCC AR5 report notes there is a possibility of sea level rise "substantially above" their best estimate of a likely range because of uncertainties regarding the response of the Antarctic ice sheet (AR5 Working Group I, Chapter 13). In AR5 the IPCC also discusses semi-empirical methods, stating a low confidence in projections based on such methods, which calibrate a mathematical model against observations rather than projecting individual processes. However, the IPCC did not entirely discount these methods. Further supporting the use of semi-empirical methods, the U.S. National Climate Assessment uses an average of the high end of semi-empirical projections in order to define their "Intermediate-High" Scenario (Parris et al., 2012). Therefore, it is reasonable for one out of three models used by the IWG to include some reliance upon semi-empirical methods.

The IWG is aware that more sophisticated yet still relatively simplified climate models, such as MAGICC, could be used to replace the highly simplified climate science components of the three IAMs. However, given the range of climate models available and the technical issues associated with such a change, replacing the climate modules or other structural features of the IAMs requires additional investigation before it can be applied to SCC estimation. The IWG will continue to follow and evaluate the latest science

on climate modeling and seek external expert advice on the technical merits and challenges of potential approaches to updating this component of the IAMs in future revisions to the SCC estimates.

We agree with the commenters who suggested the IAMs do not fully capture the impacts associated with changes in climate variability and weather extremes. For example, as discussed in the 2010 TSD, the calibrations in FUND and DICE do not account for increases in climate variability that may occur and would affect the agricultural sector. Similarly, we agree that the models' functional forms may not adequately capture potentially discontinuous "tipping point" behavior in Earth systems. In fact, large-scale earth system feedback effects (e.g., Arctic sea ice loss, melting permafrost, large scale forest dieback, changing ocean circulation patterns) are not modeled at all in one IAM, and are imperfectly captured in the others. This limitation of the three IAMs is discussed extensively in the 2010 TSD, and again in the 2013 update. The SCC estimate associated with the 95th percentile of the distribution based on the 3 percent discount rate is included in the recommended range partly to address this concern. The IWG will continue to follow and evaluate the latest science on climate variability and potential tipping points, and seek external expert advice on the technical merits and challenges of potential approaches to improve the representation of these components of the modeling in future revisions.

(3) Uncertainty in Climate Science

A number of commenters discussed limitations in the current state of climate science and climate modeling generally. Some expressed skepticism about the link between anthropogenic CO_2 emissions and climate change. Others suggested that the SCC estimates are unreliable because climate modeling in general is unreliable and too uncertain for use in regulatory analysis. These commenters suggested that the climate models are flawed, have not been properly validated, can disagree with each other, and have biased projections. In many cases these commenters suggested that a recently observed reduction in the rate of surface temperature warming is evidence that the current generation of climate models should not be used to estimate the SCC. One commenter suggested that the SCC estimates don't adequately take into account the potential of a significantly cooler future climate absent GHG emissions, while another suggested that mainstream climate scientists have not appropriately considered the prediction of a grand solar minimum that could lead to a cooling cycle.

Some commenters voiced general criticisms of the IWG approach to the ECS due to the uncertainty about the shape of the climate sensitivity distribution and the sensitivity of the SCC estimates to the specification of the ECS distribution. One commenter suggested that the IPCC has not made progress in reducing uncertainty about climate sensitivity and therefore the IPCC consensus should not be used. Several commenters objected to the IWG use of the Roe and Baker (2007) distribution for the ECS. One of these commenters cited Pindyck (2013), stating that feedback loops within the climate system are largely unknown and therefore the shape of the distribution is unknown. The commenter suggested that Roe and Baker's assumption of a normally distributed climate feedback factor may not be theoretically correct, and suggested the use of alternative distributions. The commenter was particularly concerned that the use of a right-skewed distribution for the ECS would lead to an overestimate of the mean SCC if the ECS distribution would be more appropriately modeled as symmetric, though another commenter suggested that the Roe and Baker approach correctly captured the right-skewed nature of the distribution.

Response

Links between CO_2 and temperature are established beyond question by laboratory measurements, physical theory, paleoclimate observations, instrumental observations, and observations of other planets. Climate change and its impacts, such as sea level rise, have been exhaustively documented, and synthesized internationally by the IPCC and domestically by the U.S. National Climate Assessment. Based on the wide acceptance of these conclusions in the scientific community, the IWG believes that: (1) anthropogenic emissions of greenhouse gases are causing atmospheric levels of greenhouse gases in our atmosphere to rise to levels unprecedented in human history; (2) the accumulation of greenhouse gases in our atmosphere is exerting a warming effect on the global climate; (3) there are multiple lines of evidence, including increasing average global surface temperatures, rising ocean temperatures and sea levels, and shrinking ice in glaciers, ice sheets, and the Arctic, all showing that climate change is occurring, and that the rate of climate change in the past few decades has been unusual in the context of the past 1000 years; (4) there is compelling evidence that anthropogenic emissions of greenhouse gases are the primary driver of recent observed increases in average global temperature; (5) atmospheric levels of most greenhouse gases are expected to continue to rise for the foreseeable future; and (6) risks and impacts to public health and welfare are expected to grow as climate change continues, and that climate change over this century is expected to be greater compared to observed climate change over the past century.

While there are inherent uncertainties associated with modeling climate systems over long time spans, the general circulation models (GCMs) upon which estimates of ECS and other climate science research are based have been extensively evaluated. For example, since 1989 the DOE has had a large program (The Program for Climate Model Diagnosis and Intercomparison) dedicated to evaluating these models.

Predictions of future solar activity are highly uncertain. However, even if a new solar minimum of the magnitude of the Maunder minimum (the solar low during the Little Ice Age) were to occur, its cooling tendency would be much less than the warming tendency from human greenhouse gases (e.g., Feulner and Rahmstorf, 2010).

The ECS parameter is a useful parameter for summarizing the strength of the climate system's response to accumulating GHG concentrations in the atmosphere. However, it is influenced by many highly complex and uncertain natural processes, some of which adjust over very long periods of time. Therefore, persistent uncertainty about the ECS is not surprising. Furthermore, persistent uncertainty does not suggest an absence of useful information. However, the IWG does not agree that progress has not been made in reducing this uncertainty. Over the last 30 years the scientific community has elucidated many aspects of the climate system's response to GHGs accumulating in the atmosphere. While the AR5 "likely" range is slightly larger than that of AR4, the assessment presented greater confidence in the tails. AR5 found that climate sensitivity is very unlikely to be greater than 6°C, whereas AR4 stated that the "lack of strong constraints limiting high climate sensitivities prevents the specification of a 95th percentile bound." Similarly, while the AR5 and the IPCC's (2001) Third Assessment Report (TAR) bounds look similar, the TAR bounds were presented as a range without estimated probabilities.

In response to the commenter citing Pindyck on climate feedbacks and the shape of the ECS distribution, we agree that potential climate feedbacks and their strength are uncertain. However, the IWG chose a

distribution from the peer-reviewed literature based on its evaluation of the scientific literature and the relationship between this distribution and IPCC range of the ECS. Regarding the skewness of the calibrated ECS distribution, this characteristic is common among the many approaches that have been used to study the ECS distribution and is not unique to the theoretical approach used by Roe and Baker to define the functional form of their distribution. Consistent with the AR4 discussion on limiting the distribution to a range considered possible by experts, such as from 0°C to 10°C, the IWG truncated the distribution at 10°C (Hegerl 2007, p 719).

4 Socioeconomic and Emissions Scenarios

Several commenters discussed the socioeconomic-emissions scenarios that are used as inputs for the IAMs. One commenter voiced general support for the IWG's approach, noting that the "use of EMF-22 [scenarios] represents a carefully considered and scientifically defensible decision." Other comments can be grouped into three main categories: the socioeconomic-emissions scenarios should be updated; concerns with the selected scenarios, including potential inconsistencies with other aspects of the modeling; and future updates of the scenarios should include a formal uncertainty analysis.

(1) The socioeconomic-emissions scenarios should be updated

A number of commenters recommended that the scenarios be updated to reflect newer modeling results. Some comments suggested that the SCC should be estimated using the scenarios in the IPCC's Fifth Assessment Report. In some cases the comments specifically suggested use of the representative concentration pathways (RCPs) and the associated shared socioeconomic pathways (SSPs) that were developed to identify a range of future socioeconomic scenarios that could lead to the RCPs. In other cases the commenters did not specify which AR5 scenarios should be used. In addition to the development of the RCP/SSP scenarios, the IPCC supported the AR5 assessment through an open call for qualified scenarios produced since the publication of AR4. The result of the open call was a database of more than 1,200 scenarios from 32 models that represent both "business-as-usual" (BAU) and policy cases, which were used extensively by Working Group III.

