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Via Electronic Submission and e-mail

Attn: Docket ID No. EERE-2008-BT-STD-0015-0073, 2013-09-11 Energy Conservation Program: Energy Conservation Standards for Walk-In Coolers and Freezers; Notice of proposed rulemaking (NOPR) and public meeting; and

Docket ID No. EERE-2010-BT-STD-0003, Energy Conservation Standards for Commercial Refrigeration Equipment.

Comments submitted by: Environmental Defense Fund, Institute for Policy Integrity, Natural Resources Defense Council, and the Union of Concerned Scientists

Our organizations respectfully submit these comments regarding the Department of Energy's proposed rule to establish revised energy efficiency standards for commercial refrigeration and walk-in coolers. In particular, we focus these comments on the use of the social cost of carbon (SCC) in the calculation of benefits from this rule, which were included in the regulatory impact analysis (RIA) of the rule. In the proposed rule, the Department used the SCC calculated by the Interagency Working Group (IWG), of which the Department was a part. We strongly support the Department's use of the IWG's SCC. We urge the Department to thoroughly consider and respond to our comments on the SCC and any other comments that it receives. Our comments are summarized in six sections:

1. Introduction - the social cost of carbon is important in estimating benefits of greenhouse gas emission reductions that would accrue from this standard

2. The IWG's analytic process was transparent, and every use of the SCC in a rulemaking provides opportunity for public comment

3. The IWG modeling framework is based on sound, peer-reviewed scientific and economic theory

4. Contrary to industry claims, the SCC should not be zero as a matter of well-established law and fundamental economics

5. Current SCC values are likely significant underestimates of the true values, and steps should be taken to address this in future updates

6. Concluding remarks

1. Introduction - the social cost of carbon is important in estimating benefits of greenhouse gas emission reductions that would accrue from this standard

The SCC estimates the economic cost of the 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 – such as burning fossil fuels to produce energy – that produce greenhouse gas emissions and contribute to climate change. The SCC is also important for evaluating the benefits of policies that would reduce the amount of those emissions going into the atmosphere. Energy conservation standards, like the walk-in cooler and commercial refrigeration standards, help reduce the amount of electricity used by these appliances and thus reduce the greenhouse gas emissions emitted by the power plants supplying that electricity. In order to properly evaluate energy efficiency standards, it is important to understand the benefits they will provide, including the benefit of reducing carbon pollution and the harm it causes.

Although the exercise inevitably involves uncertainty, 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 Reagan. The executive order currently in effect provides that agencies:

- "Propose 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);"

- "Select, 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 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 inform decision-makers about the societal benefits of different policy choices that limit pollution. Of course, benefit-cost analysis cannot be the sole criteria for making regulatory decisions, especially in cases where there are overriding public health or safety imperatives.[2] And in a few instances not relevant here, legal protections prohibit the consideration of benefit-cost analysis.

Without an SCC estimate, regulators would be by default using a value of zero for the benefits of reducing carbon pollution, implying that carbon pollution has no costs. That is patently 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. And it would be arbitrary for a federal agency to consider societal benefits and 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 transparent, and every use of the SCC provides opportunity for public comment

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 the IWG in 2010 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 2010 estimate of carbon pollution reduction benefits was used in the benefit-cost analysis in this proposed energy efficiency rulemaking and other federal rules. The IWG recently released an updated set of SCC estimates, centered at approximately $37 per metric ton of CO_2 for emissions in the year 2015, in 2007 dollars at a 3 percent discount rate.[5] The 2013 SCC estimates are higher than those from 2010, reflecting our growing

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[1] Exec. Order No. 13,563, 76 Fed. Reg. 3,821 (Jan. 18, 2011).

[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, 58 Fed. Reg. 51,735 (Sept. 30, 1993).

[3] Center for Biological Diversity v. National Highway Traffic Safety Admin., 538 F.3d 1172 (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 Energy, Department of Transportation, Environmental Protection Agency, National Economic Council, Office of Management and Budget, Office of Science and Technology Policy, and the Department of the Treasury.

[5] 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), *available at*

understanding of the costs that climate impacts will impose on society. (The 2010 central estimate for 2015 was $24/ton.)

The increase in the SCC estimate is consistent with scientific and economic research on the growing risks and costs of climate change, but is still very likely an underestimate of the true cost of our carbon emissions. The increase is also consistent with 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.[6]

In its calculations of the SCC, the IWG relied on the three Integrated Assessment Models (IAMs) with the longest records of peer-reviewed publications that link physical and economic effects: the Dynamic Integrated Model of Climate and the Economy (DICE),[7] the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND),[8] and Policy Analysis of the Greenhouse Effect (PAGE).[9] 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 SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures."[10]

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.[11] Because the 2013 IWG made no changes to the input

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http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf

[6] NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, EXPLAINING EXTREME EVENTS OF 2012 FROM A CLIMATE PERSPECTIVE (2013), *available at* http://www.ametsoc.org/2012extremeeventsclimate.pdf.

[7] WILLIAM D. NORDHAUS & JOSEPH BOYER, WARMING THE WORLD (2000).

[8] 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.

[9] 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).

[10] 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 (2010), *available at* http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf.

[11] There were several opportunities for the public to comment on the original interagency process. 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

assumptions and procedures for deriving its SCC estimates, the 2013 TSD discusses only how the three IAMs, i.e., DICE, FUND, and PAGE, were updated over the three year interim period. The 2013 TSD also establishes that the increase in the SCC estimate from 2010 to 2013 resulted solely from updates to the three underlying IAMs.[12]

DICE, FUND, and PAGE are peer-reviewed models, and they are 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. It is true that these models do not fully capture the costs of climate impacts to society, but importantly the IWG process 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.[13] More importantly, virtually all uncertainties and current omissions point to a higher true SCC value.

To transparently address uncertainty, the IWG conducted sensitivity analysis within their modeling framework over socio-economic and emission scenarios[14] and the two

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(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.

[12] 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 has an exogenous growth path that matches FUND and PAGE for the purposes of modeling various socio-economic and emission scenarios. 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 (2010), *available at* http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf.

[13] The IWG stated in its 2010 TSD that "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." 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), *available at* http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf).

[14] The 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

parameters over which the SCC estimates are most sensitive: the climate sensitivity parameter[15] and the discount rate.[16] The assumptions for both are clearly stated in the TSD. In addition to their sensitivity analysis, the IWG conducted a Monte Carlo simulation over the climate sensitivity parameter and the other random variables specified within the three IAMs.[17]

3. The IWG modeling framework is based on sound, peer-reviewed scientific and economic theory

Industry groups have argued that the IWG analysis is flawed in its use of discount rates, consideration of scientific uncertainty, and in counting both domestic and global damages caused by our emissions. None of these criticisms have merit. Indeed, the IWG process uses assumptions that accord with economic and scientific theory.

