November 7, 2016

Attn: EERE-2015-BT-STD-0016, Energy Conservation Standards for WICF Refrigeration Systems
EERE-2014-BT-STD-0031, Energy Conservation Standards for Residential Furnaces

Comments submitted by: Environmental Defense Fund, Institute for Policy Integrity at New York University School of Law, Natural Resources Defense Council, and Union of Concerned Scientists.

Our organizations respectfully submit these comments regarding DOE's valuation of the benefits of its energy efficiency standards—specifically, the use of the Social Cost of Carbon, and the non-use of the Social Cost of Methane methodology. Our organizations may separately and independently submit other comments regarding the proposed standards themselves.

We strongly affirm that the current Social Cost of Carbon (SCC) values are sufficiently robust and accurate to continue to be the basis for regulatory analysis going forward. We further encourage DOE to monetize the benefits of other greenhouse gas reductions, such as through the Social Cost of Methane (SCM) methodology. As demonstrated below, if anything, current values are significant underestimates of the SCC and SCM. As economic and scientific research continues to develop in the future, the values should be revised, and we offer recommendations for that future revision.

Our comments are summarized in six sections:

1. Introduction: The SCC is an important policy tool.

2. The Interagency Working Group's (IWG) analytic process was science-based, open, and transparent.

3. The SCC is an important and accepted tool for regulatory policy-making, based on well-established law and fundamental economics.

4. Recommendations on further refinements to the SCC.

5. Support for the Social Cost of Methane methodology, and recommendations on refinements.

6. Conclusion: Recommendations on the use of the SCC and Social Cost of Methane in regulatory impact analyses.

1. Introduction: The SCC is an important policy tool.

The SCC estimates the economic cost of climate impacts—specifically the additional economic harm caused by one additional metric ton of carbon dioxide (CO_2) emissions. SCC calculations are important for evaluating the costs of activities that produce greenhouse gas emissions and contribute to climate change, such as burning fossil fuels to produce energy. The SCC is also important for evaluating the benefits of policies that would reduce the amount of those emissions going into the atmosphere.

As with all economic impact analyses, the exercise can only provide a partial accounting of the costs of climate change (those most easily monetized) and inevitably involves incorporating elements of uncertainty. However, accounting for the economic harms caused by climate change is a critical component of sound benefit-cost analyses of regulations that directly or indirectly limit greenhouse gases. This endeavor is important because benefit-cost analysis is a central tool of regulatory policy in the United States, first institutionalized in a 1981 executive order by President Ronald Reagan. The executive order currently in effect provides that agencies:

- "[P]ropose or adopt a regulation only upon a reasoned determination that its benefits justify its costs (recognizing that some benefits and costs are difficult to quantify); . . .
- "[S]elect, in choosing among alternative regulatory approaches, those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity); . . .
- "In applying these principles, each agency is directed to use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible. Where appropriate and permitted by law, each agency may consider (and discuss qualitatively) values that are difficult or impossible to quantify, including equity, human dignity, fairness, and distributive impacts."[1]

Benefit-cost analysis has long been a staple of agency rulemakings, usually conducted as part of the regulatory impact analysis associated with proposed rules. Even though the analysis is generally not able to encompass all of the effects of a policy, and it is challenging to translate impacts on health, mortality, and welfare into dollar values, benefit-cost analysis is an important economic tool to help inform decision-makers about the societal benefits of different policy choices. Of course, benefit-cost analysis cannot be the sole criterion for making regulatory decisions, especially in cases where there are overriding public health, equity, or safety imperatives.[2] And in a few instances, legal protections prohibit the consideration of benefit-cost analysis.

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. That, sadly, is not the case, as evidenced by the large body of research outlining the sobering health, environmental, and economic impacts of rising temperatures, extreme weather, intensifying smog, and other climate impacts. If anything, most evidence points to the fact that current numbers significantly underestimate the SCC. It would be arbitrary for a federal agency to weigh the societal benefits and

[1] Exec. Order No. 13,563 §§ 1(b)-(c), 76 Fed. Reg. 3,821 (Jan. 18, 2011); *see also infra* on how this and subsequent orders, including Exec. Order No. 13,609, inform the use of a global SCC value.

[2] President Clinton issued Executive Order 12,866 in 1993, establishing new guidance for benefit-cost analysis and explicitly directing agencies to consider, in addition to costs and benefits for which quantitative estimates are possible, "qualitative measures of costs and benefits that are difficult to quantify, but nevertheless essential to consider." Exec. Order No. 12,866 § 1(a), 58 Fed. Reg. 51,735 (Sept. 30, 1993).

costs of a rule with significant carbon pollution effects but to assign no value at all to the considerable benefits of reducing carbon pollution.[3]

2. The IWG's analytic process was science-based, open, and transparent.

To facilitate accounting for the costs of climate impacts and the benefits of reducing carbon pollution in regulatory proceedings undertaken by different agencies, the United States government assembled an Interagency Working Group (IWG) to develop an estimate of a social cost of carbon that can be utilized in rulemakings and other pertinent settings across the federal government.[4] The IWG's estimates—first released in 2010 and updated in 2013 and 2015—have been used in numerous benefit-cost analyses related to federal rulemakings.[5] The IWG recently released an updated set of SCC estimates, centered at approximately $40 per metric ton of CO_2 for emissions in the year 2015, in 2015 dollars at a 3% discount rate.[6] The 2015 SCC estimates are higher than those

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[3] Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1199 (9th Cir. 2008) (holding unlawful NHTSA's fuel economy standards for passenger vehicles when NHTSA ascribed a value of "zero" to the benefits of mitigating carbon dioxide, reasoning that "NHTSA assigned no value to *the most significant benefit* of more stringent CAFE standards: reduction in carbon emissions" (emphasis added)).

[4] The IWG involved a large number of agencies, including the Council of Economic Advisers, Council on Environmental Quality, Department of Agriculture, Department of Commerce, Department of Transportation, Environmental Protection Agency, National Economic Council, Office of Energy and Climate Change, Office of Management and Budget, Office of Science and Technology Policy, and the Department of the Treasury. *See* INTERAGENCY WORKING GROUP ON THE SOCIAL COST OF CARBON, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12,866 (2010) [hereinafter "2010 TSD"], *available at* http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf.

[5] The SCC has been used in numerous notice-and-comment rulemakings by various agencies since it was published in 2010, and each of these occasions has provided opportunity for public comment on the SCC. *See, e.g.*, Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers, 77 Fed. Reg. 32,381 (May 31, 2012); Energy Conservation Program: Energy Conservation Standards for Residential Dishwashers, 77 Fed. Reg. 31,964 (May 30, 2012); Energy Conservation Program: Energy Conservation for Battery Chargers and External Power Supplies, 77 Fed. Reg. 18,478 (Mar. 27, 2012); Energy Conservation Program: Energy Conservation Standards for Standby Mode and Off Mode for Microwave Ovens, 77 Fed. Reg. 8526 (Feb. 14, 2012); Energy Conservation Program: Energy Conservation Standards for Distribution Transformers, 77 Fed. Reg. 7282 (Feb. 10, 2012); Energy Conservation Program for Certain Industrial Equipment: Energy Conservation Standards and Test Procedures for Commercial Heating, Air-Conditioning, and Water-Heating Equipment, 77 Fed. Reg. 2356 (Jan. 17, 2012); 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, 76 Fed. Reg. 74,854 (Dec. 1, 2011); Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews, 76 Fed. Reg. 52,738 (Aug. 23, 2011); Energy Conservation Program: Energy Conservation Standards for Residential Furnaces and Residential Central Air Conditioners and Heat Pumps, 76 Fed. Reg. 37,549 (June 27, 2011); Energy Conservation Program: Energy Conservation Standards for Residential Clothes Dryers and Room Air Conditioners, 76 Fed. Reg. 22,324 (Apr. 21, 2011); Energy Conservation Program: Energy Conservation Standards for Fluorescent Lamp Ballasts, 76 Fed. Reg. 20,090 (Apr. 11, 2011); National Emission Standards for Hazardous Air Pollutants: Mercury Emissions from Mercury Cell Chlor-Alkali Plants, 76 Fed. Reg. 13,852 (Mar. 14, 2011); Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, 75 Fed. Reg. 74,152 (Nov. 30, 2010); Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Sewage Sludge Incineration Units, 75 Fed. Reg. 63,260 (Oct. 14, 2010); Energy Conservation Program: Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers, 75 Fed. Reg. 59,470 (Sept. 27, 2010); Federal Implementation Plans to Reduce Interstate Transport of Fine Particulate Matter and Ozone, 75 Fed. Reg. 45,210 (Aug. 2, 2010). The undersigned organizations have provided comment on the SCC in a number of these proceedings.

[6] INTERAGENCY WORKING GROUP ON THE SOCIAL COST OF CARBON, TECHNICAL SUPPORT DOCUMENT: TECHNICAL UPDATE OF THE SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12,866 (2015); *see also* INTERAGENCY WORKING GROUP ON THE SOCIAL COST OF CARBON, TECHNICAL SUPPORT DOCUMENT: TECHNICAL UPDATE OF THE SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12,866 (2013) [hereinafter "2013 TSD"], *available at* http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf.

from 2010, reflecting the growing understanding of the costs that climate impacts will impose on society.