Response

OMB guidance in Circular A-4 requires benefits and costs to be computed relative to a baseline that represents "the best assessment of the way the world would look absent the proposed action." The IWG determined that BAU socioeconomic scenarios best reflect this approach. While the IWG agrees that, all else equal, the baseline used for the SCC calculation should be updated periodically to reflect the latest projections of BAU scenarios, the RCP/SSP scenarios used in support of AR5 may not be easily adaptable for use in SCC modeling.

To understand why, it is important to note some key differences between the criteria used by the IWG to select socioeconomic-emissions scenarios and what the RCP/SSP scenarios represent and how they were developed. Each scenario in the EMF-22 exercise used by the IWG was clearly identified as reflecting a reference case BAU or a specific CO_2 stabilization scenario. Lacking data on the probabilities of specific

scenarios, the IWG chose four BAU scenarios and one scenario representing stabilization at 550 ppm CO_2-e and weighted them equally in its analysis. The IWG acknowledges that this is not a precise characterization of the baseline but believes it is a reasonable approach at present, in light of data limitations.

Some of the AR5 scenarios differ from these scenarios in ways that make them difficult to adapt to the SCC context. An ad-hoc group was formed in anticipation of AR5 to develop new scenarios to support climate impacts, adaptation, and vulnerability research. The initial work focused on the development of RCPs, which represent a wide range of potential radiative forcing pathways over the 21st century. The SSPs are a series of human development pathways that could lead to radiative forcing pathways described by the RCPs. The RCPs are not based on a fixed future path of key socioeconomic parameters, which means that multiple SSPs are associated with an RCP. No assessment was made as to the likelihood of any particular RCP being realized, but some of the scenarios clearly would require large-scale global mitigation efforts to be achieved and U.S. involvement in these efforts may be necessary for their success.

In other words, the developers did not assign likelihoods that the various scenarios would achieve the RCPs in the absence of policy interventions, which means that it is not clear which scenarios could reasonably serve as BAU projections. Therefore, using the RCP/SSP scenarios would require the IWG to conduct an assessment of which RCP/SSPs represent BAU scenarios, or of the probability that each scenario occurs in a BAU case. The IWG believes that data are currently lacking to conduct such an assessment.

The IWG will continue to follow and evaluate the latest science on socioeconomic-emissions scenarios and seek external expert advice on the technical merits and challenges of potential approaches to update these scenarios in future revisions to the SCC estimates.

(2) Concerns with the selected scenarios, including potential inconsistencies with other aspects of the modeling

A number of commenters felt the explanation of the selected socio-economic and emissions scenarios was inadequate in both the 2010 and 2013 TSDs and highlighted potential inconsistencies between the GDP, population, emissions, and non-CO_2 radiative forcing trajectories, and in their application to the SCC estimates. For example, one commenter suggested that a better rationale is needed for the choice of the scenarios from the EMF exercise. Other commenters suggested that the scenario assuming immediate and substantial global mitigation efforts is an implausible BAU scenario. Similarly, another commenter suggested that policy scenarios are not appropriate for SCC estimation because using emission scenarios that assume future abatement and mitigation efforts may introduce a downward bias when using the SCC as a benchmark for evaluating the very abatement and mitigation efforts that are assumed to be in place in the future. Other commenters suggested that extrapolation of the scenario variables from 2100 to 2300 may not have properly accounted for correlations among the variables; one commenter noted that work is underway to extend the AR5 SSPs out to 2300 along the extended RCPs and that use of such scenarios may improve consistency of the scenarios past 2100. Commenters also noted that treating certain variables as exogenous to the IAMs might introduce inconsistences if other relevant variables or

assumptions differ between the models used to develop the scenarios and the IAMs using them as inputs to estimate the SCC. Other commenters suggested that the average annual global GDP per capita growth rate in the scenarios is too high compared with long term historic growth rates observed in the United States, and that the IWG should have rejected the EMF scenarios because the EMF exercise is not part of a public process and the EMF scenarios are "extreme outliers" relative to recent Energy Information Administration forecasts.

Response

The rationale for using the EMF-22 scenarios is explained in the 2010 TSD. In addition to the fact that they were recent, peer-reviewed, and publicly available, they had the key advantage that GDP, population, and emissions trajectories are internally consistent for each model and scenario evaluated. As noted in the 2010 TSD, the scenarios used "span a wide range, from the more optimistic (e.g. abundant low-cost, low-carbon energy) to more pessimistic (e.g. constraints on the availability of nuclear and renewables)."

Regarding the inclusion of a scenario associated with stabilization of atmospheric concentrations of GHGs at 550 ppm CO_2-e, the 2010 TSD clearly notes that this is "not derived from an assessment of what policy is optimal from a benefit-cost standpoint. Rather, it is indicative of one possible future outcome." As noted above, OMB guidance in Circular A-4 states that the correct baseline for regulatory impact analysis is an agency's best assessment of the state of the world without the regulation, and specifically states that this may include the potential for new domestic and foreign policies that would occur absent the regulation. Including a scenario representative of future mitigation actions is consistent with this guidance, as long as those future policy actions are expected to occur with or without the regulation under examination. As explained in the 2010 TSD, the IWG aimed to select scenarios that span most of the plausible range of outcomes for the socioeconomic variables. Given the level of uncertainty in these trajectories, the IWG felt that it was appropriate to consider a trajectory with significant global mitigation, assuming that this is a distinct possibility even in the absence of U.S. actions. Because there were five scenarios, and each received equal weighting, the stabilization scenario received 20% of the total probability weight.

Regarding potential inconsistencies between scenarios and IAMs, given the nature of estimating the SCC and available data/resources, a full harmonization along all possible dimensions of the three IAMs used to estimate the SCC with the four models used to develop the scenarios was not possible. Therefore, the IWG chose to harmonize the models with respect to the scenario variables to which SCC estimates are most sensitive (GDP, population, and emissions) using common techniques in the literature. The scenarios used were developed by highly respected international modeling groups and published in the peer-reviewed literature. In terms of potential inconsistencies across scenario variables past 2100, an effort was made to account for some basic correlations among scenario variables in the post-2100 extrapolation. For example, extrapolations were based on GDP per capita growth, which implicitly correlates population and GDP growth, rather than GDP levels or growth alone. Similarly, extrapolations were based on CO_2 emissions intensity with respect to GDP, which correlates emissions and GDP growth, rather than CO_2 emissions levels or growth alone.

Consistent with historical observations, it is expected that growth rates of rapidly developing economies will exceed those of already developed economies in the near term. Scenarios with projections of global economic growth that exceed recent trends in developed economies are consistent with this expectation.

The chosen scenarios capture a wide range of potential future states of the world, but were not intended to represent a comprehensive accounting of the full range of uncertainty, and therefore it is possible that future outcomes will fall outside of this range. The IWG acknowledges that the projection of the scenarios beyond 2100 has greater uncertainty than shorter-term projections and will continue to monitor the literature, including the development of extended RCP/SSP scenarios, for ways to improve the estimated trajectories and improve internal consistency.

(3) Future updates should include a formal uncertainty analysis of socio-economic and emissions scenarios.

Multiple commenters noted that the SCC estimates are not based on a detailed accounting of uncertainty over future socioeconomic and emissions conditions, and suggested that in future updates, the estimates should more formally address such uncertainty. It was also suggested that the equal weighting of the five selected scenarios might be inconsistent with their actual probabilities; for example, some commenters felt that given current policies the scenario leading to stabilization of atmospheric GHG concentrations at 550 ppm CO_2-e by 2100 is unlikely to have the same probability as the four BAU scenarios

Response

The IWG acknowledges that the SCC estimates do not include a formal, probabilistic assessment of uncertainty. Rather, the IWG attempted to span a reasonable range of uncertainty by including a range of estimates for key input variables, including climate sensitivity, socioeconomic trajectories, and discount rates. As noted in the 2010 TSD, the IWG considered formally assigning probability weights to different socioeconomic scenarios, but this proved challenging to do in an analytically rigorous way given the dearth of information on the likelihood of a full range of future socioeconomic pathways. In this situation, the IWG determined that, because no basis for assigning differential weights was available, the most transparent way to present a range of uncertainty was simply to weight each of the five scenarios equally for the consolidated estimates. The TSD also presented the results for each scenario separately, to show how the SCC estimates varied across the scenarios.

The IWG will continue to follow and evaluate the latest science on incorporating formal uncertainty analysis over socioeconomic-emissions scenarios, and will seek external expert advice on the technical merits and challenges of potential approaches to incorporate scenario uncertainty in future revisions to the SCC estimates.

5 Discount Rates

Numerous commenters discussed the discount rates used to estimate the SCC. Their comments can be grouped into three main categories: it would be appropriate to include a 7 percent discount rate in the range used to estimate the SCC; the central SCC estimate should be based on a discount rate lower than

3 percent or on a rate that declines over time; and a Ramsey framework should be used to endogenously determine the discount rates.

(1) It would be appropriate to include a 7 percent discount rate in the range used to estimate the SCC.