Economic models, and the scientific models they are drawing from, are of course improving continuously. So future updates to the SCC can 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.

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pathway with CO_2 concentrations stabilizing at 550 ppm. Given the possibility of increases in emissions above those expressed by Business As Usual Scenarios, a high- CO_2 emission pathway should also been considered.

[15] 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 (PDF) 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. 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), *available at* http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf.

[16] With respect to the discount rate, the IWG conducts sensitivity analysis of the results to three discount rates: 2.5%, 3%, and 5%.

[17] 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.

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 of the SCC estimates.[18,19]

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 heavily penalizes future generations due to compounding effects, especially at high discount rates. For example, at a rate of 3%, $1 million 300 years hence is equivalent to only around $140 today, and at 5% it equals less than 50 cents. Some might even consider a 1% discount rate too high: $1 million 300 years hence would be valued at $50,000 today.[20]

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," (see footnote 32) 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 discount rates). Second, climate change is expected to affect primarily consumption, not traditional capital investments.[21] OMB guidelines note that in this

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[18] The moments of a distribution (of SCC estimates in this case) are, loosely speaking, the various values that tell you the shape of the distribution: 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).

[19] A percentile is a statistical measure of the value (the SCC value in this case) at which a specified percentage of (SCC) observation falls below. 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 other observed SCC values fall.

[20] Dallas Burtraw & Thomas Sterner, *Climate Change Abatement: Not Stern Enough?*, RESOURCES FOR THE FUTURE, (Apr. 4, 2009), *available at* http://www.rff.org/Publications/WPC/Pages/09_04_06_Climate_Change_Abatement.aspx; Robert Litterman, *What Is the Right Price for Carbon Emissions,* REGULATION, Summer 2013, at 38, *available at* http://www.cato.org/sites/cato.org/files/serials/files/regulation/2013/6/regulation-v36n2-1-1.pdf.

[21] "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."

circumstance, consumption discount rates are appropriate. Third, 7% is considered much too high for reasons of discount rate uncertainty and intergenerational concerns (more discussion below).

The IWG correctly adopted as one of its discount rates a value reflecting long term interest rate uncertainty

The IWG chose as one of its constant discount rates 2.5%. This rate served as a proxy for a declining discount rate, taken from an estimate by Newell and Pizer (2003).[22] A consensus has emerged among leading climate economists that declining discount rates should be used for climate damages to reflect long term uncertainty in interest rates (Arrow et al, 2013),[23] as recognized in OMB guidelines. The use of declining discount rates is standard practice for the UK and French governments.[24] 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. Using a constant discount rate, which makes more sense when applied to individuals (firms and households) within current generations, can lead to substantially undervaluing future generations, given increasing uncertainties related to the future discount rate itself. Therefore an actual declining discount rate schedule would be preferable. The Newell-Pizer results suggest that the expected benefits from climate change mitigation could be understated by a factor of 2 in analyses that ignore uncertainty in the discount rate.

The IWG used solid economic tools to address uncertainty

The IWG was rigorous in addressing **uncertainty**. First, it conducted Monte Carlo simulations (see footnote 17) over the IAMs specifying different possible outcomes for climate sensitivity (represented by a Roe and Baker Distribution). It also used five different emissions growth scenarios and three discount rates. Second, the IWG reported the various moments (see footnote 18) and percentiles (see footnote 19) of the resulting SCC estimates. Third, the IWG put in place an updating process, e.g., the 2013 revision, which updates the models with new information.[25] As such, the IWG used the various tools that economists

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Maureen Cropper, *How Should Benefits and Costs Be Discounted in an Intergenerational Context?*, RESOURCES FOR THE FUTURE, *available at* http://www.rff.org/Publications/Resources/Pages/183-Benefits-and-Costs-in-Intergenerational-Context.aspx.

[22] Richard G. Newell & William A. Pizer, *Discounting the Distant Future: How Much Do Uncertain Rates Increase Valuations?,* 46 J. ENVTL. ECON. & MGMT. 52 (2003).

[23] K. Arrow, M. Cropper, C. Gollier, B. Groom, G. Heal, R. Newell, W. Nordhaus, R. Pindyck, W. Pizer, P. Portney, T. Sterner, R.S.J. Tol & M.L. Weitzman, *Determining Benefits and Costs for Future Generations*, 341 SCIENCE 349 (2013).

[24] Richard G. Newell & William A. Pizer, *Discounting the Distant Future: How Much Do Uncertain Rates Increase Valuations?*, 46 J. ENVTL. ECON. & MGMT. 52 (2003).

[25] 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

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 new research becomes available.

The Monte Carlo framework took a step toward addressing what is probably 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,[26] including the climate sensitivity parameter; tipping points - an environmental threshold over which small changes in the environmental state can causes rapid, frequently irreversible changes in ecosystem characteristics; and "black swan" events – which refer to unknown unknowns.[27]

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;[28] 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.[29] To reflect uncertainty in estimates resulting from the right skewed distribution of SCC estimates, the IWG reported the SCC value for the 95th percentile (see footnote 19) from the central 3% discount rate distribution.[30] This is done to reflect the estimation uncertainty in terms of the possibility of higher-than-expected economic impacts from climate change.

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and consider public comments as part of the ongoing interagency process." 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), *available at* http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf).

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

[27] 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. Therefore, standard decision theory does not apply.

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

[29] The point here is that we miss the big picture if we ignore the tails, or upper most values in the case of the right skewed SCC, and as a result come to the wrong conclusions. An every-day analogy might be if an individual who is trying to watch his or her weight by going on a diet focused on their median calorie intake per meal in a given month instead of the mean; the median calorie meal would be the meal such that half of all meals had calories below its value, and half above, and the mean calorie meal would be the total number of calories in a month divided by the number of meals eaten. Dieters often deviate from their plan by occasionally having normal or excessive-calorie meals. If they focused on their median calorie intake, they'd never count the high calorie deviations and would undermine their efforts to lose weight. Indeed, they could even gain weight. Rather than the median, the mean would be the correct metric to use because it would capture these infrequent, high calorie breaks with the diet. Unlike in the median, going out to a meal of burgers, fries, a shake, and dessert would affect the average number of calories consumed when using the mean. Another 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 how damaging the extremes could be; all we know is that there is a very real possibility they could be devastating.

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

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 events go completely unaddressed in the IWG modeling framework.