The increase in the SCC estimate is important because it reflects the growing scientific and economic research on the risks and costs of climate change, but is still very likely an underestimate of the economic cost of carbon emissions. The increase also reflects the costs of climate change that we are already experiencing, such as those associated with sea level rise and rising temperatures. Climate change is making coastal flooding, drought, and impacts from extreme weather worse. A rapidly increasing body of evidence has linked ever more recent events directly to climate change.[7]

The analytic work of the IWG has been transparent. The 2010 Technical Support Document (TSD) set out in detail the IWG's decision-making process with respect to how it assessed and employed the models.[8] Furthermore, the Government Accountability Office (GAO) found that "the working group's processes and methods reflected the following three principles: *Used consensus-based decision making, Relied on existing academic literature and models, and Took steps to disclose limitations and incorporate new information."*[9]

Because the 2013 IWG made no changes to the input assumptions and procedures for deriving its SCC estimates, the 2013 TSD discussed only how the three Integrated Assessment Models (IAMs) used in the analysis were updated in the academic literature over the three-year interim period by the independent researchers who have developed these models. The 2013 TSD also established that the increase in the SCC estimate from 2010 to 2013 resulted solely from updates to the three underlying IAMs.[10]

The 2015 TSD update provided detailed responses[11] to public comments collected through an opportunity for public participation initiated by the Office of Management and Budget (OMB).[12] Additionally, the comment period on these proposed standards is yet another opportunity for continued dialogue about areas requiring further study. Such repeated comment processes and updates demonstrate that the IWG's SCC estimates were developed—and are being used—transparently. Given their strong grounding in the best science available, nothing should prevent the current, continued use of this well-established estimate. As economic and scientific research continues to develop, future revisions will be able to further refine existing estimates based on the latest peer-reviewed literature and the latest updates to the quality of the overall modeling exercise.

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[7] *See generally* Thomas C. Peterson et al. eds., *Explaining Extreme Events of 2012 from a Climate Perspective*, 94 BULL. AMER. METEOR. SOC. s1-74 (2013), and IPCC, *Special Report: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (2012). On the scientific research connecting weather and other climate-related events to climate change, see Peter A. Stott et al., "Attribution of Weather and Climate-Related Events." In *Climate Science for Serving Society*, edited by Ghassem R. Asrar and James W. Hurrell. Netherlands: Springer s307-37 (2013).

[8] *See generally* 2010 TSD, *supra* note 4.

[9] GAO, REGULATORY IMPACT ANALYSIS: Development of Social Cost of Carbon Estimates, GAO-14-663 (2014).

[10] The 2010 and 2013 IWGs did very little to adjust the three IAMs. The main adjustment by IWG was to DICE to ensure that the IAM had an exogenous growth path that matched FUND and PAGE for the purposes of modeling various socio-economic and emission scenarios. *Id.* at 24.

[11] OMB & Interagency Working Group, Response to Comments on Social Cost of Carbon (July 2015).

[12] OMB, Notice of Availability and Request for Comments, Technical Support Documents: Social Cost of Carbon for Regulatory Impact Analysis, 78 Fed. Reg. 70,586 (Nov. 26, 2013).

3. The SCC is an important and accepted tool for regulatory policy-making based on well-established law and fundamental economics.

The legal and analytic basis for using the SCC is clear and well established. ***As a matter of law and economics, uncertainty in benefits estimates does not mean they should be excluded from regulatory impact analyses***. No benefit or cost estimates are certain. Further, the courts have explicitly rejected the argument that uncertainty in assessing the costs of climate impacts provided a basis for ignoring them in assessing the benefits and costs of regulations, and executive orders dating back as far as the Reagan administration have all issued guidelines specifying explicit consideration of benefits even if the precise size of the benefit is uncertain.

In 2008, the U.S. Court of Appeals for the Ninth Circuit determined that agencies could not assign a zero dollar value to the social costs of the impacts of climate change. It determined that *failing* to count SCC benefits would be illegal. In this case, the National Highway Traffic Safety Administration (NHTSA) had decided not to count any avoided climate damages in issuing fuel economy standards. The court concluded: "NHTSA's reasoning is arbitrary and capricious for several reasons. First while the record shows that there is a ***range of values***, the value of carbon emission reductions is certainly ***not zero*** (emphasis added)."[13]

Like the Court of Appeals, executive orders dating back to 1981 have also required agencies to assess benefits and costs even when significant uncertainty exists. Every president since (and including) Ronald Reagan has issued directives requiring that agencies conduct cost-benefit analyses of proposed regulations where permitted by statute.[14] Specifically, agencies are directed to "take into account benefits and costs, both quantitative and qualitative . . . and use the ***best available techniques*** to quantify anticipated present and future benefits and costs as accurately as possible."[15] The IWG's use of Integrated Assessment Models (IAMs) reflects the best available, peer-reviewed science to tally the benefits and costs of specific regulations with impacts on carbon dioxide emissions. While we address ways for improvement in the next section, current IAMs include benefits and costs that have been quantified to date.

The bottom line is that the IWG has properly and lawfully used the best available techniques to quantify the benefits of carbon emission reductions, basing its analysis on the peer-reviewed literature. When agencies use the IWG's estimates of the SCC to calculate the benefits of a rulemaking, they have taken, and will continue to take, comment on the SCC and the process used to derive that value. That is what the law—and good policy—requires.

The IWG Correctly Used a Global SCC Value.

To design the economically efficient policies necessary to forestall severe and potentially catastrophic climate change, all countries must use a global SCC value. Given that the United States and many other significant players in the international climate negotiations have already applied a global SCC framework in evaluating their own climate policies, the continued use of the global value in U.S. regulatory decisions may be strategically important as the United States seeks to set an example for other countries, harmonize regulatory systems, and take the lead in ongoing

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[13] Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1200 (9th Cir. 2008) (emphases added).

[14] Stuart Shapiro, *The Evolution of Cost-Benefit Analysis in U.S. Regulatory Decisionmaking*, *in* HANDBOOK ON THE POLITICS OF REGULATION 385-392 (David Levi-Faur ed., 2011).

[15] Exec. Order No. 13,563 §§ 1(a)-(c), 76 Fed. Reg. 3,821 (Jan. 18, 2011) (emphasis added).

international negotiations. Binding legal obligations, basic ethical responsibilities, and practical considerations further counsel in favor of the United States using a global SCC value.

To avoid a global "tragedy of the commons" and an economically inefficient degradation of the world's climate resources, all countries should set policy according to a global SCC value. The climate and clean air are global common resources, meaning they are free and available to all countries, but any one country's use—i.e., pollution—imposes harms on the polluting country as well as the rest of the world. Because greenhouse gases do not stay within geographic borders but rather mix in the atmosphere and affect climate worldwide, each ton of carbon pollution emitted by the United States not only creates domestic harms, but also imposes additional and large externalities on the rest of the world, including disproportionate harms to some of the least-developed nations. Conversely, each ton of carbon pollution abated in another country will benefit the United States along with the rest of the world.

If all countries set their greenhouse gas emission levels based on only their domestic costs and benefits, ignoring the large global externalities, the collective result would be substantially sub-optimal climate protections and significantly increased risks of severe harms to all nations, including to the United States. "[E]ach pursuing [only its] own best interest . . . in a commons brings ruin to all."[16] By contrast, a global SCC value would require each country to account for the full damages of its greenhouse gas pollution and so to collectively select the efficient level of worldwide emissions reductions needed to secure the planet's common climate resources.

Thus, well-established economic principles demonstrate that the United States stands to benefit greatly if all countries apply a global SCC value in their regulatory decisions. A rational tactical option in the effort to secure that economically efficient outcome is for the United States to continue using a global SCC value itself. The United States is engaged in a repeated strategic game of international negotiations and regulatory coordination, in which several significant players—including the United States—have already adopted a global SCC framework.[17] For the United States to now depart from this implicit collaborative dynamic by reverting to a domestic-only SCC estimate could undermine the country's long-term interests in future climate negotiations and could jeopardize emissions reductions underway in other countries, which are already benefiting the United States.[18] A domestic-only SCC value could be construed as a signal that the United States does not recognize or care about the effects of its policy choices on other countries, and signal that it would be acceptable for other countries to ignore the harms they cause the United States. Further, a sudden about-face could undermine the United States' credibility in negotiations. The United States has recently reasserted its desire to take a lead in both bilateral and international climate negotiations.[19] To set an example for the rest of the world, to advance its own long-term climate interests, and to secure greater cooperation toward reducing global emissions, strategic factors support the continued use a global SCC value in U.S. regulatory decisions.

Though the Constitution balances the delegation of foreign affairs power between the executive and legislative branches, "[t]he key to presidential leadership is the negotiation function. Everyone agrees that the President has the exclusive power of official communication with foreign governments."[20] The development and analysis of U.S. climate regulations are essential parts of the

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[16] Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968).

[17] *See infra* notes 26 and 32 to 35, and accompanying text, detailing use of a global SCC value by Canada, Mexico, the United Kingdom, France, Germany, and Norway.

[18] *See* ROBERT AXELROD, THE EVOLUTION OF COOPERATION 10-11 (1984) (on repeated prisoner's dilemma games).

[19] EXEC. OFFICE OF THE PRES., THE PRESIDENT'S CLIMATE ACTION PLAN 17-21 (2013).