Most commenters who made this comment cited OMB's Circular A-4, which identifies 3 percent and 7 percent as appropriate discount rates for regulatory impact analysis conducted pursuant to Executive Order 12866. A few commenters offered more specific rationales for using a higher discount rate. One commenter noted that in the United States market interest rates of around 7 percent per year have typically been associated with per capita GDP growth rates of around 1.5 percent per year, and the socio-economic scenarios used in estimating the SCC assume per capita GDP growth rates at least this high. Another commenter noted that low discount rates place relatively more weight on outcomes further in the future, which are more uncertain than near term outcomes. Several commenters indicated that a 7 percent discount rate is appropriate because it represents a better estimate of the opportunity cost of capital investments that would be displaced under compliance with a potential regulation to mitigate CO_2 emissions.

Response

OMB guidance in Circular A-4 recommends that discount rates of 3 percent and 7 percent be used in regulatory impact analysis. The 7 percent rate is an estimate of the average before-tax real rate of return to private capital in the U.S. economy. It is a broad measure that reflects the returns to real estate and small business and corporate capital and is meant to approximate the opportunity cost of capital in the United States. The 3 percent rate is an estimate of the real rate at which consumers discount future consumption flows to their present value, often referred to as the social rate of time preference or the consumption rate of interest. As stated in the 2010 TSD, in a market with no distortions, the return to savings would equal the private return on investment, and the market rate of interest would be the appropriate choice for the social discount rate. In the real world, however, risk, taxes, and other market imperfections drive a wedge between the risk-free rate of return on capital and the consumption rate of interest.

While most regulatory impact analysis is conducted over a time frame in the range of 20 to 50 years, OMB guidance in Circular A-4 recognizes that special ethical considerations arise when comparing benefits and costs across generations. Although most people demonstrate time preference in their own consumption behavior, it may not be appropriate for society to demonstrate a similar preference when deciding between the well-being of current and future generations. Future citizens who are affected by such choices cannot take part in making them, and today's society must act with some consideration of their interest. Even in an intergenerational context, however, it would still be correct to discount future costs and benefits generally (though perhaps at a lower rate than for intragenerational analysis), due to the expectation that future generations will be wealthier and thus will value a marginal dollar of benefits or costs less than the current generation. Therefore, it is appropriate to discount future benefits and costs relative to current benefits and costs, even if the welfare of future generations is not being discounted. Estimates of the discount rate appropriate in this case, from the 1990s, ranged from 1 to 3 percent. After

reviewing those considerations, Circular A-4 states that if a rule will have important intergenerational benefits or costs, agencies should consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent.

The IWG examined the economics literature and concluded that the consumption rate of interest is the correct concept to use in evaluating the net social costs of a marginal change in CO_2 emissions, as the impacts of climate change are measured in consumption-equivalent units in the three IAMs used to estimate the SCC. This is consistent with OMB's guidance in Circular A-4, which states that when a regulation is expected to primarily affect private consumption—for instance, via higher prices for goods and services--it is appropriate to use the consumption rate of interest to reflect how private individuals trade-off current and future consumption.

As explained in the 2010 TSD, after a thorough review of the discounting literature, the IWG chose to use three discount rates to span a plausible range of constant discount rates: 2.5, 3, and 5 percent per year. The central value, 3 percent, is consistent with estimates provided in the economics literature and OMB's Circular A-4 guidance for the consumption rate of interest. The upper value of 5 percent represents the possibility that climate damages are positively correlated with market returns, which would suggest a rate higher than the risk-free rate of 3 percent. Additionally, this discount rate may be justified by the high interest rates that many consumers use to smooth consumption across periods. The low value, 2.5 percent, is included to incorporate the concern that interest rates are highly uncertain over time. It represents the average rate after adjusting for uncertainty using a mean-reverting and random walk approach as described in Newell and Pizer (2003), starting at a discount rate of 3 percent. Further, a rate below the riskless rate would be justified if climate investments are negatively correlated with the overall market rate of return. Use of this lower value also responds to the ethical concerns discussed above regarding intergenerational discounting.

The IWG recognizes that disagreement remains in the academic literature over the appropriate discount rate to use for regulatory analysis of actions with significant intergenerational impacts, such as CO_2 emissions changes that affect the global climate on long time scales. The IWG will continue to follow and evaluate the latest science on intergenerational discounting and seek external expert advice on issues related to discounting in the context of climate change.

(2) The central SCC estimate should be based on a discount rate lower than 3 percent or a rate that declines over time.

Several commenters noted that uncertainty about future economic growth rates implies that future benefits and costs should be discounted to the present at a rate lower than what would be appropriate in the absence of uncertainty. Some comments also recommended that the pure rate of time preference, one component of the discount rate, be set to zero to ensure that the welfare of all generations is given equal weight in the analysis. One commenter suggested that expected future benefits and costs should be discounted at a rate that is the sum of two components: the risk-free rate of return, which is typically associated with the interest rate on short-term government bonds, and a "risk premium" based on the correlation between the benefits of the policy and the growth rate of the broader economy (including

both market and non-market goods and services). Some commenters indicated that lower discount rates should be used as a sort of hedge against the risk of "climate catastrophes." Other commenters recommended a declining discount rate; they emphasized discount rate uncertainty and cited research by Weitzman (2001), Newell and Pizer (2003), and Arrow et al. (2013) on this topic, noting that these studies show that under persistent uncertainty about the discount rate, and/or economic growth, the maximization of expected net present value implies a discount rate that declines over time.

Response

As noted above, the IWG selected a range of discount rates from 2.5 to 5 percent; a review of the literature and the reasoning that led to the selection of this range are discussed in detail in the 2010 TSD. Several of the issues raised by commenters were explicitly considered and were part of the rationale for the selected range.

The TSD discusses both descriptive and prescriptive approaches to selecting discount rates. A descriptive approach reflects a positive (non-normative) perspective based on observations of people's actual choices (e.g., savings versus consumption and allocation of savings over more and less risky investments). The prescriptive approach adds a normative component and incorporates judgments that decision makers believe should be reflected in the policy choices that the discount rate is intended to inform. For example, some have argued on ethical grounds that in the Ramsey formula—which dissects market rates into three components, the pure rate of time preference (ρ), growth rate of per-capita consumption (g), and coefficient of relative risk aversion (η)—the ρ component should be set to zero so that the welfare of all generations is valued equally. After considering a range of plausible values from the literature for g and η, the IWG concluded that setting a very low ρ (e.g., 0.1 percent per year) could yield rates in the range of 1.4 to 3.1 percent.

The TSD also discussed uncertainty and its effects on discount rates. The certainty equivalent values of the future benefits of reducing current CO_2 emissions will be lower than the expected value if the benefits and future consumption are positively correlated, assuming people are risk averse on average. This in turn implies that when discounting expected future benefits a discount rate that accounts for uncertainty should exceed a riskless rate. As explained in the TSD, this consideration was part of the logic for setting the upper end of the selected range at 5 percent.

The IWG also considered the issue of "climate catastrophes." To the extent that such outcomes may not be adequately represented in the IAMs, the central tendency estimates from these models may not capture the full range of potential damages from CO_2 emissions. For this reason, in addition to the three mean SCC estimates using discount rates of 2.5, 3 and 5 percent, the IWG recommended including a rate based on the 95th percentile damage estimate (with a 3 percent discount rate) for the upper end of the range of plausible SCC estimates.

Finally, with respect to declining discount rates, the IWG agrees that this is an important area of emerging research. However, no widely-accepted declining discount rate schedule has yet been developed. Some key technical issues warrant careful consideration before adopting a declining discount rate schedule, such as determining how to update the discount rate schedule as uncertainty is resolved over time and

ensuring that the use of declining discount rates does not lead to the possibility of time-inconsistent choices. A recent workshop sponsored by the federal government resulted in a paper in *Science* authored by thirteen prominent economists who concluded that a declining discount rate would be appropriate to analyze impacts that occur far into the future (Arrow et al., 2013). However, additional research and analysis is still needed to develop a methodology for implementing a declining discount rate and to understand the implications of applying these theoretical lessons in practice. The IWG will continue to follow and evaluate the latest science on the use of declining discount rates in intergenerational contexts and seek external expert advice on issues related to discounting in the context of climate change.

(3) A Ramsey framework should be used to determine the discount rates.

Some commenters supported use of a Ramsey framework for determining discount rates and noted that the original developers of the IAMs used by the IWG routinely use a Ramsey framework in their own applications of their models. A Ramsey framework, derived from a representative agent who maximizes the sum of discounted utility under specific assumptions, relates the consumption discount rate to the elasticity of the marginal utility of consumption, the growth rate of per capita consumption, and the pure rate of time preference. Some commenters also stated that the socioeconomic scenarios used to calculate the SCC imply growth rates of per capita consumption that change over time, so under the Ramsey framework the discount rates also should change endogenously over time based on the economic growth rates assumed in the underlying socio-economic scenarios.