Calculated the global SCC

The IWG correctly used a global SCC in order to account for damages from carbon pollution. Carbon pollution does not stay within any one nation's borders but mixes in the atmosphere and contributes to harm all across the world. This means that each ton of carbon pollution emitted in the United States will contribute to harm both in the United States and abroad. Conversely, each ton of carbon pollution emitted abroad will contribute to harm in its country of origin and in the United States. When evaluating the harm caused by a pollutant with global impacts and global sources, a global SCC is the appropriate value to use in federal rulemaking.

This is the case for several reasons. First, basic moral principles prescribe a global SCC. Greenhouse gas emissions cause significant harm to other countries and preventing this cross-border harm is a basic principle of international environmental law.[31] For the United States to knowingly set pollution levels in light of only domestic harm, with the knowledge that its pollution is directly imposing environmental risk—including catastrophic risks—on other countries, would be a violation of basic norms of comity and corrective justice between countries . The United States would be knowingly causing foreseeable harm to other countries, without compensation, and without any 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 beliefs about fairness and distributive justice.

Second, severe and potentially catastrophic harms from global warming can be avoided only if all major emitting countries account for the full harm caused by the carbon pollution they emit. Because carbon pollution emitted in any country causes harm globally, a domestic-only SCC ignores most of the harm caused by each ton of carbon pollution. If each nation were to consider only domestic harms when calculating the SCC and make pollution reductions appropriate to that domestic-only SCC, there would be substantially sub-optimal protection of climate stability. Each country would take steps significantly below those required to avoid highly damaging impacts from climate change and the collective effect would be significantly worse harm in all nations, including the United States. Economists refer to this as a "public goods" problem, a situation where everyone acting only in their narrow self-interest leaves everyone worse off.[32]

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[31] *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 [this principle] reflects a rule of customary international law").

[32] A public good is one that is "non-rivalrous" and "non-excludable." Non-rival refers to the idea that one person's consumption of the good does not take away from another person's consumption of it (we are not "competing" for who gets it, as we all get it in equal measure). Non-excludable refers to the fact that we can't

Conversely, if major emitting nations consider the harms from the carbon pollution they emitted, then the harms to the United States – and every other nation – will be accounted for and appropriate protections can be taken.[33] In other words, it is only through the reciprocal consideration of global harms that we can ensure that the full measure of harm to the United States can be avoided.

Third, the United States should use a global SCC because this is consistent with the practices of other nations that calculate a SCC. England, Canada and France all include global harms in their calculation of the SCC.[34] Such regulatory cooperation is called for by Executive Order 13,609 on "Promoting International Regulatory Cooperation."[35] Moreover, the consistent use of a global SCC will help ensure that other nations also use a global SCC when they calculate SCC values for use in their regulatory decision-making.

Fourth, use of a global SCC is critical for the United States' credibility as it seeks to persuade other nations to control greenhouse gas emissions. Use of a domestic SCC would signal that the United States refuses to recognize that carbon pollution generated in the United States causes harm well beyond its borders (and similarly, emissions from other countries can imperil the United States). In this instance, U.S. leadership itself might determine whether society will overcome the public goods problem. And without an international agreement and action to reduce carbon emissions, severe harms in the United States from climate change will be unavoidable.

Finally, even if use of a domestic-only SCC were not inappropriate for the reasons described, harms that occur in other countries will have significant negative spillover effects on the United States. These spillover effects, such as global financial crises or international conflict, are not accounted for in any of the IAMs. The magnitude of these spillovers is uncertain, but they could be large. The mesh of the global economy is woven tightly enough to guarantee that disruptions in one place can have consequences around the world. Financial crises transmit around the world at a breakneck pace.[36] Similarly,

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stop other people from enjoying it. A normal market good is exactly the opposite: only one person can consume the item (at the expense of another not consuming it), and the seller is able to prevent anyone other than the purchaser from consuming the product. The non-rivalrous and non-excludability aspects of a public good result in an economically inefficient under-provision of it; in this situation, compensating the supplier of the good is extremely difficult, if not impossible—so the good will either be under-provided or not provided at all. Climate mitigation confronts exactly this problem. The enjoyment of climate stability by one person does not interfere with the enjoyment of climate stability by another person. And once climate stability is provided, there is no way to "exclude" anyone from enjoying its benefits. Under these conditions, we can expect, and in fact have seen, under-provision of this good. From an economic perspective, there is too little investment in climate stability.

[33] At the moment, 10% of the world's population, a third of global economic output, is covered by some carbon cap or price (http://www.edf.org/climate/worlds-carbon-markets).

[34] https://www.gov.uk/government/collections/carbon-valuation--2#group_2669; http://www.canadianenergylaw.com/2013/06/articles/climate-change/us-government-increases-the-social-cost-of-carbon-emissions/; Balazs Égert, France's Environmental Policies: Internalising Global and Local Externalities, OECD Economics Department Working Papers, No. 859 (2011), *available at* http://dx.doi.org/10.1787/5kgdpn0n9d8v-en (discussing global impacts).

[35] Exec. Order No. 13,609, 77 Fed. Reg, 26,413 (2012).

[36] 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).

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.[37] Given its unique place in the world—both as the largest global economy with trade- and investment-dependent links throughout the world, and as the only military superpower—the United States is especially vulnerable to spillover effects. Use of a domestic SCC that failed to account for such spillover effects and their disproportionate effects on the United States would be significantly misleading.

The 2010 TSD has an extensive discussion of global versus domestic SCC estimates, and the 2010 IWG set out a rigorous examination of their use of the global SCC that is consistent with the above discussion. The 2010 IWG came to the conclusion that it should estimate a global SCC due to 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. The Department of Energy should affirm that use of a global SCC estimate is the appropriate approach.

4. Contrary to industry claims, the SCC should not be zero as a matter of well-established law and fundamental economics

Several industry groups recently submitted a petition to the Office of Management and Budget (OMB) and the individual agencies involved in the IWG to prohibit the use of the 2010 and 2013 social cost of carbon (SCC) estimates by it and other executive branch agencies and withdraw the supporting documents that describe their calculation.[38] Several U.S. senators also sent a letter to the Department of Energy (DOE), the Environmental Protection Agency (EPA), and the OMB citing some of the same arguments made by the petitioners.