[20] Phillip R. Trimble, *The President's Foreign Affairs Power*, 83 AM. J. OF INTL. L. 750, 755 (1989).

dialogue between the United States and foreign countries about climate change. Using a global SCC value communicates a strong signal that the United States wishes to engage in reciprocal actions to mitigate the global threat of climate change. The President is responsible for developing and executing the negotiation strategy to achieve the United States' long-term climate interests. Currently, the President has instructed federal agencies to use a global SCC value as one important step that encourages other countries to take reciprocal actions that also account for global externalities. The President's constitutional powers to negotiate international agreements would be seriously impaired if federal agencies were forced to stop relying on a global SCC value.[21]

In fact, the United States has already begun to harmonize with other countries its policies on climate change and on the valuation of regulatory benefits. The recent U.S.-China agreement is but the latest example. For instance, the United States has entered into a joint Regulatory Cooperation Council with Canada, which has adopted a work plan that commits the two countries to synchronizing "aggressive" greenhouse gas reductions, especially in the transportation sector.[22] A separate Regulatory Cooperation Council with Mexico calls generally for improving and harmonizing policy "by strengthening the analytic basis of regulations,"[23] and its work plan acknowledges the transboundary nature of environmental risks.[24] Mexico and Canada have both adopted greenhouse gas standards for vehicles that harmonize with the U.S. standards[25] and that calculate benefits according to a global SCC value.[26] Canada has also used the IWG's global SCC value in developing carbon dioxide standards for its coal-fired power plants, estimating $5.6 billion

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[21] *See* David Remnick, *The Obama Tapes*, NEW YORKER, Jan. 23, 2014, *available at* http://www.newyorker.com/online/blogs/newsdesk/2014/01/the-obama-tapes.html (quoting interview with President Obama: "[M]y goal has been to make sure that the United States can genuinely assert leadership in this issue internationally, that we are considered part of the solution rather than part of the problem. And if we are at the table in that conversation with some credibility, then it gives us the opportunity to challenge and engage the Chinese and the Indians, as long as we take into account the fact that they've still got, between the two of them, over a billion people in dire poverty. . . . This is why I'm putting a big priority on our carbon action plan here. It's not because I'm ignorant of the fact that these emerging countries are going to be a bigger problem than us. It's because it's very hard for me to get in that conversation if we're making no effort.").

[22] UNITED STATES-CANADA REGULATORY COOPERATION COUNCIL, JOINT ACTION PLAN, at 16 (2011), *available at* http://www.whitehouse.gov/sites/default/files/omb/oira/irc/us-canada_rcc_joint_action_plan.pdf.

[23] UNITED STATES-MEXICO HIGH-LEVEL REGULATORY COOPERATION COUNCIL, WORK PLAN at 3 (2012), *available at* http://www.whitehouse.gov/sites/default/files/omb/oira/irc/united-states-mexico-high-level-regulatory-cooperation-council-work-plan.pdf.

[24] *Id.* at 11 (noting that oil drilling activities in the Gulf of Mexico conducted by either country "present risks for both countries, and both countries would benefit from a common set of drilling standards").

[25] *See* INT'L COUNCIL ON CLEAN TRANSP., MEXICO LIGHT-DUTY VEHICLE CO_2 AND FUEL ECONOMY STANDARDS 4 (Policy Update, July 2013), *available at* http://www.theicct.org/sites/default/files/publications/ICCTupdate_Mexico_LDVstandards_july2013.pdf (noting that Mexico's standards were based on the U.S. and Canadian standards).

[26] *See* Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations, SOR/2013-24, 147 Can. Gazette pt. II, 450, 544 (Can.), *available at* http://canadagazette.gc.ca/rp-pr/p2/2013/2013-03-13/html/sor-dors24-eng.html ("The SCC is used in the modelling of the cost-benefit analysis . . . . It represents an estimate of the economic value of avoided climate change damages *at the global level*. . . . The values used by Environment Canada are based on the extensive work of the U.S. Interagency Working Group on the Social Cost of Carbon.") (emphasis added); Instituto Nacional de Ecología, Mexico, Regulatory Impact Analysis on *PROY-NOM-163- SEMARNAT-ENER-SCFI-2012, Emisiones de bióxido de carbono (CO_2) provenientes del escape y su equivalencia en términos de rendimiento de combustible, aplicable a vehículos automotores nuevos de peso bruto vehicular de hasta 3857 kilogramos* (July 5, 2012), *available at* http://207.248.177.30/mir/formatos/defaultView.aspx?SubmitID=273026 ("[S]e obtienen beneficios ambientales por la reducción del consumo de combustible, los cuales se reflejan en beneficios a la salud de la población en el caso de contaminantes criterio, y en *beneficios globales para las emisiones evitadas de CO_2*.") (emphasis added).

(Canadian dollars) worth of global climate benefits.[27] The direct U.S. share of the net benefits from that Canadian regulation will likely total in the hundreds of millions of dollars.[28]

Further efforts at regulatory harmonization are currently underway. For example, the United States is now negotiating a Transatlantic Trade and Investment Partnership with the European Union, and a key element is regulatory coordination.[29] The European Union has already adopted an Emissions Trading Scheme (ETS) to cap its greenhouse gas emissions, and its Aviation Directive is just one of the climate policies that could be shaped by these negotiations.[30] The European Commission has indicated its willingness to further reduce its ETS cap if other major emitters make proportional commitments[31]—a result that will only occur if countries consider more than their own domestic costs and benefits from reducing greenhouse gas emissions. Moreover, several individual European nations—including the United Kingdom,[32] France,[33] Germany,[34] and Norway[35]—have adopted a global SCC value for use in their regulatory analyses. Some other European countries, such as Sweden, have adopted carbon taxes that implicitly operate as a high SCC that accounts for global externalities.[36]

As further evidence of how the United States' use of a global SCC value is already influencing other international actors to follow suit, the International Monetary Fund (IMF) applies in its policy

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[27] Reduction of Carbon Dioxide Emissions from Coal-Fired Generation of Electricity Regulations, SOR/2012-167, 146 Can. Gazette pt. II, 1951, 2000, 2044 (Can.), *available at* http://www.gazette.gc.ca/rp-pr/p2/2012/2012-09-12/html/sor-dors167-eng.html.

[28] $5.6 billion in Canadian dollars is worth $5.0 billion in U.S. dollars (using February 2014 conversion rates). Seven to twenty-three percent of $5 billion is between $350 million and $1.15 billion. *See* 2010 TSD, *supra* note 4, at 11 (provisionally calculating the direct U.S. share of a global SCC value at between 7-23%, though ultimately recommending "that using the global (rather than domestic) value . . . is the appropriate approach," for reasons consistent with these comments).

[29] *See* EUR. COMM'N, TRANSATLANTIC TRADE AND INVESTMENT PARTNERSHIP: THE REGULATORY PART (2013).

[30] *See* SIERRA CLUB, THE TRANSATLANTIC FREE TRADE AGREEMENT: WHAT'S AT STAKE FOR COMMUNITIES AND THE ENVIRONMENT at 9-10 (2013).

[31] Eur. Comm'n, Working with International Partners, http://www.e.europa.eu/clima/policies/international ("The EU is offering to step up its 2020 reduction targets to 30% if other major economies commit.").

[32] ECONOMICS GROUP, DEFRA, U.K., THE SOCIAL COST OF CARBON AND THE SHADOW PRICE OF CARBON: WHAT THEY ARE, AND HOW TO USE THEM IN ECONOMIC APPRAISAL IN THE UK 1 (2007); *see also* Ministry of Finance, Norway, Cost-Benefit Analysis: Carbon Price Paths, *available at* http://www.regjeringen.no/en/dep/fin/Documents-and-publications/official-norwegian-reports-/2012/nou-2012-16-2/10.html?id=713585 ("The United Kingdom has changed its method for the valuation of greenhouse gas emissions. Prior to 2009, the estimated global social cost of carbon was used, but one [sic] has now switched over to pricing in line with the necessary marginal cost of meeting long-term domestic emission reduction targets in conformity with the EU Climate and Energy Package.").

[33] *See* Balázs Égert, *France's Environmental Policies: Internalising Global and Local Externalities* 8-10 (OECD Economics Department Working Papers No. 859, 2011), *available at* http://dx.doi.org/10.1787/5kgdpn0n9d8v-en (discussing global impacts and France's history of calculating the SCC); Oskar Lecuyer & Philippe Quirion, funded by the European Union's Seventh Framework Programme, *Choosing Efficient Combinations of Policy Instruments for Low-Carbon Development and Innovation to Achieve Europe's 2050 Climate Targets—Country Report: France* at 8 (2013) (noting the prospects for a carbon tax in 2014-15, and explaining that "A 2009 stakeholder and expert group led by the 'Conseil d'analyse stratégique' (a public body in charge of expertise and stakeholder dialogue) set the optimal level of the carbon tax (the social cost of carbon) at € 32/tCO 2 in 2010, and rising to € 100 in 2030 and € 200 in 2050.").

[34] Testimony of Howard Shelanski, OIRA Admin., before the H. Comm. on Oversight & Gov't Reform's Subcomm. on Energy Policy, Healthcare, and Entitlements, July 18, 2013, at 3 (explaining that the global SCC value estimated by the IWG is consistent with values used by Germany and the United Kingdom).

[35] *See* Ministry of Finance, *supra* note 32 (explaining that, for projects not already covered by a binding emission limitation, the carbon price should "be based on the marginal social cost of carbon," meaning "the global cost of emitting one additional tonne of CO_2e"). Note that Norway has joined the E.U.'s trading scheme.

[36] Henrik Hammar, Thomas Sterner & S. Åkerfeldt, *Sweden's CO_2 Tax and Taxation Reform Experiences*, in REDUCING INEQUALITIES: A SUSTAINABLE DEVELOPMENT CHALLENGE (Genevey, R. et al. eds., 2013).

reviews an SCC estimate based on the IWG number.[37] Given the potential influence of the IMF on the environmental policies of developing countries,[38] the pull that the IWG's global estimate has at the IMF could be very advantageous to the United States, by motivating industrializing countries to use similar numbers in the future.