Response

The IWG agrees that a Ramsey framework can be useful in informing the selection of an appropriate range of discount rates for estimating the SCC. As noted above, this was one of the approaches considered by the IWG in the selection of the 2.5, 3, and 5 percent range.

The IWG considered this framework explicitly in exploring the implications of setting the ρ term (pure rate of time preference) at or near zero to give equal weight to the welfare of all future generations. As explained above, this analysis was part of the basis for selecting the lower end of the range. However, after reviewing several approaches to estimating specific parameters, the IWG noted that there is no consensus in the literature on the appropriate approach for selecting specific values for the components of the Ramsey equation. For this reason, the IWG used this analysis to inform its choice of a range of discount rates, but concluded that the Ramsey equation alone should not determine a specific choice of discount rate.

The IWG agrees that the Ramsey framework could, in theory, support a formulation where discount rates change over time. In a paper summarizing the aforementioned workshop on discounting, thirteen prominent economists indicated that the Ramsey framework "provides a useful framework for thinking about intergenerational discounting" but also pointed out that there is disagreement in the literature about what individual parameters in the Ramsey framework represent (η, in particular), which makes it difficult to select defensible values (Arrow et al., 2012). As noted above, the IWG believes it is premature to use the Ramsey framework as the sole basis for deriving discount rates, either fixed or variable, but did

consider the Ramsey literature in deriving the range of 2.5 to 5 percent for use in estimating the SCC. The IWG will continue to evaluate new research on the Ramsey framework and its applicability to SCC estimation and seek external expert advice on issues related to discounting in the context of climate change.

6 Aggregation of Results and Selection of Final Estimates

A number of comments are related to the aggregation of model results and the selection of the final range of SCC estimates. These comments can be grouped into three main categories: concerns with averaging of SCC estimates, the use of means rather than medians as a measure for the central tendency of the SCC estimates, and the use of low and high end estimates in regulatory analyses.

(1) Concerns with averaging of SCC estimates

Some commenters were concerned that pooling the SCC estimates across scenarios and models ignores variability and uncertainties in the estimates. While one commenter explicitly stated that the IWG synthesized model outputs appropriately, several other commenters expressed concern that pooling the results across models and scenarios masks significant differences between models and inappropriately implies that the "true" value of the SCC falls within the range of estimates calculated by the three models. One commenter argued that pooling the results across models and scenarios should be abandoned given the uncertainty around the factors that drive the estimates.

Response

Both the 2010 TSD and the 2013 TSD update present information about the full distribution of SCC estimates within and across possible combinations of the three models and five socioeconomic-emissions scenarios, for each of three discount rates (45 combinations in total) (see tables A2-A4 in Appendix A of the TSDs). Additional summary statistics for the distributions of the SCC estimates are also provided for each of the three models (see Table A5 in Appendix A). The IWG believes that the information presented in the TSDs is sufficiently disaggregated to reflect the variability of the SCC estimates across models, input assumptions, and discount rates. In addition, the IWG has provided the full set of Monte Carlo modeling results (10,000 model runs for each combination, for a total of 450,000 observations per emissions year) to outside researchers upon request and will continue to do so.

As discussed in the 2010 TSD, using the full distribution of the SCC estimates from the 45 scenarios would be impractical in a regulatory impact analysis. To produce a range of plausible estimates that still reflects the uncertainty about the SCC estimates, the results from the various model and scenario combinations (150,000 observations per emissions year for each of the three discount rates) were pooled to produce three separate probability distributions for the SCC for emissions in a given year, one for each assumed discount rate (2.5, 3 and 5 percent). Three point estimates were then derived from these pooled distributions representing the mean at each discount rate. The IWG considers this approach for presenting expected SCC values across a range of discount rates to be appropriate for representing the central tendency of the SCC estimates across scenarios. The fourth value, the 95th percentile of the pooled

distribution using a 3 percent discount rate, is included to represent higher-than-expected economic impacts from climate change further out in the tail of the SCC distribution - i.e., impacts that may have lower probability of occurring but relatively high damages. For purposes of representing the uncertainties involved, the TSDs emphasized the importance of considering and presenting the full range of these four estimates in regulatory impact analysis.

The IWG agrees that the modeling of uncertainty in our analysis, including the uncertainty explicitly represented in the IAMs, may not capture the full range of uncertainty of the "true" value of the SCC. This concern is common to most quantitative assessments of uncertainty. By definition, the modeling of uncertainty requires a model, and therefore cannot capture the uncertainty associated with model selection. However, the IWG does not agree that pooling results across models implies that the estimates capture the full range of uncertainty, nor did the IWG make such a claim in the TSDs. Rather, the IWG attempted to capture a reasonable range of uncertainty using information available in the peer-reviewed literature and the uncertainty analysis built into the models themselves. Using three models rather than one helps address, but does not eliminate, uncertainty associated with model choice.

(2) Use of means rather than medians as a measure of the central tendency of the SCC estimates

A few commenters suggested that the median of the distribution of SCC estimates rather than the mean, as used by the IWG, would be a more appropriate measure of the central tendency of the SCC estimates. Another commenter suggested using both the mean and the median, along with presenting other distributional information (e.g., variances, low and high end percentile estimates, and other characteristics of distributions).

Response

The choice of the mean or the median as a measure of central tendency depends on the context. In skewed distributions, such as for the SCC estimates, the median will often give a more "typical" outcome, while the mean will give full weight to the tails of the distribution. In some cases, the typical outcome is of most interest. For example, in describing household incomes the median is most often used because the focus is on understanding the income of the typical household, and using the mean might distort this picture by giving undue weight to a small number of very wealthy households. In the climate change context, however, sound decision-making requires consideration of not only the typical or most likely outcomes, but also less likely outcomes that could have very large (or small, or even negative) damages (the tails of the distribution). Use of the median to represent the SCC in a regulatory impact analysis would not necessarily lead to the most efficient policy choice that uses resources wisely to mitigate potential climate impacts (e.g., maximize the expected net benefits). In this case, the IWG believes that the mean is the appropriate measure of central tendency.

(3) Use of low and high end estimates in regulatory analyses

Several commenters suggested that both lower and upper end estimates should be part of the final range of estimates used in regulatory analyses. Specifically, they believe the range should include a 5^{th} percentile estimate, in addition to the 95^{th} percentile estimate from the pooled distribution using the 3 percent

discount rate. In contrast, one commenter suggested that, because the models do not presently account for high-end risks, RIAs should compensate by using only the most conservative estimates reported by the IWG (i.e., the 95th percentile estimate using the 3 percent discount rate). Another commenter similarly suggested using only the worst case (highest) estimate out of all the simulation results in place of the mean estimate.

Response

Along with the four selected SCC estimates for each emissions year, the IWG presented more detailed information about the full distribution of SCC estimates for emissions in the year 2020. Specifically, the 2013 TSD reports information on the full distribution of the SCC estimates for emissions in year 2020 for each model, scenario, and discount rate combination , including the low-end percentiles (i.e., 1st, 5th and 10th percentiles).[11] In addition, as noted above, complete distributions for all emissions years are available upon request. While the IWG did not present a summary 5th percentile estimate (i.e., pooling results across the models and scenarios) for use in regulatory impact analysis, for reasons discussed below, the model and scenario specific statistics for 2020 provide a general sense of how the 5th percentile relates to the mean. Furthermore, as we note above the IWG has provided the full set of Monte Carlo modeling results to outside researchers upon request and will continue to do so. This information may be used to calculate a full set of 5th percentile summary statistics that are comparable to the 95th percentile estimates provided in the TSDs.

As the 2010 TSD discusses, the SCC estimates derived from the three integrated assessment models have several significant limitations that could lead to a substantial underestimation of the SCC. These limitations include the incomplete treatment and monetization of non-catastrophic damages, the incomplete treatment of potential "catastrophic" damages, and uncertainty in extrapolation of damages to high temperatures. The IPCC Fourth Assessment Report, which was the most current IPCC assessment available at the time of the IWG's 2009-2010 review, discussed these limitations and concluded that it was "very likely that [SCC] underestimates" climate change damages. Based on the current scientific understanding of climate change and its impacts, and on the limitations of the IAMs in quantifying and monetizing the full array of potential "catastrophic" and non-catastrophic damages, the IWG concluded that the distribution of SCC estimates may be biased downwards. Since then, the peer-reviewed literature has continued to support this conclusion. For example, the IPCC Fifth Assessment report observed that SCC estimates continue to omit various impacts that would likely increase damages. The 95th percentile estimate was included in the recommended range for regulatory impact analysis to address these concerns.

In addition, as acknowledged in the 2010 TSD, the SCC estimates derived from the three IAMs did not take into consideration the possibility of risk aversion. That is, individuals may have a higher willingness-to-pay to reduce the likelihood of low-probability, high-impact damages than they do to reduce the likelihood of higher-probability, lower-impact damages with the same expected cost. The inclusion of the 95th

[11] The 2010 TSD including information on the full distribution of SCC estimates for the emission year 2010, however the 2013 TSD presented this information for the 2020 emissions year as 2010 was then a historical year.

percentile estimate in the SCC values was also motivated by this concern. In contrast, the IWG is not aware of systematic upward biases in the estimates comparable to the downward biases discussed above. For this reason, while the IWG has been fully transparent regarding the entire range of uncertainty reflected in the probability distributions, we did not include a 5th percentile estimate in the selected range for regulatory impact analysis.