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[37] *See, e.g.*, John M. Broder, *Climate Change Seen as Threat to U.S. Security*, N.Y. TIMES, Aug. 8, 2009; *Climate Change and Global Security: Challenges, Threats, and Global Opportunities: Hearing Before the S. Comm. on Foreign Relations*, 111th Cong. (2009) (statement of Vice Admiral Dennis McGinn), *available at* http://foreign.senate.gov/testimony/2009/McGinnTestimony090721p.pdf; U.S. GOV'T ACCOUNTABILITY OFFICE, KEY CHALLENGES REMAIN FOR DEVELOPING AND DEPLOYING ADVANCED ENERGY TECHNOLOGIES TO MEET FUTURE NEEDS (2006),
available at http://www.gao.gov/new.items/d07106.pdf; GEN. CHARLES F. "CHUCK" WALD ET AL., CNA MILITARY ADVISORY BOARD, POWERING AMERICA'S DEFENSE: ENERGY AND THE RISKS TO NATIONAL SECURITY, at i, vii, x (2009), *available*
at http://www.cna.org/documents/PoweringAmericasDefense.pdf; PETER SCHWARTZ & DOUG RANDALL, AN ABRUPT CLIMATE CHANGE SCENARIO AND ITS IMPLICATIONS FOR UNITED STATES NATIONAL SECURITY (2003).

[38] This group consists of the America's Natural Gas Alliance, the American Chemistry Council, the American Petroleum Institute, the National Association of Home Builders, the National Association of Manufacturers, the Portland Cement Association, and the U.S. Chamber of Commerce.

Broadly speaking, the petitioners' claims fall into three general categories:

- That estimates of the SCC are purportedly too uncertain and imprecise to be used for regulatory analysis. The petitioners contend that alleged uncertainty and imprecision renders the SCC an illegitimate tool for use in regulatory impact analyses. They discuss a number of technical estimation issues with the SCC models used by the IWG, and mistakenly conclude that these limitations preclude the IWG's use of them. Petitioners misrepresent both the view of the Intergovernmental Panel on Climate Change (IPCC) and economists' own assessments of SCC limitations.

- That the IWG supposedly did not follow appropriate protocols in either its estimation or use of the SCC. The petitioners accuse the IWG of hiding the uncertainties in its analysis; of failing to follow requirements with respect to discount rates and the choice of a global rather than domestic SCC; of failing to have its analysis peer reviewed; and of denying stakeholders proper notice or opportunity to comment on the IWG's analysis.

- In light of these two claims, these industry critics argue that the SCC must be banned from use while it undergoes a wholly new public review process. They assert that the IWG's SCC estimates are "arbitrary and capricious," and likely overestimated. While the SCC would be under re-review, the petitioners request that OMB require agencies to assign a value of zero to carbon pollution damages.

The attached appendix, "Response to Industry Petition to OMB," explains the various claims the petitioners used to support these arguments and why they are wrong.

Before going into these details, two general points need to be made with respect to the petitioners' claim that uncertainties involved in estimating the SCC prohibit its use in regulatory analysis, and their assertion that the IWG's SCC estimates were not properly peer reviewed or open for public comment.

First, ***as a matter of law and economics, uncertainty in benefits estimates does not mean they should be excluded from regulatory impact analyses***. In fact, the courts have explicitly rejected this argument with respect to the SCC, 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 2007, 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's (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."***[39] The court's decision directly contradicts the petitioners' argument

[39] Center for Biological Diversity v. National Highway Traffic Safety Adm., 538 F.3d 1172 (9th Cir. 2008) (emphases added).

that uncertainty renders the SCC invalid, as well as their demand that agencies use a value of zero.

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.[40] 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 (emphasis added)." [41]

Second***, while agencies are expected to use the best available science to inform their regulatory impact analyses, there is no legal requirement, for demanding that an agency's analysis itself undergo academic peer review.*** What *is* required is that agencies undertaking rulemakings provide public notice and an opportunity for public comment on their analyses, and respond to those comments.

The petitioners have had multiple opportunities to comment on the IWG's analysis and will have additional opportunities to do so in future rulemakings. The IWG's estimates have been referenced in more than 40 rulemakings to date, and agencies have responded to relevant comments submitted thus far. Indeed, many of the changes the IWG made in its updated methodology were made in *response* to such comments.

It is up to each agency to decide whether to rely on the IWG estimates of the SCC in its decisions, to modify those values, or to choose a different means of estimating the cost of carbon pollution, either in the first instance or after receiving comment on the IWG estimate. Affected parties have the opportunity for judicial review at the end of each rulemaking. To our knowledge, no party has raised issues pertaining to the IWG estimates of the SCC in judicial review of any rules.

Finally, it is important to note that in all of those rulemakings, benefits greatly exceeded costs even without any consideration of the SCC. Thus, it is almost certain that the standards set in such rules would have been the same even if the SCC had not been considered. Accordingly, to date the SCC has not been responsible for any additional legal obligation, restriction, or burden on the petitioners.

Whatever role the SCC plays in future rulemakings, the petitioners will have ample opportunity to present their arguments and competing data. Dissatisfied parties will have the right to file lawsuits challenging final rules, and to try to persuade a court that the agency's use of the SCC was arbitrary, capricious, or otherwise unlawful.

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 best peer reviewed science. When agencies utilize the IWG's estimates of the SCC to

[40] Stuart Shapiro, *The Evolution of Cost–Benefit Analysis in U.S. Regulatory Decisionmaking*, *in* HANDBOOK ON THE POLITICS OF REGULATION (David Levi-Faur ed., 2011).
[41] Exec. Order No. 13,563, 76 Fed. Reg. 3,821 (Jan. 18, 2011).

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 petitioners offer no alternative (or better) estimation procedure. They simply ask OMB to contravene the Ninth Circuit's decision by substituting zero for the IWG's best estimate of the costs of carbon pollution.

5. Current SCC values are likely significant underestimates, and steps should be taken to address this in future updates[42]

The three IAMs used in IWG model framework are incomplete and make various simplifying assumptions. Most of the resulting biases tend towards an SCC estimate that underestimates the damages of climate change.[43]

The IAMs do not currently capture and evaluate many major impacts of climate change; the components of the IAMs that need to be improved strongly point toward an *under*estimate of the harmful effects of climate change.[44] The models inadequately account for catastrophic risks and risk aversion, omit important categories of harm, use outdated damage estimates, underestimate climate damages at high temperatures, make simplifications that likely lead to understated damages, and include conservative assumptions about discount rates. Each of these factors biases the model downward; collectively they may result in a substantial underestimate.

Failure to sufficiently account for catastrophic damages

Climate science tells us that low-probability high-impact events, often referred to as climate "tipping points," are a major threat posed by climate change. Tipping points are an environmental threshold over which small changes in the environmental state can cause rapid, frequently irreversible changes in ecosystem characteristics. Their small but real probabilities of occurring imply "fat tail" distributions, and the potential for "black swan" events. A "fat-tailed" distribution refers to a distribution with a long extended "tail" at the upper end, as opposed to a normal bell curve.[45] Black swan events are unknown unknowns, and refer to tipping points that we are currently unaware of and parameters for which we do not know their probability distribution function.