In addition to this compelling strategic argument—namely, that it is rational for the United States and other countries to continue their reciprocal use of a global SCC value to achieve the economically efficient outcome on climate change (and avoid catastrophic climate impacts)—legal obligations further prescribe using a global SCC value. A basic ethical responsibility to prevent transboundary environmental harms has been enshrined in customary international law.[39] For the United States to knowingly set pollution levels in light of only domestic harms, willfully ignoring that its pollution directly imposes environmental risks—including catastrophic risks—on other countries, would violate norms of comity among countries. The United States would be knowingly causing foreseeable harm to other countries, without compensation or just cause. Given that the nations most at risk from climate change are often the poorest countries in the world, such a policy would also violate basic and widely shared ethical beliefs about fairness and distributive justice. Indeed, taking a global approach to measuring climate benefits is consistent with the ideals of transboundary responsibility and justice that the United States commits to in other foreign affairs.[40]

Binding international agreements also require consideration and mitigation of transboundary environmental harms. Notably, the United Nations Framework Convention on Climate Change—to which the United States is a party—declares that countries' "policies and measures to deal with climate change should be cost-effective so as to ensure *global benefits* at the lowest possible cost."[41] The Convention further commits parties to evaluating global climate effects in their policy decisions, by "employ[ing] appropriate methods, for example *impact assessments* . . . with a view to minimizing adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change."[42] The unmistakable implication of the Convention is that parties—including the United States—must account for global economic, public health, and environmental effects in their impact assessments.

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[37] *E.g.*, Benedict Clements et al., International Monetary Fund, *Energy Subsidy Reforms: Lessons and Implications* 9 (IMF Policy Paper, Jan. 28, 2013).

[38] *See* Natsu Taylor Saito, *Decolonization, Development, and Denial*, 6 FL. A & M U. L. REV. 1, 16 (2010) (quoting former IMF counsel as saying "today it is common to find these institutions [IMF and World Bank] requiring their borrowing member countries to accept and adhere to prescribed policies on environmental protection").

[39] *See* PHILIPPE SANDS, PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW 241 (2d ed. 2003) (noting that "the responsibility not to cause damage to the environment of other states or of areas beyond national jurisdiction has been accepted as an obligation by all states[;] . . . there can be no questions but that Principle 21 [of the Stockholm Declaration on the Human Environment] reflects a rule of customary international law").

[40] *See* Paul Baer & Ambuj Sagar, *Ethics, Rights and Responsibilities*, in CLIMATE CHANGE SCIENCE AND POLICY (Stephen Schneider et al., eds., 2009).

[41] United Nations Framework Convention on Climate Change, May 9, 1992, S. Treat Doc. No. 102-38, 1771 U.N.T.S. 107, Article 3(3) (emphasis added); *see also id.* at Article 3(1) ("The Parties should protect the climate system for the *benefit of present and future generations of humankind*, on the basis of *equity* and in accordance with their common but *differentiated responsibilities* and respective capabilities.") (emphasis added); *id.* at Article 4(2)(a) (committing developed countries to adopt policies that account for "the need for equitable and appropriate contributions by each of these Parties to the global effort").

[42] *Id.* at Article 4(1)(f) (emphasis added); *see also id.* at Article 3(2) (requiring parties to give "full consideration" to those developing countries "particularly vulnerable to the adverse effects of climate change"). *See also* North American Agreement on Environmental Cooperation (1993), 32 I.L.M. 1480, art. 10(7) (committing the United States to the development of principles for transboundary environmental impact assessments).

Similar obligations exist in domestic U.S. law as well. For example, the U.S. National Environmental Policy Act recognizes "the worldwide and long-range character of environmental problems"[43] and requires federal agencies to include reasonably foreseeable transboundary effects in their environmental impact statements.[44] While some individual statutes under which federal agencies will craft climate policies may be silent on the issue of considering extraterritorial benefits, arguably the most important statute for U.S. climate policy—the Clean Air Act—requires the control of air emissions that affect other countries and so encourages a global assessment of greenhouse gas effects. Specifically, Section 115 of the Clean Air Act directs EPA and the states to mitigate U.S. emissions that endanger foreign health and welfare.[45] The global perspective on climate costs and benefits required by that provision should inform all regulatory actions developed under the Clean Air Act, and may provide useful guidance under other statutes as well.[46]

Presidential orders on regulatory analysis also support use of a global SCC value. In 2012, President Obama issued Executive Order 13,609 on promoting international regulatory cooperation.[47] The Order built on his previous Executive Order 13,563, which in turn had affirmed its 1993 predecessor, Executive Order 12,866, in requiring benefit-cost analysis of significant federal regulations.[48] Though White House guidance published in 2003 on regulatory impact analysis under E.O. 12,866 assumed that most analyses would focus on domestic costs and benefits, it ultimately deferred to the discretion of regulatory agencies on whether to evaluate "effects beyond the borders of the United States."[49] More importantly, since the publication of that guidance, President Obama has issued his own supplemental orders on regulatory analysis, including E.O. 13,609, which clarified the importance of international cooperation to achieve U.S. regulatory

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[43] 42 U.S.C. § 4332(2)(F).

[44] COUNCIL ON ENVIRONMENTAL QUALITY, GUIDANCE ON NEPA ANALYSIS FOR TRANSBOUNDARY IMPACTS (1997), *available at* http://www.gc.noaa.gov/documents/transguide.pdf; *see also* CEQ, DRAFT NEPA GUIDANCE ON CONSIDERATION OF THE EFFECTS OF CLIMATE CHANGE AND GREENHOUSE GAS EMISSIONS at 2 (2010), *available at* http://www.whitehouse.gov/sites/default/files/microsites/ceq/20100218-nepa-consideration-effects-ghg-draft-guidance.pdf (defining climate change as a "global problem"); *see also* Exec. Order No. 12,114, *Environmental Effects Abroad of Major Federal Actions*, 44 Fed. Reg. 1957 §§ 1-1, 2-1 (Jan. 4, 1979) (applying to "major Federal actions . . . having significant effects on the environment outside the geographical borders of the United States," and enabling agency officials "to be informed of pertinent environmental considerations and to take such considerations into account . . . in making decisions regarding such actions").

[45] 42 U.S.C. § 7415.

[46] For details on the applicability of Section 115, see Petition from the Institute for Policy Integrity, to EPA, for Rulemakings and Call for Information under Section 115, Title VI, Section 111, and Title II of the Clean Air Act to Regulate Greenhouse Gas Emissions (Feb. 19, 2013); *see also* Nathan Richardson, *EPA and Global Carbon: Unnecessary Risk*, COMMON RESOURCES, Feb. 28, 2013 (explaining how Section 115 authorizes use of a global SCC value when regulating under other Clean Air Act provisions).

[47] 77 Fed. Reg. 26,413 (May 4, 2012).

[48] *Id.* § 1 (explaining the order intends to "promot[e] the goals of Executive Order 13563"); *see also* Exec. Order No. 13,563, *Improving Regulation and Regulatory Review*, § 1(b), 76 Fed. Reg. 3821 (Jan. 18, 2011) (reaffirming Exec. Order No. 12,866, 58 Fed. Reg. 51,741 (Sept. 30, 1993) and requiring benefit-cost analysis).

[49] OMB, CIRCULAR A-4, at 15 (2003). In sharp contrast to the Circular's ultimate deferral to agencies on the issue of considering transboundary efficiency effects, the Circular makes very clear that international transfers and distributional effects should be assessed as costs and benefits to the United States: "Benefit and cost estimates should reflect real resource use. Transfer payments are monetary payments from one group to another that do not affect total resources available to society. . . . However, transfers from the United States to other nations *should* be included as costs, and transfers from other nations to the United States as benefits, as long as the analysis is conducted from the United States perspective." *Id.* at 38 (emphasis original). In other words, even if federal agencies use a global SCC value to assess efficiency effects relating to their climate policies, that global valuation will not prevent the agencies from also counting international transfers or distributional effects that benefit the United States as benefits. *See* Comments from the Institute for Policy Integrity, to EPA, on Proposed Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards, at 12-13 (Nov. 27, 2009) (explaining that, depending on the relevant statutory mandate, agencies may calculate a monopsony benefit to the United States even while using a global SCC value).

goals. This 2012 order explicitly recognizes that significant regulations can have "significant international impacts,"[50] and it calls on federal agencies to work toward "best practices for international regulatory cooperation with respect to regulatory development."[51] By employing a global SCC value in U.S. regulatory development, and by encouraging other countries to follow that best practice and account for the significant international impacts of their own climate policies, federal agencies will advance the mission of this presidential order on regulatory harmonization.

Finally, two practical considerations counsel in favor of a global SCC value. First, unlike some other significant international environmental impacts, no methodological limitations block the quantitative estimation of a global SCC value. In recent regulatory impact analyses for major environmental rules, EPA has qualitatively considered important transnational impacts that could not be quantified. For example, in the Mercury and Air Toxics Standards, EPA concluded that a reduction of mercury emissions from U.S. power plants would generate health benefits for foreign consumers of fish, both from U.S. exports and from fish sourced in foreign countries. EPA did not quantify these foreign health benefits, however, due to complexities in the scientific modeling.[52] Similarly, in the analysis of the Cross-State Air Pollution Rule, EPA noted—though could not quantify—the "substantial health and environmental benefits that are likely to occur for Canadians" as U.S. states reduce their emissions of particulate matter and ozone—pollutants that can drift long distances across geographic borders.[53] Yet where foreign costs or benefits are important and quantifiable, other federal agencies frequently include those calculations.[54] Given that sophisticated models already exist to quantify the global SCC, the global estimate is appropriate to use.