Regarding the suggestion that only the high end of the range or worst-case scenario should be used in regulatory cost-benefit analysis, the IWG disagrees. The recommended range represents the central tendency of SCC estimates across three reasonable discount rates, plus a high-end estimate to account for missing damage categories and "catastrophic" outcomes. It is the judgment of the IWG that this approach will best inform decision makers and the public about both the range of "likely" damages and the possibility that actual damages could be much higher.

7 Consideration of Uncertainty

The IWG received a number of comments on the analyses and presentation of uncertainty in the TSD, as well as comments regarding the implications of uncertainty for the use of the SCC estimates in regulatory impact analysis.

(1) Analysis and presentation of uncertainty

Several commenters suggested that the IWG was rigorous in addressing uncertainty by conducting Monte Carlo simulations with the IAMs to estimate distributions of the SCC over probabilistic specifications of the equilibrium climate sensitivity and other uncertain parameters as identified by the model developers. Other commenters suggested that key uncertainties merit further exploration and discussion in the TSD. Several commenters recommended that additional uncertainty analysis be conducted on key aspects of the modeling, such as assumptions regarding the carbon cycle, physical responses to climate change, technological change, adaptation, and post-2100 extrapolations of the socioeconomic-emission scenarios, among others. One commenter called for a separate section in the TSD that identifies key sources of uncertainty, along with a qualitative assessment of the impact those key uncertainties have on the SCC estimates, and to the extent feasible, a quantitative assessment as well. Some commenters suggested that the references in the 2013 TSD to discussions of uncertainty in the 2010 TSD are inadequate and make it difficult for the reader to understand the uncertainty associated with the revised estimates. One commenter questioned whether the IWG reported too many significant digits given the degree of uncertainty about the estimates. Several commenters also suggested that it would be appropriate to shorten the modeling time horizon due to the uncertainty associated with projecting impacts out to 2300. Two commenters suggested a time horizon of 2100 to be consistent with the time horizon considered in IPCC assessment reports. In addition, several commenters requested that additional graphical information be presented, and electronic copies of the results be made publically available.

Response

The IWG agrees with the comments that supported the rigor of its uncertainty analysis. Uncertainty is inherent in all regulatory impact analysis. It is especially salient in regards to the SCC estimates because of their broad spatial and temporal dimensions. In addition to conducting Monte Carlo analysis for a subset of key parameters, the IWG included extensive discussion of uncertainty in the TSDs, and the documentation for the individual IAMs themselves contains additional discussion of the assumptions and uncertainties in the models. The 2010 TSD and the updated 2013 TSD provided visual depictions of the distributions of the SCC estimates in addition to detailed statistics including percentiles and higher order moments. In addition to the extensive information provided in the TSDs, the IWG has provided the full range of model results to outside researchers upon request and will continue to do so.

The IWG also agrees that the trajectory of socioeconomic-emission scenarios beyond 2100 is uncertain. However, as the 2010 TSD notes, because of the long atmospheric lifetime of CO_2, using too short a time horizon could miss a significant fraction of damages under certain assumptions about the growth of marginal damages. Therefore, the IWG ran each model through 2300. The IWG will continue to follow and evaluate the scientific literature on long-term scenario development.

The IWG reported SCC estimates out to one decimal place (i.e., at least two significant digits) in the 2010 TSD and to the nearest dollar in the 2013 TSD (i.e., two or three significant digits, depending on the year and discount rate/statistic). The IWG chose not to use decimal places in the 2013 TSD to avoid the impression of artificial precision but will also explore presentation with a consistent number of significant digits. The IWG welcomes the recommendations to strengthen the characterization of uncertainty and plans to seek external expert advice on the technical merits and challenges of potential approaches to improve the characterization and analysis of uncertainty in future updates.

(2) Implications of uncertainty for the use of the SCC estimates in regulatory impact analysis

Some commenters suggested the degree of uncertainty in the SCC estimates makes them too speculative for use in regulatory analysis. These commenters argued that SCC is an unknown quantity and cannot be discerned in meteorological or economic data going back a century or more. Some commenters suggested that if non-validated climate parameters, arbitrary damage functions, or below-market discount rates were used, analysts could produce almost any result they desire. Another commenter suggested that the large variance associated with the distributions of the SCC estimates relative to the mean indicates that the estimates are not of sufficient precision to be informative in regulatory analysis. In contrast, other commenters stated that uncertainty in benefits estimates does not mean they should be excluded from regulatory impact analyses. These commenters pointed out that no benefit or cost estimate is certain and both court decisions and executive orders dating back to 1981 have recognized this. To address this, agencies have been directed to use best available estimates and acknowledge uncertainties, which they suggested is appropriately done in the TSDs.

Response

All regulatory impact analysis involves uncertainty. The IWG acknowledges uncertainty in the SCC estimates but disagrees that the uncertainty is so great as to undermine use of the SCC estimates in regulatory impact analysis. The uncertainty in the SCC estimates is fully acknowledged and

comprehensively discussed in the TSDs and supporting academic literature. While uncertainty must be acknowledged and addressed in regulatory impact analyses, even an uncertain analysis provides useful information to decision makers and the public. For example, if an analysis shows that benefits of a policy option consistently do (or do not) justify costs even over a broad range of estimates, this may increase confidence in the robustness of this conclusion. Conversely, if choices among parameter estimates within a plausible range significantly affect the conclusions of the analysis, this is an important consideration in deciding how to weigh the analytical results in the decision making process. The presence of uncertainty is thus not a reason to exclude the best available estimates of quantified/monetized benefits, as long as it is appropriately characterized. Rather, good regulatory practice requires that agencies use the best available scientific, technical and economic information to derive the best estimates of costs and benefits that they can, and then communicate to the public the limitations and uncertainties of the analyses. This is what the IWG has attempted to do in developing and discussing the SCC estimates. As noted in the TSDs, the IWG is committed to periodic updates in the estimates to reflect ongoing developments in our understanding of the science and economics of climate change, including the treatment of uncertainty.

8 Use of Global vs. Domestic SCC Estimates

Many commenters discussed the scope of the SCC estimates, and the degree to which damages experienced outside U.S. borders should be considered in domestic regulatory analysis. These comments can be grouped into two main categories: those that felt that the focus on global damage estimates is appropriate, and those that felt that domestic damage estimates received inadequate attention. Responses to these comments are provided below. In addition, many commenters stated that domestic SCC estimates must be used in RIAs to ensure consistency with OMB Circular A-4 requirements. This issue is addressed in Section 10 below.

(1) The focus on global damage estimates is appropriate.

A number of commenters supported the IWG's decision to base the SCC estimates on global damages. Commenters explained that climate change is a global commons problem because carbon pollution does not remain within one country's borders, and that the use of global damages in the SCC is consistent with the economic theory of the commons. One commenter further stated that if damage estimates are limited to only those within each country's borders, any actions based on those estimates would lead to a collective failure to optimally mitigate GHG emissions. Another commenter referred to the importance of this effect by stating that the consideration of global damages in domestic rulemaking can be based on an expectation of reciprocity from other countries. Several commenters stressed the importance of the use of global SCC estimates as a tool in international negotiations. Finally, some commenters offered other reasons for considering damages in regions outside of the United States, including liability, national security concerns, trade-related "spillover effects", and the principle in international environmental law of reducing cross-border harm.

Response

The IWG agrees that a focus on global SCC estimates in RIAs is appropriate. As discussed in the 2010 TSD, the IWG determined that a global measure of SCC is appropriate in this context because emissions of most greenhouse gases contribute to damages around the world and the world's economies are now highly interconnected. To reflect the global nature of the problem, the SCC incorporates the full damages caused by CO_2 emissions and we expect other governments to consider the global consequences of their greenhouse gas emissions when setting their own domestic policies.

The IWG also agrees that if all countries acted independently to set policies based only on the domestic costs and benefits of carbon emissions, it would lead to an economically inefficient level of emissions reductions which could be harmful to all countries, including the United States, because each country would be underestimating the full value of its own reductions. This is a classic public goods problem because each country's reductions benefit everyone else and no country can be excluded from enjoying the benefits of other countries' reductions, even if it provides no reductions itself. In this situation, the only way to achieve an economically efficient level of emissions reductions is for countries to cooperate in providing mutually beneficial reductions beyond the level that would be justified only by their own domestic benefits. By adopting a global estimate of the SCC, the U.S. government can signal its leadership in this effort. In reference to the public good nature of mitigation and its role in foreign relations, thirteen prominent academics noted that these "are compelling reasons to focus on a global SCC" in a recent article on the SCC (Pizer et al., 2014). In addition, as noted by commenters, there is no bright line between domestic and global damages. Adverse impacts on other countries can have spillover effects on the United States, particularly in the areas of national security, international trade, public health and humanitarian concerns.