Examples of tipping points include melting of either (or both) the Greenland or Antarctic ice sheets, the release of vast stores of methane trapped under the melting permafrost, and radical changes in the jet stream or ocean currents that could affect major weather patterns like the monsoons. The probability level and severity of potential extreme climate change events are poorly understood. These risks, which would impose almost unimaginable

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[42] The following section relies heavily on K. Arrow, L. Goulder, R. E. Kopp, M. Livermore, M. Oppenheimer, R. Revesz, T. Sterner, *Counting the Costs of Climate Change* (manuscript).

[43] Robert E. Kopp & Bryan K. Mignone, *The US Government's Social Cost of Carbon Estimates after Their First Two years: Pathways for Improvement, in* ECONOMICS: THE OPEN-ACCESS, OPEN-ASSESSMENT E-JOURNAL, May 4, 2012, at 1.

[44] Robert E. Kopp, & Bryan K. Mignone. *The US Government's Social Cost of Carbon Estimates after Their First Two Years: Pathways for Improvement*, *in* ECONOMICS: THE OPEN-ACCESS, OPEN-ASSESSMENT E-JOURNAL, May 4, 2012, at 1.

[45] Very high damages with a low, but real chance, of occurring are represented in these tails.

hardship on human societies should they occur, provide one of the most convincing and forceful reasons to aggressively reduce greenhouse gas emissions.[46]

Currently, the IAMs do not sufficiently account for extreme and catastrophic damages.

The possible levels of climate damages are often modeled as a distribution describing the probabilities of various economic outcomes. The IWG estimated the SCC by analyzing probability distributions generated by three IAMs, using those distributions to calculate the expected climate damages society would experience at various concentrations of greenhouse gases. IAMs, however, generally undervalue the possible damages associated with catastrophic climate change by reducing the complexity of the problem[47]—though scientific research predicts a non-negligible chance of a planet-wide, truly disastrous climate catastrophe, IAMs do not give much weight to such low-probability scenarios that exist on the far end of the probability distribution curves.[48]

Each of the IAMs addresses tipping points differently. The FUND model ignores them altogether. The DICE model has shifted from modeling willingness to pay to avoid a catastrophe to a meta-analysis of other estimates, most of which do not include catastrophic damages via tipping points.[49] Unlike the other two models, the newest version of PAGE[50] explicitly models catastrophic damages via tipping points, but assumes only a single, general event (i.e. not a specific damage, like melted ice sheets) that has a probability of occurring in each time period.

Black swan events are all together ignored by the IAMs and IWG. At the current moment, there is no specific strategy on how to address them. The best the IWG can do is to be transparent about their existence.

In short, the true probability distribution of climate damages has a longer and fatter right-hand tail than is represented in IAMs.[51] Weitzman argues that considering such "fat tails" increases the expected damages significantly, which could exert enormous influence on society's willingness to pay for emissions abatement.[52] That is, because extreme climate outcomes would impose such enormous economic losses, even relatively unlikely scenarios can shift the expected damages from climate change dramatically to the right. Should the possibility of these outcomes be great enough, the effect of such catastrophic damages

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[46] Timothy M. Lenton & Juan-Carlos Ciscar. *Integrating Tipping Points Into Climate Impact Assessments*. 117 CLIMATIC CHANGE 585 (2013).

[47] *See* NAT'L RES. COUNCIL, NAT'L ACAD. OF SCI., HIDDEN COSTS OF ENERGY: UNPRICED CONSEQUENCES OF ENERGY PRODUCTION AND USE 256-57 (2009).

[48] See Martin Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 REV. ECON. & STAT. 1 (2009).

[49] Compare DICE-1999 and DICE-2007 with DICE-2010 and DICE-2013 (meta-analysis based on estimates in Table 1 of Tol (2009)). *See* Richard S.J. Tol, *The Economic Effects of Climate Change*, J. ECON. PERSP., Spring 2009, at 29.

[50] PAGE09.

[51] See NAT'L RES. COUNCIL, NAT'L ACAD. OF SCI., HIDDEN COSTS OF ENERGY: UNPRICED CONSEQUENCES OF ENERGY PRODUCTION AND USE 293 (2009); Martin Weitzman, *Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change*, 5 REV. ENVTL. ECON. & POL'Y 275 (2011).

[52] *See* Martin Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 REV. ECON. & STAT. 1 (2009).

could dominate the analysis. Tol notes similar difficulties with IAMs,[53] and the National Academy of Sciences found that IAMs insufficiently measure the totality of these effects.[54] (The fact that both Weitzman and Tol find similar problems with IAMs is notable given their history of disagreement over optimal mitigation policies[55]).

Failure to include a risk premium and account for risk aversion

The IAMs fail to include risk premiums for high and catastrophic damages. This is the amount of money society would require (if it were given the option) to accept the uncertainty over the magnitude of damages from climate change. While this risk premium is not accounted for by current IAMs, it will be positive due to current assumed shape of the social welfare function in these models.[56] Like its response to option value (see below), the EPA (2010) agreed that a risk premium should be included, but concluded then that "further research in this area is needed to develop a reasonable approach to account for catastrophic risks in regulatory analyses."

The IWG decided in early 2010 to continue "investigating" the issue of risk aversion in lieu of including a risk premium in the SCC. The IWG did note that Anthoff, Tol, and Yohe found that risk aversion is at least as important as the discount rate (see earlier discussion) - a topic that the IWG discussed in great detail.[57] However, without citing studies with different results, it still concluded that further investigation was necessary before including a risk premium in the SCC.[58,59]

The IWG discussion failed to mention the work of Heal and Kristrom,[60] Heal,[61] Hennlock,[62] Tol,[63] Yohe and Tol,[64] or additional work by Weitzman,[65] among many others that suggest