Second, a global SCC value is in the national interest because harms experienced by other countries could significantly impact the United States. Climate damages in one country could generate large spillover effects to which the United States is especially vulnerable. The mesh of the global economy is woven tightly, and disruptions in one place can have consequences around the world. As seen historically, economic disruptions in one country can cause financial crises that reverberate globally at a breakneck pace.[55] In a similar vein, national security analysts in government and academia increasingly emphasize that the geopolitical instability associated with climatic disruptions abroad poses a serious threat to the United States.[56] Due to its unique place among countries—both as the largest global economy with trade- and investment-dependent links throughout the world, and as a military superpower—the United States is particularly vulnerable to international spillover effects.

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[50] 77 Fed. Reg. at 26,414, § 3(b).

[51] 77 Fed. Reg. at 26,413, § 2(a)(ii)(B) (defining the goals of the regulatory working group).

[52] EPA, REGULATORY IMPACT ANALYSIS FOR THE FINAL MERCURY AND AIR TOXICS STANDARDS at 65 (2011) ("Reductions in domestic fish tissue concentrations can also impact the health of foreign consumers . . . [and] reductions in U.S. power plant emissions will result in a lowering of the global burden of elemental mercury . . . .").

[53] Federal Implementation Plans to Reduce Interstate Transport of Fine Particulate Matter and Ozone, 75 Fed. Reg. 45,209, 45,351 (Aug. 2, 2010).

[54] *E.g.*, Unique Device Identification System, 78 Fed. Reg. 58,786 (Sept. 24, 2013) ("[I]n our final regulatory impact analysis we include an estimate of the costs to foreign labelers."); Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption, 78 Fed. Reg. 3504 (Jan. 16, 2013) (including costs to foreign farms); U.S. Customs and Border Protection Regulatory Agenda, RIN 1651-AA96 Definition of Form I-94 to Include Electronic Format (2013) (preliminarily estimating net benefits to foreign travelers and carriers).

[55] Steven L. Schwarz, *Systemic Risk*, 97 GEO. L.J. 193, 249 (2008) (observing that financial collapse in one country is inevitably felt beyond that country's borders).

[56] *See, e.g.*, Department of Defense, Climate Change Adaptation Roadmap (2014); CNA Military Board, National Security and the Accelerating Risks of Climate Change (2014).

The 2010 TSD included a rigorous examination of global versus domestic SCC estimates.[57] Consistent with the above discussion, the 2010 IWG reached the conclusion to estimate a global SCC value, citing both the global impacts of climate change and the global action needed to mitigate climate change. The IWG restated these arguments in the 2013 TSD, and refers back explicitly to its discussion in the 2010 TSD.[58] DOE should continue using a global SCC estimate in its regulatory impact analyses.

4. Recommendations on further refinements to the SCC.[59]

The IWG process uses assumptions that accord with economic and scientific theory. Economic models, and the scientific analyses they draw from, are of course improving continuously. Future updates to the SCC should build on these and go further. As further refinements better account for climate change impacts not yet incorporated into the modeling, all indications are that the estimated benefits of curbing carbon pollution will rise substantially over current estimates.

The IWG appropriately used consumption discount rates rather than returns on capital.

With respect to the **discount rate**, the IWG conducted sensitivity analysis of the results to three constant consumption discount rates: 2.5%, 3%, and 5%; for each of the discount rates, the TSDs reported the various moments and percentiles[60] of the SCC estimates.

The discount rate is one of the most important inputs in models of climate damages, with plausible assumptions easily leading to differences of an order of magnitude in the SCC. The climate impacts of present emissions will unfold over hundreds of years. When used over very long periods of time, discounting penalizes future generations heavily due to compounding effects. For example, at a rate of 1%, $1 million 300 years hence equals over $50,000 today; at 5% it equals less than 50 cents.[61] The discount rate changed by a factor of five, whereas the discounted value changed by more than five orders of magnitude. Depending on the link between climate risk and economic growth risk, even a rate of 1% may be too high.[62] Uncertainty around the correct discount rate pushes the rate lower still.[63]

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57 2010 TSD, *supra* note 4, at 10-11.

58 2013 TSD, *supra* note 6, at 14-15.

59 The following section relies heavily on Richard L. Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, 508 NATURE 173 (2014), on Gernot Wagner & Martin L. Weitzman, *Climate Shock*, Princeton University Press (2015), on Frank J. Convery & Gernot Wagner, *Reflections—Managing Uncertain Climates: Some Guidance for Policy Makers and Researchers* (forthcoming in REVIEW OF ENVIRONMENTAL ECONOMICS AND POLICY) as well as on several papers cited in footnotes throughout.

60 The moments of a distribution (of SCC estimates in this case) are, loosely speaking, the various values that describe the distribution's shape: what value is the distribution centered around (mean); how wide is the distribution (the variance); whether the distribution is lopsided (skewness); and whether it is tall and skinny or short and fat (kurtosis). A percentile is a statistical measure of the value (the SCC value in this case) below which a specified percentage of (SCC) observations falls. The 1st percentile indicates the SCC value above which (the other) 99% of observed SCC values fall. The 99th percentile indicates the SCC value below which 99% of all observed SCC values fall.

61 Dallas Burtraw & Thomas Sterner, *Climate Change Abatement: Not "Stern" Enough?* (Resources for the Future Policy Commentary Series, Apr. 4, 2009), *available at* http://www.rff.org/Publications/WPC/Pages/09_04_06_Climate_Change_Abatement.aspx.

62 "If climate risk dominates economic growth risk because there are enough potential scenarios with catastrophic damages, then the appropriate discount rate for emissions investments is lower tha[n] the risk-free rate and the current price of carbon dioxide emissions should be higher. In those scenarios, the "beta" of climate risk is a large negative value and emissions mitigation investments provide insurance benefits. If, on the other hand, growth risk is always dominant because catastrophic damages are essentially impossible and minor climate damages are more likely to

The IWG correctly excluded a 7% discount rate, a typical private sector rate of return on capital, for several reasons. First, typical financial decisions, such as how much to save in a bank account or invest in stocks, focus on private decisions and utilize private rates of return. Private market participants typically have short time horizons. However, here we are concerned with social discount rates because emissions mitigation is a public good, where individual emissions choices affect public well-being broadly. Rather than evaluating an optimal outcome from the narrow perspective of investors alone, economic theory would require that we make the optimal choices based on societal preferences (and social discount rates). Second, climate change is expected to affect primarily consumption, not traditional capital investments.[64] OMB guidelines note that in this circumstance, consumption discount rates are appropriate.[65] Third, 7% is considered much too high for reasons of discount rate uncertainty and intergenerational concerns (further discussed below).

The IWG correctly adopted as one of its discount rates a value reflecting long-term interest rate uncertainty, and—as a primary extension to current results—should go further by directly implementing a declining discount rate.

The IWG was correct in choosing as one of its discount rates an estimate based upon declining discount rates (2.5%). Since the IWG undertook its initial analysis, a consensus has emerged among leading climate economists that a declining discount rate should be used for climate damages to reflect long-term uncertainty in interest rates. Arrow *et al* (2013) presents several arguments that strongly support the use of declining discount rates for long-term benefit-cost analysis.[66]

Perhaps the best reason is the simple fact that there is considerable uncertainty around which interest rate to use: uncertainty in the rate points directly to the need to use a declining rate, as the impact of the uncertainty grows exponentially over time. The uncertainty about future discount rates could stem from a number of reasons particularly salient to climate damages, including uncertainties in future economic growth, consumption, and the interest rate reaped by investments.

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occur when growth is strong, times are good, and marginal utility is low, then the "beta" of climate risk is positive, the discount rate should be higher than the risk-free rate, and the price of carbon dioxide emissions should be lower." Robert B. Litterman, *What Is the Right Price for Carbon Emissions?,* REGULATION*,* Summer 2013, at 38, 41, *available at* http://www.cato.org/sites/cato.org/files/serials/files/regulation/2013/6/regulation-v36n2-1-1.pdf

[63] See following subsection.

[64] "There are two rationales for discounting future benefits—one based on consumption and the other on investment. The consumption rate of discount reflects the rate at which society is willing to trade consumption in the future for consumption today. Basically, we discount the consumption of future generations because we assume future generations will be wealthier than we are and that the utility people receive from consumption declines as their level of consumption increases . . . . The investment approach says that, as long as the rate of return to investment is positive, we need to invest less than a dollar today to obtain a dollar of benefits in the future. Under the investment approach, the discount rate is the rate of return on investment. If there were no distortions or inefficiencies in markets, the consumption rate of discount would equal the rate of return on investment. There are, however, many reasons why the two may differ. As a result, using a consumption rather than investment approach will often lead to very different discount rates." Maureen Cropper, *How Should Benefits and Costs Be Discounted in an Intergenerational Context?*, 183 RESOURCES 30, 33.

[65] *See* CIRCULAR A-4, *supra* note 49, at 33.