(2) Domestic damage estimates receive inadequate attention.

A number of commenters suggested that the use of global damages creates a mismatch between estimates of costs and benefits in agency RIAs. Use of a global rather than domestic SCC may overstate the net benefits to the United States of reducing emissions, because global benefits are compared to domestic costs. A policy that appears cost-justified from a global perspective may not be from a purely domestic U.S. perspective. Therefore, these commenters suggest that a global SCC is only appropriate when the analysis considers global costs and benefits in the context of a global carbon mitigation program.

Other commenters indicated that the IWG should update and report domestic climate damages separately from global estimates for several reasons, including the public's right to know the domestic benefits of domestic regulatory actions. A few comments stated that the IWG should more clearly articulate that the SCC includes global damages, which they felt was particularly unclear in the 2013 TSD.

Finally, commenters also addressed the provisional range of domestic damages that was presented in the 2010 TSD. Several comments stated that the range discussed in the 2010 TSD for the domestic SCC was too high. Two commenters suggested a range for the domestic share of total global damages of 6 to 8.7 percent based on a paper by Nordhaus (2011). One commenter stated that the methods used to estimate the domestic damages as 7 to 23 percent of global damages is too speculative for quantification of the SCC.

Response

As stated in the prior section, GHG emissions in the United States will have impacts abroad, some of which may, in turn, affect the United States. For this reason, a purely domestic measure is likely to understate actual impacts to the United States. Also, as stated above, the IWG believes that accounting for global benefits can encourage reciprocal action by other nations, leading ultimately to international cooperation that increases both global and U.S. net benefits relative to what could be achieved if each nation considered only its own domestic costs and benefits when determining its climate policies.

Further, as explained in the 2010 TSD, from a technical perspective, the development of a domestic SCC was greatly complicated by the relatively few region- or country-specific estimates of the SCC in the literature, and impacts beyond our borders have spillover effects on the United States, particularly in the areas of national security, international trade, and public health. As a result, it was only possible to include an "approximate, provisional, and highly speculative" range of 7 to 23 percent for the share of domestic benefits in the 2010 TSD. This range was based on two strands of evidence: direct domestic estimates resulting from the FUND model, and an alternative approach under which the fraction of GDP lost due to climate change is assumed to be similar across countries. We note that the estimated U.S. share of global damages based on the Nordhaus (2011) study cited by several commenters largely falls within the provisional range offered in the 2010 TSD.

In conclusion, the IWG believes that the only way to achieve an efficient allocation of resources for emissions reduction on a global basis is for all countries to base their policies on global estimates of damages and will therefore continue to recommend the use of global SCC estimates in regulatory impact analyses. The IWG will also continue to review developments in the literature, including more robust methodologies for estimating SCC values based on purely domestic damages, and explore ways to better inform the public of the full range of carbon impacts, both global and domestic.

9 Other Comments

Other comments include those related to "leakage" and valuation of changes in non-CO2 GHG emissions.

(1) CO_2 emissions "leakage"

Several commenters suggested that the methods used to estimate climate damages should account for "leakage" of emissions in the quantification of the SCC. Specifically, commenters suggested that in cases where a new regulation increases domestic operating costs and causes industrial activity to shift to jurisdictions with less stringent regulations, net GHG emissions could fall less than predicted, or even increase. In these cases, the actual emissions reduction would be lower than indicated in a simple analysis. Commenters suggested that this effect be addressed either by the provision of additional guidance to agencies conducting RIAs, or in the estimated SCC value itself by adjusting estimated climate damages to account for it.

Response

The IWG agrees that this is an important issue for analysts to consider in determining the net CO_2 reductions to be valued in an RIA. However, this does not affect the calculation of the SCC itself, which is an estimate of the marginal benefit of a net one-ton reduction in CO_2 emissions. The SCC estimates are multiplied by estimates of net GHG emissions changes to calculate the value of benefits associated with a policy action in a given year. It is in the estimation of net GHG emissions, and not the SCC, that any leakage should be accounted for.

(2) Valuation of changes in non-CO_2 GHG emissions

Several commenters recommended that estimates be developed for valuing changes in the emissions of other greenhouse gases, such as methane, HFCs, and black carbon, as soon as possible. One commenter specified that the direct modeling approach for estimating the social cost of methane is preferable, but even an approximation approach (e.g., based on the use of the global warming potential (GWP) gas comparison metric) has merit and would be better than no estimate. The commenter asserted that the failure to set a social cost of methane estimate has the effect of eliminating any benefit of methane reductions from regulatory consideration and such a failure is arbitrary and capricious. Another commenter advocated for the use of both 100 and 20-year GWPs for converting non-CO_2 GHG emission changes into CO_2 equivalents before applying the SCC estimates.

Response

The IWG recognizes the importance of quantifying and monetizing the benefits of regulations to the extent feasible, and discussing qualitatively any benefits that cannot be quantified. The IWG does not agree that benefits that are not monetized are eliminated from regulatory consideration. On the contrary, most RIAs include discussion of non-quantified benefits and these may be an important factor in decision-making, depending on their projected significance. However, as noted by the commenters, the IWG has not established a methodology for valuing the social cost of other GHGs. In the absence of such estimates, a few recent rulemakings have included sensitivity analyses in which the GWP gas comparison metrics are used to convert non-CO_2 emissions reductions to CO_2 equivalents, which are then valued using the SCC estimates. For example, the 2012 New Source Performance Standards and Amendments to the National Emissions Standards for Hazardous Air Pollutants for the Oil and Natural Gas Industry and the 2017-2025 Light-duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards used this approach in sensitivity analyses.

Although more directly modeled estimates of the climate change benefits of reducing some GHGs (e.g., methane) have been presented in the scientific literature, the methodology behind these estimates differs from the methodology behind the USG SCC estimates. Assessing the strengths and limitations of alternate approaches for estimating economic damages from other GHGs has so far been outside the scope of the IWG's assessment of economic damages from CO_2 emissions, though the 2010 TSD identified this as an area we hope to address in future updates. We also note that a recently published paper (Marten et al., 2014) develops estimates of the social cost of CH_4 and N_2O using a methodology that is intended to be consistent with the IWG estimates of the SCC. The IWG will continue to follow and evaluate the literature on the social cost of non-CO_2 GHGs and the feasibility of developing non-CO_2 social cost estimates.

10 Process Related Comments

Many commenters either voiced support for or criticized particular aspects of the interagency process used to develop the SCC estimates. Process issues raised included legal/statutory authority for issuing the estimates, consistency with applicable OMB guidance documents, transparency, opportunity for public comment, and appropriate use of the estimates.

(1) Legal/statutory authority for issuing the SCC estimates

One group of commenters asserted that the legal basis for using the SCC is clear and well-established. These commenters highlighted the 2007 Ninth Circuit decision that concluded that a National Highways and Transportation Safety Administration rule was arbitrary and capricious for not including a monetized estimate of the SCC. The Court noted that "…while the record shows that there is a range of values, the value of carbon emissions reductions is certainly not zero."

Other commenters argued that OMB's adoption of the SCC estimates is arbitrary, capricious, and contrary to law because OMB requires all Federal agencies to use its SCC estimates without identifying any legal basis or authority for doing so. These commenters argued that because OMB's "promulgation" of the SCC values falls within the APA's broad definition of a rule, OMB must comply with the procedural and substantive requirements laid out in the APA for rulemaking. These commenters further stated that the TSDs do not show a "rational connection between the facts found and the choices made," and that even if the three IAM models themselves were entirely sound, the non-public inputs into those models would render the SCC estimates arbitrary and capricious.

Response

As a preliminary matter, the IWG notes that although the development of the SCC estimates was co-chaired by OMB and CEA, the estimates and supporting TSDs were not issued by OMB, but rather through a consensus based process involving the entire working group.

The IWG agrees with commenters who believe that it has legal authority to develop these estimates, and was cognizant of the Ninth Circuit decision referenced by these commenters when it decided to do so. The IWG does not agree that issuance of the SCC estimates constitutes an APA rule making. The APA definition of a rule is "an agency statement of general or particular applicability and future effect designed to implement, interpret, or prescribe law or policy." The SCC estimates are not designed to implement, interpret, or prescribe law or policy. Rather they are intended to provide guidance to agencies on a science-based methodology for estimating the benefits of CO_2 reductions in regulatory impact analysis.