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[53] *See* Richard S. J. Tol, *Is the Uncertainty About Climate Change Too Large for Expected Cost-Benefit Analysis?*, 56 CLIMATE CHANGE 265 (2003).
[54] *See* NAT'L RES. COUNCIL, NAT'L ACAD. OF SCI., HIDDEN COSTS OF ENERGY: UNPRICED CONSEQUENCES OF ENERGY PRODUCTION AND USE 256-57 (2009).
[55] Martin Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 REV. ECON. & STAT. 1, 1 (2009); Richard S. J. Tol, *Is the Uncertainty About Climate Change Too Large for Expected Cost-Benefit Analysis?*, 56 CLIMATE CHANGE 265 (2003).
[56] IAMs currently assume a utility function that is increasing at a decreasing rate in per capita consumption.
[57] INTERAGENCY WORKING GROUP ON THE SOCIAL COST OF CARBON, UNITED STATES GOVERNMENT, TECHNICAL SUPPORT DOCUMENT: TECHNICAL UPDATE OF THE SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12,8666, at 31 (2010) (citing David Anthoff, Richard S. J. Tol, & Gary W. Yohe, *Risk Aversion, Time Preference, and the Social Cost of Carbon*, 4 ENVTL. RESEARCH LETTERS 1, 1 (2009) ("[T]he assumed rate of risk aversion is at least as important as the assumed rate of time preference in determining the social cost of carbon.")).
[58] EPA-HQ-OAR-2010-0799-9480-A1, p. 6.
[59] EPA-HQ-OAR-2010-0799-9480-A1, p. 7.
[60] Geoffrey Heal & Bengt Kristrom, *Uncertainty and Climate Change*, 22 ENVTL. RESOURCE ECON. 3 (2003) (analogizing climate change to insurance markets).
[61] Geoffrey Heal, *The Economics of Climate Change: A Post-Stern Perspective*, 96 CLIMATE CHANGE 275 (2009) (identifying the effects of uncertainty and risk aversion and suggesting that society will pay to avoid climate change risks).
[62] Magnus Hennlock, *Robust Control in Global Warming Management: An Analytical Dynamic Integrated Assessment* (University of Gothenberg, Working Papers in Economics No. 354, 2009) (finding that the preference for avoiding uncertainty entails a higher SCC due to the need for an ambiguity premium).

the use of significant risk premiums should be included in estimating the SCC. The current failure to include a risk premium in the SCC is thus inconsistent with the economics literature. Although scholars use different methods for calculating risk premiums and arrive at different results, disagreement over the size of these values does not suggest that they should be zero.[66] The degree of risk society faces is a subject of contention, but most economists believe that there is some non-negligible risk premium that must be accounted for in the SCC.[67]

More important than the precise value is the realization that risk aversion to climate change warrants incorporating a positive risk premium into the SCC.[68] Mitigation steps

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[63] Richard S. J. Tol, *The Social Cost of Carbon: Trends, Outliers, and* Catastrophes 2 ECONOMICS: THE OPEN-ACCESS, OPEN-ASSESSMENT E-JOURNAL (2008).

[64] *See* Gary W. Yohe & Richard S. J. Tol, *The Stern Review and the Economics of Climate Change: An Editorial Essay*, 89 CLIMATE CHANGE 231, 237 (2008).

[65] Martin L. Weitzman, *Additive Damages, Fat-Tailed Climate Dynamics, and Uncertain Discounting*, 3 2 ECONOMICS: THE OPEN-ACCESS, OPEN-ASSESSMENT E-JOURNAL 1 (2009); Martin L. Weitzman, *GHG Targets as Insurance Against Catastrophic Climate Damages* (NBER, Working Paper No. 16136, 2010).

[66] *See, e.g.,* Gary Yohe, *Toward an Integrated Framework Derived from a Risk-Management Approach to Climate Change*, 95 CLIMATE CHANGE 325, 329 (2009) (suggesting the need to account for risk and uncertainty in climate change policy); Gary W. Yohe & Richard S. J. Tol, *The Stern Review and the Economics of Climate Change: An Editorial Essay*, 89 CLIMATE CHANGE 231, 237 (2008) (arguing that the optimal carbon tax must be augmented by a non-zero risk premium); Geoffrey Heal & Bengt Kristrom, *Uncertainty and Climate Change*, 22 ENVTL. RESOURCE ECON. 3 (2003); Geoffrey Heal, *The Economics of Climate Change: A Post-Stern Perspective*, 96 CLIMATE CHANGE 275 (2009); Magnus Hennlock, *Robust Control in Global Warming Management: An Analytical Dynamic Integrated Assessment* (University of Gothenberg, Working Papers in Economics No. 354, 2009); Antony Millner, Simon Dietz, & Geoffrey Heal, *Ambiguity and Climate Policy* (Center for Climate Change Economics and Policy, Working Paper No. 28, 2010) (finding that aversion to uncertainty in some cases leads to very large "ambiguity" premiums); Michael D. Gerst, Richard B. Howarth & Mark E. Borsuk*, Accounting for the Risk of Extreme Outcomes in an Integrated Assessment of Climate Change*, 38 ENERGY POL'Y 4540 (2010) (showing that ignoring uncertainty underestimates climate damages); and Robert E. Kopp et al., The Influence of the Specification of Climate Change Damages on the Social Cost of Carbon (ECONOMICS: THE OPEN-ACCESS, OPEN-ASSESSMENT E-JOURNAL, Discussion Paper No. 2011-22, 2011) (finding that uncertainty and risk aversion can significantly increase the SCC). Much of this literature review is based on Carolyn Kousky, Robert E. Kopp & Roger Cooke, *Risk Premia and the Social Cost of Carbon: A Review* 5 (ECONOMICS: THE OPEN-ACCESS, OPEN-ASSESSMENT E-JOURNAL, Discussion Paper No. 2011-19, 2011). See also Ctr. for Biological Diversity v. NHTSA, 538 F.3d 1172, 1200 (9th Cir. 2008).

[67] *See, e.g.,* David Anthoff, Richard S. J. Tol & Gary W. Yohe, *Risk Aversion, Time Preference, and the Social Cost of Carbon*, 4 ENVTL. RESEARCH LETTERS 1, 5 (2009) (finding SCC estimates over $5,000 per ton of carbon dioxide for some parameter values); Antony Millner, Simon Dietz & Geoffrey Heal, *Ambiguity and Climate Policy* (Center for Climate Change Economics and Policy, Working Paper No. 28, 2010); Carolyn Kousky, Robert E. Kopp & Roger Cooke, *Risk Premia and the Social Cost of Carbon: A Review* 14, *in* ECONOMICS: THE OPEN-ACCESS, OPEN-ASSESSMENT E-JOURNAL, Discussion Paper No. 2011-19, 2011) (concluding after surveying the literature on risk and uncertainty premiums that these premiums could be "quite large").

[68] *See* Gary Yohe, *Toward an Integrated Framework Derived from a Risk-Management Approach to Climate Change*, 95 CLIMATE CHANGE 325, 329 (2009); Gary W. Yohe & Richard S. J. Tol, *The Stern Review and the Economics of Climate Change: An Editorial Essay*, 89 95 CLIMATE CHANGE 231, 237 (2008) ("While reasonable people disagree how much of a risk premium should be placed on top of the Pigou tax, it should be clear that no reasonable person would argue that this premium should be zero."); Carolyn Kousky, Robert E. Kopp & Roger Cooke, *Risk Premia and the Social Cost of Carbon*: A Review 5 (ECONOMICS: THE OPEN-ACCESS, OPEN-ASSESSMENT E-JOURNAL, Discussion Paper No. 2011-19, 2011). *See also* Klaus Keller, Gary Yohe, & Michael Schlesinger, *Managing the Risks of Climate Thresholds: Uncertainties and Information Needs*, 91 CLIMATE CHANGE 5 (2008) (discussing the proper portfolio of mitigation policies).

taken today can be understood as an investment that is part of a larger portfolio of investments made by society. To the extent that other investments are more risky than mitigation, mitigation lowers the overall risk profile of a portfolio. More importantly, it might significantly reduce the likelihood of a catastrophic state, reducing overall risk substantially.