[66] The arguments here are primarily based on: Kenneth J. Arrow et al., *Determining Benefits and Costs for Future Generations*, 341 SCIENCE 349 (2013); Kenneth J. Arrow et al., *Should Governments Use a Declining Discount Rate in Project Analysis?*, REV ENVIRON ECON POLICY 8 (2014); Richard G. Newell & William A. Pizer, *Discounting the Distant Future: How Much Do Uncertain Rates Increase Valuations?,* 46 J. ENVTL. ECON. & MGMT. 52 (2003); Maureen L. Cropper et al., *Declining Discount Rates*, AMERICAN ECONOMIC REVIEW: PAPERS AND PROCEEDINGS (2014); S.K. Rose, D. Turner, G. Blanford, J. Bistline, F. de la Chesnaye, and T. Wilson. *Understanding the Social Cost of Carbon: A Technical Assessment.* EPRI Report #3002004657 (2014).

A possible declining interest rate schedule for consideration by the IWG is the one proposed by Weitzman (2001).[67] It is derived from a broad survey of top economists and the profession at large in a climate change context and explicitly incorporates arguments around interest rate uncertainty. Arrow *et al* (2013, 2014), Cropper *et al* (2014), and Gollier and Weitzman (2010), among others, similarly argue for a declining interest rate schedule and lay out the fundamental logic.[68]

Moreover, the United States would not be alone in using a declining discount rate. It is standard practice for the United Kingdom and French governments, among others.[69] The U.K. schedule explicitly subtracts out an estimated time preference.[70] France's schedule is roughly similar to the United Kingdom's. Importantly, all of these discount rate schedules yield lower present values than the constant 2.5% Newell-Pizer rate, suggesting that even the lowest discount rate evaluated by the IWG is too high.[71] The consensus of leading economists is that a declining discount rate schedule should be used, consistent with the approach of other countries like the United Kingdom. Adopting such a schedule would increase the SCC substantially from the administration's central estimate, suggesting that even the high end of the range presented by the administration is likely too low.

The IWG's choice of three IAMs was fully justified but should still be revisited in its next iteration.

In its calculations of the SCC, the IWG relied on the three Integrated Assessment Models (IAMs) available at the time, all with a long record of peer-reviewed publications that link physical and economic effects: the Dynamic Integrated Model of Climate and the Economy (DICE),[72] the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND),[73] and Policy Analysis of the Greenhouse Effect (PAGE).[74] The government's first SCC estimates, published in 2010, used the then-current versions of the models; the recent update employed revised, peer-reviewed versions of the models but maintained the underlying assumptions of the 2010 IWG analysis. As stated by the 2010 IWG, "the main objective of [the 2010 IWG modeling] process was to develop a range of

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[67] Martin L. Weitzman, *Gamma Discounting*, 91 AM. ECON. REV. 260, 270 (2001). Weitzman's schedule is as follows:

1-5 years	6-25 years	26-75 years	76-300 years	300+ years
4%	3%	2%	1%	0%

[68] Arrow et al. (2013, 2014), Cropper et al. (2014), *supra* note 66. Christian Gollier & Martin L. Weitzman, *How Should the Distant Future Be Discounted When Discount Rates Are Uncertain?* 107 ECONOMICS LETTERS 3 (2010).

[69] *Id.*

[70] Joseph Lowe, H.M. Treasury, U.K., Intergenerational Wealth Transfers and Social Discounting: Supplementary Green Book Guidance 5 (2008), *available at* http://www.hm-treasury.gov.uk/d/4(5).pdf. The U.K. declining discount rate schedule that subtracts out a time preference value is as follows:

0-30 years	31-75 years	76-125 years	126-200 years	201-300 years	301+ years
3.00%	2.57%	2.14%	1.71%	1.29%	0.86%

[71] Using the IWG's 2010 SCC model, Johnson and Hope find that the U.K. and Weitzman schedules yield SCCs of $55 and $175 per ton of CO_2, respectively, compared to $35 at a 2.5% discount rate. Laurie T. Johnson & Chris Hope, *The Social Cost of Carbon in U.S. Regulatory Impact Analyses: An Introduction and Critique*, 2 J. ENVTL. STUD. & SCI. 205, 214 (2012).

[72] William D. Nordhaus, *Estimates of the social cost of carbon: concepts and results from the DICE-2013R model and alternative approaches*, 1 JOURNAL OF THE ASSOCIATION OF ENVIRONMENTAL AND RESOURCE ECONOMISTS 1 (2014).

[73] David Anthoff & Richard S.J. Tol, THE CLIMATE FRAMEWORK FOR UNCERTAINTY, NEGOTIATION AND DISTRIBUTION (FUND), TECHNICAL DESCRIPTION, VERSION 3.6 (2012), *available at* http://www.fund-model.org/versions.

[74] Chris Hope, *The Marginal Impact of CO_2 from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern*, 6 INTEGRATED ASSESSMENT J. 19 (2006).

SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures."[75]

DICE, FUND, and PAGE are well-established, peer-reviewed models. They represent the state-of-the-art IAMs. Each of these models has been developed over decades of research, and has been subject to rigorous peer review, documented in the published literature. However, 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. One such model is Climate and Regional Economics of Development (CRED); another is the World Bank's ENVironmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) model.

CRED borrows its fundamental structure from William Nordhaus's DICE and RICE models but also offers significant changes. For one, it uses updated damage functions and Marginal Abatement Cost Curves (MACC). Moreover, it uses different global equity weights, and uses additional state-of-the-art methodologies.[76]

ENVISAGE represents a broader modeling effort by the World Bank, where perhaps the largest contribution is a more detailed sectoral breakdown, using 57 different sectors.[77] This level of analysis allows for a more detailed view of agriculture as well as food and energy sectors that are particularly important to any climate-economy modeling.

Moreover, the broader policy and research community at large ought to consider creating the right incentive structure within the economic and scientific community to engage many more researchers on working with the core IAMs. Doing so could speed up the process of capturing the latest research on climate damages.

No model fully captures the costs of climate impacts to society. In fact, virtually all uncertainties and current omissions point to a higher SCC value. That makes it essential to use the established IWG process, which provides for updating the SCC estimates every two to three years in order to capture the advances in physical and social sciences that have been incorporated into the models during the intervening period, in order to revisit both the choice of models and the key inputs used.[78]

The IWG should update its socio-economic assumptions to reflect the latest Shared Socio-economic Pathways (SSPs).

One key input is the use of socio-economic scenarios reflected in the choice of economic growth rates and emissions trajectories. Current IWG socio-economic and emissions scenarios were chosen from the Stanford Energy Modeling Forum exercise, EMF-22, and consist of projections for income/consumption, population, and emissions (CO_2 and non-CO_2). The IWG selected five sets of trajectories, four of which represent business as usual (BAU) trajectories (MiniCAM, MESSAGE, IMAGE, and MERGE models) and a fifth that represents a CO_2 emissions pathway with CO_2 concentrations stabilizing at 550 ppm. Given the possibility of increases in emissions above those

[75] 2010 TSD, *supra* note 4, at 1.

[76] Frank Ackerman, Elizabeth A. Stanton & Ramón Bueno, *CRED: A New Model of Climate and Development*, 85 ECOLOGICAL ECONOMICS 166 (2013).

[77] World Bank, ENVISAGE, http://go.worldbank.org/8DTXIDMRM0 (last visited Feb. 4, 2014).

[78] 2010 TSD, *supra* note 4, at 1-3 ("The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts . . . . Specifically, we have set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area.").

expressed by Business As Usual Scenarios, a high-CO_2 emissions pathway should also be considered. The assumptions used in calculating the SCC should be updated regularly to reflect the latest thinking around possible scenarios, reflecting the latest Shared Socio-economic Pathways (SSPs).[79] These SSPs represent the latest, consistent pathways, feeding, for example, into the latest IPCC report.

The current inclusion of CO_2 fertilization benefits likely overstates its effects.

The models do not reflect recent research on agricultural changes, which suggest the 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 (e.g., extreme heat, pests, and weeds).[80] If the agency is not able to adequately model all agricultural impacts it should, at a minimum, remove CO_2 fertilization benefits.

The specific functional form assumptions in IAMs ought to be re-evaluated.

Climate damages in IAMs are assumed to affect levels of economic output rather than economic growth rates. Similarly, standard modeling assumptions assume multiplicative damage functions—i.e. substitutability across economic sectors—rather than additive functions—i.e. limited substitutability across sectors. IAMs ought to probe the impacts of both assumptions. Recent literature supports the conclusion that climate change will effect economic growth rates.[81]

Similarly, models ought to better capture the impacts of wildly heterogeneous climate damages. Each of the models used to calculate the SCC assume one representative household, going as far as to consider damages by relatively large regions. Such averaging ignores the enormously diverse effects of damages. It similarly contributes to not fully capturing the effects of extreme outcomes and tail risks. Instead, models ought to attempt to capture a much broader array of damages and climate impacts.[82]

The IWG used solid economic tools to address uncertainty and ought to go further in capturing the full extent of its implications.

The IWG was rigorous in addressing **uncertainty**. First, it conducted Monte Carlo simulations over the IAMs specifying different possible outcomes for climate sensitivity (represented by a Roe and Baker Distribution).[83] It also used five different emissions growth scenarios and three discount

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[79] Kristie L. Ebi et al., *A New Scenario Framework for Climate Change Research: Background, Process, and Future Directions*, 122 CLIMATIC CHANGE 363, 368 (2014).