OMB has long-established authority to oversee the regulatory review process, including preparation of regulatory impact analyses. OMB's authority in this area is contained in Executive Orders 12866 and 13563, among others, and has been acknowledged by Congress in a series of statutes, including the Small Business Regulatory Enforcement and Fairness Act, the Congressional Review Act, the Information Quality Act, and the Regulatory Right to Know Act. It is fully consistent with this authority for OMB to offer guidance to agencies on best practices for conducting regulatory impact analysis, as it did, for example, in

issuing Circular A-4. In the present case, OMB determined that it was appropriate to exercise this authority through a consensus-based process involving a broad range of agencies that may issue rules affecting CO_2 emissions.

The TSDs explain in detail the factual and policy basis for all of the various methodological choices involved in developing the SCC estimates. The IAMs are documented in the scientific literature. In addition, the IWG has assisted interested members of the public in obtaining additional information on the workings of the models. It has also provided full technical details of its own use of the models, including output of model runs, to interested parties upon request. However, because the SCC estimates are not a rule, as a legal matter they are not subject to the arbitrary and capricious standard of the APA.

(2) Consistency with OMB guidance documents, including the Information Quality Act guidelines, Peer Review Bulletin, and Circular A-4

Some commenters stated that the process used to develop the SCC estimates did not adhere to the OMB Information Quality Act (IQA) guidelines. The IQA requires federal agencies to take steps to maximize the quality, objectivity, and integrity of the information they disseminate, and to provide a mode of redress to correct flawed or incomplete information. These commenters stated that the SCC estimates are clearly "influential information" under the Guidelines and as such, must be reproducible and transparent with respect to: (1) the source of the utilized data; (2) the various assumptions employed; (3) the analytic methods applied; and (4) the statistical assumptions employed. Some commenters also stated that OMB's response to an IQA petition from a group of trade associations was inadequate and did not provide any information that was not already in the TSDs.

Several commenters focused on peer review in particular. These commenters stated that while peer review of the models themselves is important, it is not sufficient because the model inputs and subsequent manipulation of results (e.g., equal averaging) were not peer reviewed. They believe that the IWG must subject the SCC estimates and methodology to peer review to give the public greater confidence in the results. Some also stated that the IWG should consider model-specific peer review as well. This would consist of a review of each model's theoretical underpinnings and methodologies, as well as their appropriateness to specific applications. These commenters indicated that while specific applications may have been peer reviewed when published in the scientific literature, the models themselves were not.

Additionally, some commenters focused on the degree to which the SCC estimates are consistent with the OMB Circular A-4 guidelines for conducting regulatory impact analysis. These commenters stressed that the selected discount rates do not comply with Circular A-4 and should be selected through an open process including peer review. They noted that while Circular A-4 allows a sensitivity analysis with lower discount rates when a rule will have "important intergenerational benefits or costs," it still requires use of 3 percent and 7 percent. They also indicated that the estimates are not consistent with Circular A-4 guidelines regarding the use of domestic rather than global estimates of regulatory benefits.

Response

The IWG does not agree that the TSDs are inconsistent with the IQ Guidelines. To ensure that the IWG's methodology is transparent, the TSDs are comprehensive and technically rigorous in explaining the sources of data, the assumptions employed, the analytic methods applied, and the statistical assumptions employed. To ensure that the results are reproducible, IWG members have provided technical assistance and modeling results to external stakeholders upon request. Regarding the IQA petition, OMB responded to all of the points raised by petitioners. The fact that OMB's response used some language from the TSDs reflects OMB's judgment that these issues were already addressed in the TSDs themselves.

With regard to peer review, the IWG notes that the assumptions and models employed in generating the SCC estimates are all drawn from the peer-reviewed academic literature. To further strengthen the robustness of the SCC estimate, the IWG plans to seek external expert advice on technical opportunities to improve the SCC estimates in future updates, including many of the approaches suggested by commenters and peer-reviewed literature, and summarized in this document.

Circular A-4 is a living document, which may be updated as appropriate to reflect new developments and unforeseen issues. OMB was fully involved in the development of the SCC estimates as a working group co-chair and supports the working group's recommendations regarding the discount rate and the focus on global damages. The departure from the standard discount rate recommendations in Circular A-4 is explained in detail in the TSDs and in Section 5 of this document. Briefly, the use of 7 percent is not considered appropriate for intergenerational discounting. There is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself. The emphasis on global rather than domestic damages is also explained in detail in the TSDs. Beyond the fact that good methodologies for estimating domestic damages do not currently exist, basing decisions on only the domestic damages from carbon emissions will lead to an inefficient allocation of resources to reducing them, especially if all countries adopt a similarly short-sighted approach. An efficient outcome can only be achieved if all countries consider the full costs and benefits of their actions; the United States continues to be a leader in working to establish such a regime internationally.

(3) Transparency

Several commenters asserted that the process of selecting the models and input assumptions, including much of the basic information underlying these decisions, has been insulated from public scrutiny. Commenters expressed concern that the IWG has not revealed the identity or qualifications of its participants, the role of government contractors, or the details of its internal processes, including the frequency of meetings and the nature of its deliberations. These commenters further suggested that the TSDs discuss only a few selected inputs to the models, which, though important, are not the only important inputs. They believe greater transparency is also needed regarding the models themselves and the key differences among them.

Some commenters also suggested that the discussion in the TSD of the 2013 revisions is insufficient for understanding and interpreting the changes in the SCC estimates. Additional justification for many of the revisions would be helpful (e.g., space heating expenditure reductions, transient temperature responses, constant indirect methane radiative forcing effect, saturation, regional scaling factors, probability of a

discontinuity, adaptation, CO_2 absorption, regional climate modeling). Commenters suggested that discussion of uncertainty regarding the revisions would also be helpful. At a minimum, commenters suggested it would be reasonable to explain differences across models for similar components (e.g., sea level rise, transient temperature response, saturation, and adaptation), noting as a source of confusion that the TSDs have references to previous model versions, websites, and working papers, and suggested that a clear citation for each of the revisions in each model would be useful.

Other commenters explicitly noted ways in which they disagreed with the comments above. They indicated that the 2010 TSD sets out in detail the IWG's decision-making process with respect to how it assessed and employed the models, and that the 2013 TSD discusses how the three IAMs used in the analysis were updated in the publically-available academic literature over the three-year interim period by the independent researchers who developed them, and clarifies that the increase in the SCC estimate from 2010 to 2013 resulted solely from updates to the three underlying IAMs.

Response

The IWG believes that its process was inclusive, transparent, and appropriately considered public input. The TSDs fully document the methodology used to develop the estimates and the considerations that led the IWG to adopt this methodology. While the details of the IWG's internal processes were not discussed in the TSDs, this is common for most government (and non-government) documents. Such details were not considered germane to the public's understanding of the SCC estimates and the methodology used to produce them, but a general overview is provided here.

In developing the 2010 estimates, the IWG met frequently in the year preceding the release of the February 2010 TSD. For the 2013 update, only a few meetings were needed because the group decided to make no changes beyond incorporating the most recent versions of the IAMs. The IWG, in particular professional economic staff with modeling expertise, oversaw the primary modeling and calculations for both the 2010 and 2013 SCC estimates using the most recent versions of the three IAMs available at the time. To develop the 2010 estimates, the staff members ran two of the three models and contracted with the developer of the third model to perform those runs. The contractor did not participate in any of the interagency meetings but rather received instructions for how to conduct the model runs (e.g., specification of the three sets of input assumptions as determined by the working group). The staff members ran all three models to develop the 2013 estimates. Decision making for both the 2010 and 2013 processes was by consensus of IWG members. The details of internal discussions are deliberative, but the discussions were generally technical in nature and the issues discussed and conclusions reached are well documented in the TSDs. Regarding the transparency of the underlying models themselves, the IWG notes that they are well documented in the academic literature.

The Government Accountability Office (GAO) recently completed a review of the process used to develop the SCC estimates. GAO concluded that according to IWG participants, all major issues discussed were documented in the TSDs, which is consistent with Federal standards for internal control, and the processes and methods used were based on the principles of (1) consensus-based decision-making, (2) reliance on existing academic literature and modeling, and (3) disclosure of limitations and incorporation of new

information through consideration of public comments and revision of the estimates as updated research became available.[12]

IWG members have also assisted individual requestors in obtaining more detailed information about the modeling. For example, one requestor noted publically that IWG "modelers have been very open, collegial, and helpful."[13]

Regarding the explanation in the TSD for the 2013 revisions, no changes were made to the input assumptions developed by the IWG between the 2010 and 2013 estimates. The only changes were those made by the model developers themselves to the underlying models, which are documented in the academic literature. To assist the public in understanding these changes, the 2013 TSD provides a brief summary of the most important ones, as well as references to the relevant literature where more detailed information can be found. As with the 2010 TSD, the IWG did not attempt to evaluate the modeling choices made by the modelers. Rather, by selecting the three "most widely used impact assessment models" (NAS, 2010), the IWG intended to reflect a reasonable range of modeling choices and approaches that collectively reflect the current literature on the estimation of damages from CO_2 emissions. As explained in the 2010 TSD:

> The parameters and assumptions embedded in the three models vary widely. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches to quantifying damages taken by the key modelers in the field. An extensive review of the literature was conducted to select three sets of input parameters for these models: climate sensitivity, socio-economic and emissions trajectories, and discount rates…All other model features were left unchanged, relying on the model developers' best estimates and judgments…The sensitivity of the results to other aspects of the models (e.g. the carbon cycle or damage function) is also important to explore in the context of future revisions to the SCC but has not been incorporated into these estimates.