It may also be the case that mitigation actually *increases* returns on alternative investments. That is, the more you invest in mitigation, the higher your expected returns on other assets.[69] Each ton of emissions reduction might reduce the variance of aggregate economic damages and thereby further reduce systematic risk. This means that emissions reduction itself lowers uncertainty about future economic returns. Thus, a full risk premium in the climate change context values the ability of emissions abatement to reduce the variance of outcomes.[70]

Despite these justifications, the IWG noted that government is usually risk neutral and questioned whether the climate change context merits different treatment. In fact, the nature of the climate problem requires government to be risk averse. For most social problems, the government is large enough that it can self-insure against disaster and act without aversion to risk. But because climate change is qualitatively different than other social problems involving risk, the agencies should treat it differently. The IWG noted the suggestion in the Office of Management and Budget's Circular A-4 that government agencies should "generally" assume the perspective of a risk neutral actor. But it also observed that society should not always be risk neutral, that Circular A-4 "allows for a different assumption on risk preference in regulatory analysis if it is adequately justified,"[71] and that agencies should deviate from the risk neutral perspective when necessary.[72] The global nature of climate change catastrophes requires such a deviation. Circular A-4 endorses the use of expected values without a risk premium—here, the average damages of all possible climate outcomes—only when society is risk neutral. However, society will not be neutral when risks cannot be offset by other investments. Compensating for the loss of habitability on Earth is impossible; the ability of the planet to sustain human life is irreplaceable. The magnitude of the damages associated with the risk of catastrophic climate change overwhelms the ability of society to match these damages with gains from

[69] If it happens to be the case that whenever climate mitigation pays off, the economy also happens to be performing better for reasons unrelated to climate change, mitigation will yield a lower marginal benefit since overall wealth will be higher and thus the marginal utility from mitigation benefits lower. However, it is likely that there is a causal relationship between the two, given significantly negative effects on productivity resulting from adverse climate events, recently estimated in the literature. See Elizabeth J. Moyer, Mark D. Woolley, Michael Glotter & David A. Weisbach. *Climate Impacts on Economic Growth as Drivers of Uncertainty in the Social Cost of Carbon* (Center for Robust Decision Making on Climate and Energy Policy, Working Paper 13-02, 2013).

[70] EPA-HQ-OAR-2010-0799-9480-A1, p. 8

[71] 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), *available at* http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf.

[72] See id. at 30 (citing OFFICE OF MGT. & BUDGET, EXECUTIVE OFFICE OF THE PRESIDENT, CIRCULAR A-4, 42 (2003)).

other investments.[73] This suggests that risk aversion is necessary for society to account for the uniquely problematic nature of climate change.[74]

The IWG attempted to account for risk aversion by including a 95th percentile SCC estimate at a 3% discount rate.[75] The decision to include consideration of risk aversion in one of four estimated SCC values misses the point. Risk and uncertainty are systematic in the climate change context. Consequently, all SCC estimates should include risk premiums to account for these factors. Furthermore, it is not clear whether the selection of the 95th percentile SCC estimate was chosen based on a reasoned connection to the risks under consideration, or out of simple convenience.

Ignoring option value

The SCC estimates ignore option value, i.e., what society would be willing to pay for the additional information on damages from carbon emissions that will be available in the future if it delays the irreversible decision to emit today. This concept of option value from the environmental economics literature (see e.g., Arrow and Fisher, 1974)[76] is intuitively seen as the value of preserving natural resources so that they can be available for use in the future. The option value of delaying the emission of carbon dioxide arises due to two main characteristics of the climate problem: uncertainty and irreversibility. There are, as previously mentioned, pervasive uncertainties in connecting carbon emission increases to temperature changes and in turn temperature changes to damages. Additionally, some of the potential impacts from climate change are likely to be irreversible, once certain thresholds or "tipping points" are crossed.

Uncertainty and irreversibility together provide an argument for option value being incorporated into the SCC. Continued release of GHG emissions along the current business-as-usual trajectory moves the climate system closer to one of these unknown tipping points. At the same time, we continue to learn about the climate system. If we in a future period learn that the true climate sensitivity is toward the upper end of its currently estimated distribution, it will by then effectively be impossible to reverse the emissions released in the interim.

By contrast, a policy that reduces emissions today preserves the option to act even more aggressively in the future if the damages warrant it. In other words, emitting a marginal ton today closes an option to delay that emission (through abatement) until the magnitude of damages is better understood. This option value should properly be accounted for in estimating the damages of increased emissions, which foreclose the option.

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[73] See Martin Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 REV. ECON. & STAT. 1, 11 (2009).
[74] EPA-HQ-OAR-2010-0799-9480-A1, p. 8.
[75] 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), *available at* http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf.
[76] Kenneth J Arrow & Anthony C Fisher, *Environmental Preservation, Uncertainty, and Irreversibility*. 88 Q.J. ECON. 312 (1974).

Damages at high temperature levels

The IAMs' damage functions are calibrated using damage estimates for low temperature increases, usually using damage estimates derived from climate impacts at low temperature increases; typically damage estimates are for a 2.5 or 3 degree Celsius *average* global increase. Damages at low levels are then extrapolated to higher average global temperatures, which often underestimate damages at these higher temperatures. Furthermore, temperature extremes can diverge significantly from averages (high or low) over different geographical regions and temporal scales; these extremes are also not captured.