[80] FRANK ACKERMAN & ELIZABETH A. STANTON, CLIMATE ECONOMICS: THE STATE OF THE ART 45-56 (2013); Wolfram Schlenker et al., *Will U.S. Agriculture Really Benefit From Global Warming? Accounting for Irrigation in the Hedonic Approach*, 95 AM. ECON. REV. 395, 395-406 (2005). See also: Fisher, Anthony C., W. Michael Hanemann, Michael J. Roberts, and Wolfram Schlenker. 2012. "The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather: Comment." *American Economic Review*, 102(7): 3749-60. **DOI:** 10.1257/aer.102.7.3749

[81] *See* Melissa Dell et al., *Temperature shocks and economic growth: Evidence from the last half centur*y, 4 AMERICAN ECONOMIC JOURNAL: MACROECONOMICS 66-95 (2012); R. Bansal & M. Ochoa *Temperature, aggregate risk, and expected returns* (National Bureau of Economic Research No. w17575, 2011); E.J. Moyer et al., *Climate impacts on economic growth as drivers of uncertainty in the social cost of carbon* (University of Chicago Coase-Sandor Institute for Law & Economics Research Paper 652, 2013); S. Dietz & N. Stern, *Endogenous Growth, Convexity of Damage and Climate Risk: How Nordhaus' Framework Supports Deep Cuts in Carbon Emissions*, 125 THE ECONOMIC JOURNAL 574-620 (2015); F.C. Moore & D.B. Diaz *Temperature impacts on economic growth warrant stringent mitigation policy*, NATURE CLIMATE CHANGE (2015).

[82] See, for example, National Science Foundation-funded work by Per Krusell and Anthony A. Smith on "A Global Economy-Climate Model with High Regional Resolution" using 19,000 agents (each covering a 1 x 1° area of land).

[83] *See infra* note 95.

rates. Second, the IWG reported the various moments and percentiles[84] of the resulting SCC estimates. Third, the IWG put in place an updating process, e.g., the 2013 revision, which updates the models as new information becomes available.[85] As such, the IWG used the various tools that economists have developed over time to address the uncertainty inherent in estimating the economic cost of pollution: reporting various measures of uncertainty, using Monte Carlo simulations, and updating estimates as evolving research advances our knowledge of climate change.

The Monte Carlo framework took a step toward addressing what is the most concerning aspect of climate change, the potential for **catastrophic damages**, i.e., low probability/high damage events. These damages come from: uncertainty in the underlying parameters in IAMs,[86] including the climate sensitivity parameter; climate tipping points[87]—thresholds that, when crossed, cause rapid, often irreversible changes in ecosystem characteristics; and "black swan" events—which refer to unknown unknowns.[88]

The analysis used a right-skewed distribution of temperature (as captured in the Roe Baker climate sensitivity parameter) and an increasing, strictly convex damage function;[89] this correctly results in right-skewed distributions of damage and SCC estimates. By using the mean values of these estimates instead of the median, IWG estimates partially captured the effects of small probability, higher damages from high-level warming events.[90] To reflect uncertainty in estimates resulting from the right-skewed distribution of SCC estimates, the IWG reported the SCC value for the 95th percentile from the central 3% discount rate distribution.[91] This is done to reflect the estimation uncertainty in terms of the possibility of higher-than-expected economic impacts from climate change.

While the IAMs take different approaches to explicitly modeling tipping points, which to a great extent is lacking in current versions of FUND and DICE, the IWG improved (but in no way fixed) the representation of uncertain catastrophic damages with the Monte Carlo analysis. Still, black swan

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[84] *See supra* note 60.

[85] The federal government has committed to continuing to update SCC estimates to account for new information. The IWG stated in its 2010 TSD that "[i]t is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, we have set a preliminary goal of revisiting the SCC values within two years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, we will continue to explore the issues raised in this document and consider public comments as part of the ongoing interagency process." 2010 TSD, *supra* note 4, at 3.

[86] In this case, parameters are the various characteristic that describe the underlying climate and economic systems.

[87] *See generally* Timothy M. Lenton et al., *Tipping Elements in the Earth's Climate System*, 105 PNAS 1786 (2008).

[88] Standard decision theory under uncertainty addresses "known unknowns," which are unknowns for which we can specify a probability distribution function. In the cases of "unknown unknowns," i.e., 'black swan' events, we cannot specify a probability distribution function, raising a host of additional questions. *See*, *e.g.*, Richard J. Zeckhauser, *Investing in the Unknown and Unknowable*, CAPITALISM & SOCIETY vol. 1, iss. 2, art. 5 (2006).

[89] An increasing, strictly convex climate damage function implies a damage function that is strictly increasing in temperature at an increasing rate.

[90] The point here is that we miss the big picture if we ignore the "tails" (the upper-most values in the case of the right-skewed SCC), and as a result come to the wrong conclusions. An everyday analogy is airplane safety regulation: safety is protected by guarding against the low-probability but highly dangerous events. With climate change we do not have the luxury of knowing with certainty how damaging the extremes could be or whether they will be triggered by greenhouse gases accumulating in the atmosphere; all we know is that there is a very real possibility they could occur and could be devastating.

[91] This approach partially captures catastrophic damages via tipping points through the PAGE model.

events go completely unaddressed in the IWG modeling framework, and therefore the SCC estimates do not reflect the value of preventing the occurrence of catastrophic events.[92]

In addition to choosing an appropriate discount rate and sensitivity analyses around different SSPs, another important parameter to which the SCC estimates are sensitive is Equilibrium Climate Sensitivity (ECS)—how the climate system responds to a constant radiative forcing, which is typically expressed as the temperature response to a doubling of CO_2 concentration in the atmosphere.[93] In its current iteration, the IWG conducted extensive sensitivity analyses over a range of equilibrium climate sensitivity estimates.[94] The assumptions are clearly stated in the TSD. In addition to its sensitivity analysis, the IWG conducted a Monte Carlo simulation over the climate sensitivity parameter and the other random variables specified within the three IAMs.[95]

The range for the Equilibrium Climate Sensitivity (ECS) is derived from a combination of methods that constrain the values from measurements in addition to models. These include measured ranges from paleoclimate records, observed comparisons with current climate, as well as responses to recent climate forcings. The currently agreed "likely" range for the ECS (from both the IPCC TAR and AR5) is 1.5-4.5 degrees Celsius. Physical constraints make it "extremely unlikely" that the ECS is less than 1 degree Celsius and "very unlikely" greater than 6 degrees Celsius.[96]

A host of analyses points to the costs of such uncertainty—both for values that go outside the "likely" range and for uncertainty within it: in short, the optimal SCC tends to increase with increased uncertainty, sometimes dramatically so.[97] While the current treatment of uncertainty around climate sensitivity by the IWG highlights a range of possible uncertainties, a reconsideration of the assumptions feeding into the SCC ought to take the latest advances highlighting the potentially higher costs of deep-seated uncertainty into account. Additionally, the IWG should

[92] *See, e.g.*, Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon* (Cost of Carbon Project Report, 2014), and van den Bergh, J. C. J. M., and W. J. W. Botzen, *A lower bound to the social cost of CO_2 emissions*, 4 NATURE CLIMATE CHANGE 4 (2014).

[93] *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS—SUMMARY FOR POLICYMAKERS 14 (2013).

[94] Specifying the climate sensitivity parameter as a random variable has a basis in PAGE02, which species a probability distribution function for the parameter. The IWG calibrated the Roe and Baker distribution, a right-skewed distribution, to characterize the probability distribution function of this parameter. The 2010 TSD explains the IWG's choice of the Roe and Baker distribution. The right-skewed nature of the climate sensitivity parameter's probability distribution function is independent of the IWG's choice of the Roe and Baker distribution. Rather, this skewness results from the IPCC's finding that values of the climate sensitivity parameter above 4.5 degree Celsius cannot be excluded. As a result, all of the probability distribution functions fit by the IWG for the climate sensitivity parameter were skewed to the right (see Figure 2 in the 2010 TSD), including Roe and Baker. *See* 2010 TSD, *supra* note 4, at 14, fig. 2.

[95] A Monte Carlo simulation will run an integrated assessment model thousands of times, each time randomly picking the value of uncertain parameters from a probability distribution function, i.e. a function that assigns a probability to each possible parameter value. In the case of the SCC, the IWG ran 10,000 Monte Carlo simulations for each of the three IAMs and five socio-economic scenarios, randomizing the value of climate sensitivity, i.e., the change in average global temperature associated with a doubling of CO_2, and all other uncertain parameters in the IAMs by the original authors. For each randomly drawn set of values, the IAM estimated the associated damages, with the final SCC estimate equaling the average value across all 10,000 runs, five socio-economic scenarios, and then across all three models. Therefore, each SCC estimate is calculated using 150,000 runs.

[96] IPCC, *supra* note 93, at 14.

[97] *E.g.,* Robert S. Pindyck, *Uncertain Outcomes and Climate Change Policy*, 63 J. ENVTL. ECON. & MGMT. 289 (2012); Martin L. Weitzman, *GHG Targets as Insurance Against Catastrophic Climate Damages*, 14 J. PUB. ECON. THEORY 221 (2012); Robert S. Pindyck, *The Climate Policy Dilemma*, 7 REV. ENVTL. ECON. & POL'Y 219 (2013); Gernot Wagner & Richard J. Zeckhauser, *Confronting Deep Uncertainty on Climate Sensitivity: When Good News is Bad News*, ('Beyond IPCC' Presentation, October 17, 2014).

consider whether it relies too heavily on its 95th percentile estimates as a catchall to cover for limitations in its treatment of uncertainty and catastrophic damages.