Accordingly, the IWG did not attempt to explain in detail how the damage functions in the models were constructed or their strengths and weaknesses, either for the earlier model versions used in the 2010 estimates or for the updated versions used for the 2013 estimates. Rather, stakeholders who are interested in these details are encouraged to consult the model documentation and the related academic literature referenced in the TSDs, as well as the model developers themselves. The IWG accepts the point that clearer citations to specific model versions and revisions would be helpful and will attempt to address this in the next update of the TSD.

(4) Opportunities for public comment

While some commenters acknowledged that the public has had multiple opportunities to comment on the SCC estimates and TSDs, others felt that the opportunities for public comment have been insufficient. A few of these commenters indicated that the public has not been provided sufficient information and

[12] http://www.gao.gov/products/GAO-14-663
[13] http://dailysignal.com/2013/11/06/white-house-reopens-the-scc/

asked that additional supplemental and supporting documents be made available to the public for comment, including all of the data, models, assumptions, and analyses relied on to arrive at the SCC estimates. They suggested that OMB's responses to FOIA requests implied that there are thousands of pages of supporting documents that have not been released to the public.

Some commenters stated that the continued development of SCC estimates should have strong oversight in both the Executive branch and Congress, that there should be continued opportunities for the public to comment, and that the analysis should be conducted in an open fashion.

Response

The IWG agrees with those commenters who believe the public has had ample opportunities to comment on the SCC estimates and methodology. Opportunity for public comment on all aspects of the SCC estimates was provided on the interim estimates selected by the IWG and in the numerous proposed rules issued by Federal agencies between February 2010 and May 2013 that made use of the estimates. As a general practice, agencies request comments on all aspects of the regulatory impact analysis, thereby providing ample opportunity for the public to comment on SCC estimates used in these analyses. These comments helped inform the IWG's development of the 2013 revised estimates. In addition, OMB provided a stand-alone comment period on the 2013 estimates. This document summarizes the comments received and provides the IWG's response.

Regarding the adequacy of the information provided to the public as a basis for comment, the TSDs provide a complete record of the methodology and assumptions used to develop the SCC estimates, including references to the academic literature. Independent analysts have sought and received information from the IWG allowing them to implement the IWG approach and modify it further if they choose. Additional documentation is available in the academic literature on the IAMs themselves.

With regards to several FOIA requests received by OMB and other IWG members, the only documents withheld were deliberative documents that are protected under applicable FOIA exemptions. Most of these documents were either intermediate drafts of TSD language or e-mails exchanged among IWG participants discussing various aspects of the methodology and results. Such documents are not typically provided in the record of agency actions and are not necessary for informed public comment.

The IWG is committed to providing additional opportunities for public comment when future updates of the SCC are released and agrees that analysis should continue to be conducted in an open fashion.

(5) Use of the SCC Estimates in Regulatory Impact Analysis

In addition to expressing views about how the SCC estimates were derived, many commenters discussed the *application* of the estimates. Some commenters explicitly endorsed the use of the SCC in rulemaking analyses, highlighting that accounting for the economic harms caused by climate change is a critical component of sound benefit-cost analyses of regulations that directly or indirectly affect greenhouse gas emissions. These commenters stated that without an SCC estimate, regulators would by default be using a value of zero for the benefits of reducing carbon pollution, implying that carbon pollution has no costs.

They urged the IWG to continuously update the SCC, as new economic and scientific consensus emerges, in line with the stated intentions of the IWG.

Other commenters disagreed with continued use of SCC estimates based on both process and substance concerns. On the process side, some commenters asserted that the limitations of the process used to generate the estimates (see earlier comments in this section) render them unsuitable for use in regulatory impact analysis and requested that the IWG withdraw the TSDs until these process flaws have been corrected. Issues specifically highlighted in this area were lack of peer review and inadequate opportunity for public comment. Other commenters stated that the SCC estimates are too uncertain for decision making, and several requested that the IWG provide more explicit guidance on when and when not to use them. For example, several commenters said the TSD should explicitly note that the SCC estimates are only for use in benefit-cost analysis of Federal regulations and are not a "price" on carbon or a proxy for the anticipated cost of complying with CO_2 regulations; in addition they should not be used in NEPA environmental impact statements or state level decision making. One commenter stated that the SCC is more suitable for use in international discussions for now.

Response

The IWG agrees with those commenters who believe that use of the SCC estimates is an important component of regulatory impact analyses of rules that affect CO_2 emissions. However, it is not true that benefits that cannot be quantified or monetized are assigned zero weight in regulatory impact analysis. Although the monetized benefit estimates may not reflect unquantified benefits, the qualitative analysis provides important information about these benefits that must be given full consideration in regulatory decision-making. OMB guidance directs agencies to quantify benefits and costs of regulations to the extent feasible using the best available science and analytic techniques, but also to take non-quantified benefits into consideration when determining if the benefits of a regulatory action justify its costs. The SCC estimates and supporting TSDs are intended to assist agencies in adopting a consistent approach, based on the best available science and economics, for monetizing this important category of benefits. The IWG also agrees that the estimates should be updated periodically based on advances in the scientific and economic literature and has committed to do so.

Previous sections have addressed the perceived process flaws that have led some commenters to suggest that the estimates not be used until a future update that corrects these perceived flaws is completed. As noted, the IWG has accepted the suggestion of increased opportunity for public comment and plans to seek external expert advice as it considers futures updates, but does not feel that it is appropriate to withdraw the current estimates in the meantime as they represent the best available science in a form that is currently usable for monetized benefits estimates.

Regarding uncertainty, the IWG notes that most if not all benefits estimates in regulatory analyses are uncertain. This does not negate the value of the estimates. It does underscore the importance of a full and transparent discussion of uncertainty, and the TSDs have provided this (see, for example, *Section V: Limitations of the Analysis*, in the 2010 TSD, and *Section IV: Other Model Limitations and Research Gaps*, in the 2013 TSD). The TSDs are explicit that the estimates were developed for use in regulatory impact

analysis. The 2010 TSD states that the SCC estimates were developed for use in "cost-benefit analyses of regulatory actions that have small, or 'marginal,' impacts on cumulative global emissions." The IWG has not addressed the use of the SCC estimates outside the regulatory context, such as in NEPA analysis,[14] state level decision making, and "pricing" carbon in the marketplace. In addition, the 2010 TSD states, "For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions; we do not attempt to answer that question here." While the concept of an SCC is appropriate for international discussions, the IWG recognizes that any use of such estimates beyond the domestic regulatory context will require further discussion with our international partners; that said, our current work in this area can certainly help to inform such discussions.

11 Technical Addendum

As previously noted, the IWG continues to receive feedback from stakeholders through public comments on proposed Agency rulemakings that use the SCC in supporting analyses, the additional OMB comment period on the SCC, and regular interactions with stakeholders and research analysts implementing the methodology used by the IWG to compute the estimates. As a result of our engagement in this continuous review process, we recently discovered two areas where minor technical corrections are appropriate. First, the DICE model had been run up to 2300 rather than through 2300, as was intended, thereby leaving out the marginal damages in the last year of the time horizon. Second, due to an indexing error, the results from the PAGE model were in 2008 U.S. dollars rather than 2007 U.S. dollars, as was intended. A revised TSD with the corrected estimates (all models run through 2300 and all estimates in 2007 U.S. dollars) has been posted on OMB's website. On average the revised SCC estimates are one dollar less than the mean SCC estimates reported in the November 2013 TSD. The difference between the 95th percentile estimates with a 3% discount rate is slightly larger, as those estimates are heavily influenced by results from the PAGE model. The revised (July 2015) TSD includes an addition to the technical appendix (Appendix B) explaining these revisions.

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[14] On December, 18 2014, the Council on Environmental Quality released draft NEPA guidance on GHG Emissions and Climate Change Impacts (https://www.whitehouse.gov/administration/eop/ceq/initiatives/nepa/ghg-guidance). The draft guidance states: "When an agency determines it appropriate to monetize costs and benefits, then, although developed specifically for regulatory impact analyses, the Federal social cost of carbon, which multiple Federal agencies have developed and used to assess the costs and benefits of alternatives in rulemakings, offers a harmonized, interagency metric that can provide decision makers and the public with some context for meaningful NEPA review. When using the Federal social cost of carbon, the agency should disclose the fact that these estimates vary over time, are associated with different discount rates and risks, and are intended to be updated as scientific and economic understanding improves." The comment period for the draft guidance closed on March 25, 2015. CEQ is currently considering the comments received as it develops final guidance.

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