5. Support for the Social Cost of Methane methodology, and recommendations on continued improvements.

DOE acknowledges that its proposed standards will reduce significant quantifies of non-carbon dioxide greenhouse gases, including methane. DOE does not, however, include a monetary estimate of these non-carbon dioxide reductions in its net benefits calculations. By contrast, EPA and other agencies have begun using a methodology developed to specifically measure the Social Cost of Methane—namely, the Marten et al. approach[98]—in recent proposed rulemakings.[99] In their latest technical support update, the Interagency Working Group adopts the Marten methodology and includes estimates of the Social Cost of Methane and Social Cost of Nitrous Oxide for agencies to apply in their regulatory impact analyses.[100] In its final energy conservation standards, DOE should use the Social Cost of Methane metric to more accurately reflect the true benefits of the standards and to enhance the rigor and defensibility of the final rules.

EPA first developed Social Cost of Methane estimates based on one of the most recent peer-reviewed articles: Marten *et al*.[101] The Interagency Working Group has now similarly endorsed the Marten et al. approach. Marten *et al.* takes a reasonable (although conservative) approach to estimating the Social Cost of Methane and currently constitutes "the best available science" to inform agency regulation.[102] Specifically, Marten *et al*. builds on the methodology used by the Interagency Working Group to develop the SCC. The study maintains the same three integrated assessment models, five socioeconomic-emissions scenarios, equilibrium climate sensitivity distribution, three constant discount rates, and aggregation approach that were agreed upon by the Interagency Working Group. Consequently, many of the key assumptions underlying the Social Cost of Methane estimates have already gone through a transparent, consensus-driven, publically reviewed, regularly updated process, since they were borrowed from the Interagency Working Group's thoroughly vetted methodology.

Yet while sharing that carefully built framework with the SCC estimates, Marten *et al*.'s Social Cost of Methane estimates directly account for the quicker time horizon of methane's effects compared to carbon dioxide, include the indirect effects of methane on radiative forcing, and reflect the complex, nonlinear linkages along the pathway from methane emissions to monetized damages. Marten *et al*. was not only published in a peer reviewed economics journal, but EPA undertook additional internal and peer review of the approach.[103] Marten *et al*.'s estimates thus are reasonable and appropriate measurements of the Social Cost of Methane.

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[98] Marten, A.L., E.A. Kopits, C.W. Griffiths, S.C. Newbold & A. Wolverton (2014). Incremental CH4 and N2O Mitigation Benefits Consistent with the U.S. Government's SC-CO2 Estimates, Climate Policy, DOI: 10.1080/14693062.2014.912981.

[99] *See* 80 Fed. Reg. 52,099, 52,145 (Aug. 27, 2015).

[100] Interagency Working Group on the Social Cost of Greenhouse Gases, Addendum: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide 3 (2016) ("This addendum summarizes the Marten et al. methodology and presents the SC-CH4 and SC-N2O estimates from that study as a way for agencies to incorporate the social benefits of reducing CH4 and N2O emissions into benefit-cost analyses of regulatory actions").

[101] Alex L. Marten et al., *Incremental CH4 and N2O Mitigation Benefits Consistent With the US Government's SC-CO2 Estimates,* Climate Policy (2014).

[102] *See* Executive Order 13,563, 76 Fed. Reg. 3821 (January 18, 2011).

[103] http://www3.epa.gov/climatechange/pdfs/social%20cost%20methane%20white%20paper%20application%20and%20peer%20review.pdf

In fact, Marten *et al.*'s estimates are conservative and very likely underestimate the true Social Cost of Methane. To start, as the authors note, because their methodology followed the Interagency Working Group's approach, all limitations that apply to inputs and modelling assumptions for the SCC also apply to the Social Cost of Methane. As discussed above, omitted damages, socio-economic assumptions, the treatment of uncertainty and catastrophic damages, and so forth all suggest the Social Cost of Methane is underestimated, just as the SCC is.

Additionally, the integrated assessment models shared by both the Social Cost of Methane and the SCC include some features better suited to assessing carbon dioxide effects than methane effects, and so likely underestimate the costs of methane. For example, a countervailing benefit of carbon dioxide emissions—enhanced fertilization in the agricultural sector—is included in the underlying models used to develop both the SCC and Social Cost of Methane, yet does not apply to methane emissions.[104] Similarly, the damage functions used by the integrated assessment models assume some level of adaptation to climate change over time, but because methane is a much faster-acting climate pollutant than carbon dioxide, there is less opportunity for technological advancement or political progress to adapt to the climate damages imposed by methane emissions. Methane also has indirect but significant effects, via its contribution to surface ozone levels, on global health and agriculture, and such effects need to be included either in the Social Cost of Methane or elsewhere in the cost-benefit analysis, but currently are not.[105]

Overall, the Marten *et al*. methodology provides reasonable, direct estimates that reflect updated evidence and provide consistency with the Government's accepted methodology for estimating the SCC. DOE should use the Interagency Working Group's estimates of the Social Cost of Methane in future rulemakings, including the final version of these energy standards.

6. Conclusion: Recommendations on the use of the SCC and Social Cost of Methane in regulatory impact analyses.

DOE should use the latest estimates of the SCC and the SCM. The current estimates are biased downwards: more can and should be done to improve the estimates and to ensure, through regular

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[104] Interagency Working Group on the Social Cost of Carbon, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis*, 12 (February 2010), available at https://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf ("Impacts other than temperature change also vary across gases in ways that are not captured by GWP. For instance . . . damages from methane emissions are not offset by the positive effect of CO2 fertilization.").
Martin et al (2015) state that "A comparison across models further highlights the importance of CO2 fertilization impacts on the global damage potential. CO2 emissions, and the resulting increase in atmospheric concentration, have the potential to increase yields in the agriculture and forestry sector. This characteristic is not shared by other GHG emissions. Accordingly, the FUND model, which explicitly captures this effect, exerts downward pressure on the SC-CO2 that is not present for the SC-CH4 and SC-N2O, allowing for the possibility of substantially higher global damage potential estimates. The results based on the FUND model presented in this article exhibit this effect; however, the CO2 fertilization effect is not explicitly modelled in DICE and PAGE and therefore they are found to produce lower estimates of the global damage potential. For example, using the 3% discount rate, the global damage potential for CH4 as estimated by FUND ranges between 58 and 88 depending on the scenario, whereas it ranges from 19 to 28 for DICE and PAGE. As the DICE and PAGE models only consider two natural system impacts, temperature and sea level, if they do implicitly include potential CO2 fertilization benefits, they are included by using the temperature anomaly as a proxy for the increasing atmospheric CO2 concentration. Fertilization benefits would therefore be allowed to falsely accrue to perturbations of other GHG emissions besides CO2. It is not clear the degree to which these models try to incorporate CO2 fertilization effects and therefore the degree to which this issue is of concern."

[105] A study by Sarofim et al. (2015) finds that reductions in surface ozone levels from the mitigation of methane emissions would provide additional global health benefits from avoided cardiopulmonary deaths equal to 60 to 140% of climate benefits identified by Marten. Similarly, Shindell (2014) finds that the impact of methane on agriculture, via changes in surface ozone, are valued at $22 and $27 per ton, for 5% and 3% discounting respectively, in addition to his study's estimates for climate and climate-health related damages.

updates, that they reflect the latest science and economics. However, the necessary process of improving the ability of the SCC and Social Cost of Methane to fully reflect the costs of climate impacts to society cannot hold up agency rulemaking efforts. The values provide an important, if conservative, estimate of the costs of climate change and the benefits of reducing carbon pollution. To ignore these costs would be detrimental to human health and well-being and contrary to law and Presidential directives to agencies to evaluate the cost of pollution to society when considering standards to abate that pollution. In the context of agency rulemakings, the SCC and Social Cost of Methane provide the best available means to factor those costs into benefit-cost analyses.

In using the estimates in its regulatory impact analyses, however, DOE should also include a qualitative assessment of all significant climate effects that are not currently quantified in the monetized estimate. The IWG acknowledged its incomplete treatment of both catastrophic and non-catastrophic damages, and instructed agencies that "These caveats . . . are necessary to consider when interpreting and applying the SCC estimates."[106] Those instructions are consistent with Executive Orders on regulatory analysis, which tell agencies to "assess . . . qualitative measures of costs and benefits that are difficult to quantify, but nevertheless essential to consider."[107] Before the IWG published its first estimates in 2010, some agencies included a detailed chart of unquantified climate effects in their regulatory impact analyses.[108] However, most recent rulemakings only reference unquantified benefits from non-CO_2 gases and from co-pollutants, and list none of the significant, unquantified climate effects from carbon dioxide. In the final regulatory impact analysis, DOE should detail all significant, unquantified climate effects, as consistent with administration-wide policy, the IWG's instructions, past agency practices, and best economic practices.

We also suggest that DOE encourage the IWG to regularly update the SCC and Social Cost of Methane, as new economic and scientific consensus emerges. Such updates are in line with the stated intentions of the IWG, which committed to "updating these estimates as the science and economic understanding of climate change . . . improves."

Sincerely,

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* No part of this document purports to present New York University School of Law's views, if any.

[106] 2010 TSD, *supra* note 4, at 29.

[107] Exec. Order No. 12,866 § 1(a); *see also* OMB, Circular A-4.

[108] *E.g.*, EPA, 420-D-09-001, DRAFT REGULATORY IMPACT ANALYSIS:CHANGES TO RENEWABLE FUEL STANDARD PROGRAM 690 tbl. 5.3-4 (2009).