Often, resulting damage functions imply unrealistically low damages at high temperature levels. For example, according to the DICE-2007 damage function used by the 2010 IWG, 6 and 10 degree Celsius increases imply only 10.2% and 28.3% declines, respectively, in global GDP; these low damage estimates imply insufficient damage estimates and/or overly strong adaptation assumptions. As highlighted by Weitzman (2010)[77], Sherwood and Huberb (2010)[78] recently find that large portions of the earth's surface, where a majority of humans are currently distributed, will be inhospitable at a 11 or 12 degree Celsius increase due to due to hyperthermia in mammals; they see this as an upper limit on the level of adaptation.[79] Using this information, Ackerman and Stanton (2012) assume that humans cannot survive at a 12 degree Celsius increase, and assume that 99% of GDP damages are lost at this temperature value. In other words, updating the damage functions to reflect recent scientific analysis for damages at higher temperatures indicates that damages estimates should increase relative to what is currently in the IAMs. [80]

Oversimplification of modeling assumptions

An additional downward bias in the damage estimates results from various model simplifications. One important one is an implicit assumption of constant relative prices. Constant relative prices assume that there is no rise in the value of agriculture and environmental goods relative to other goods as climate change worsens, which would undoubtedly occur due to increased scarcity of food and environmental goods. Essentially, the models do not estimate agricultural losses at higher market prices than those today despite decreasing food supplies caused by climate extremes.[81] The concept also applies to ecosystems: the models all assume continued economic growth that will make us much wealthier over time, without taking into account the increasing relative value of ecosystems as they experience declines (e.g. the die off of coral reefs, and losses of

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[77] Martin L. Weitzman, *GHG Targets as Insurance Against Catastrophic Climate Damages*, 14 J. PUB. ECON. THEORY 221 (2012).
[78] Steven C. Sherwood & Matthew Huber, *An Adaptability Limit to Climate Change Due to Heat Stress*, 107 PROC. NAT'L ACAD. OF SCI. 9552 (2010).
[79] At a seven degree Celsius increase, some portions of the planet start becoming inhospitable due to hyperthermia.
[80] Frank Ackerman & Elizabeth Stanton, *Climate Risks and Carbon Prices: Revising the Social Cost of Carbon* (Economics Discussion Paper, No. 2011-40, 2011).
[81] Thomas Sterner & U. Martin Persson*, An Even Sterner Review: Introducing Relative Prices into the Discounting Debate*, 2 REV. ENVTL. ECON. & POL'Y 61 (2008).

biodiversity and ecosystems that sustain life). The current models violate the fundamental economic principle that value arises from scarcity.

Another simplifying assumption is ignoring the rate of temperature increases. Only one of the three models, FUND, accounts for this. Yet, there is a strong consensus that rapid climate change is more costly than slow climate change. With slow change, ecosystems and societies may be able to adapt up to a point, for example by abandoning coastal settlements, altering planting patterns, and anticipating climate change in infrastructure decisions. On the other hand, if climate change is rapid, these adaptation strategies become more difficult, and more costly. If climate changes are too extreme, it will probably be impossible for humans to adapt to them regardless of the time scale.

Finally, local variability of climate impacts is not captured in the models, but can have dramatic effects on overall costs. For example, timing of precipitation over the course of the year and extreme heat temperatures are very important for the viability of agricultural crops, not just the average annual amount of rainfall in a given year or above average temperatures. The global average sea level rise (8 inches since 1880) also masks significant local variation (for example, in the United States we have experienced local sea level rise of 10 inches to 46 inches in places along the East and Gulf coasts).

High and constant discount rates

The discount rates used by the IWG to value harms in the far future are based upon two problematic assumptions. First, all of its rates are derived from observed market interest rates. Second, two of its rates are based upon constant discounting, at odds with a consensus among climate economists that a declining discount rate should be used to account for uncertainty about future discount rates.[82] Such discount rates are now the official policy of the United Kingdom and France. The IWG has one discount rate that attempts to take uncertainty into account (a constant 2.5%), which is a step in the right direction, but using an average and constant rather than a declining discount rate should mean that more long-term damages are discounted at a higher rate than they would have with an actual declining discount rate schedule.

Three fundamental factors justify lower discount rates than those used by the IWG: 1) the rate of time preference; 2) negative production externalities (above CO_2 damages); and 3) a risk management perspective versus maximizing returns from mitigation investments—the philosophy underpinning cost-benefit analysis.

1) Time preference

Embedded in market interest rates is what economists call a "pure rate of time preference," or what one might term impatience. Individuals have a preference for consumption today over consumption in the future. In terms of interest rates, a positive rate of time preference results in lenders requiring compensation (interest) for delaying the use of their money.

[82] K. Arrow, M. Cropper, C. Gollier, B. Groom, G. Heal, R. Newell, W. Nordhaus, R. Pindyck, W. Pizer, P. Portney, T. Sterner, R.S.J. Tol & M.L. Weitzman, *Determining Benefits and Costs for Future Generations*, 341 SCIENCE 349 (2013).

Discounting costs and benefits based upon time preference is highly problematic when they occur over multiple generations, as is the case with climate change. To the extent that a positive rate of time preference is embedded in the discount rate used for the SCC, a greater value is assigned to damages occurring closer in time than those farther out. Costs of mitigation are similarly assigned a higher value the sooner they are incurred in time. Because the costs of mitigation tend to be up-front, and the damages such mitigation prevents would arise farther in the future, discounting tilts the benefit-cost ratio in favor of less mitigation and the current generation on both the cost and benefit sides.

Many argue that only a value of zero for time preference makes sense in the context of climate change. As OMB Circular A-4 notes, "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." (OMB Circular A-4, p.35).

Adjusting market interest rates to remove the time preference component embedded in them lowers the discount rate. The number is not small: evidence suggests a central time preference estimate of approximately 1.5 percent;[83] some papers use values as high as 3% and 4%.[84,85]

2) Adjusting the discount rate for negative externalities

Another reason for using a discount rate lower than observed market interest rates is that they do not take into account many things that decrease real output, such as depreciation of natural capital (e.g., loss of natural habitats to development) and pollution externalities (e.g., non-CO_2 pollutants from burning fossil fuels).[86]

We can get a sense of the distortion in market interest rates caused by negative externalities by examining past efforts made to adjust gross domestic product (GDP) for them. Estimates vary widely, depending upon the year(s) examined and the methodologies employed, but all find adjusted growth to be lower than unadjusted. Goodstein summarizes three studies of adjusted annual GDP per capita growth, finding a range of 0.2% to 3.1%

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[83] Her Majesty's Treasury, The Green Book: Appraisal and Evaluation in Central Government, Treasury Guidance (2003). Nordhaus uses 1.5% as a default value in a recent analysis. William Nordhaus, Estimates of the Social Cost of Carbon: Background and Results from the RICE-2011 Model, Cowles Foundation Discussion Paper No. 1826 (2011).

[84] Rates of time preference are estimated in numerous contexts, not just in asset markets. As such, some estimates can be higher than observed market interest rates.

[85] The Stern Review used a rate of pure time preference of 0.1 percent per year, based on an arbitrary estimate of the annual probability that the human race will not survive (though it adopted the view that damages in the future should not be discounted on the basis of the current generation preferring to consume now at the expense of future generations). NICHOLAS STERN, THE STERN REVIEW; THE ECONOMICS OF CLIMATE CHANGE (2007), *available at* http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

[86] GDP also excludes things that increase welfare, such as any household labor that is not bought and sold in the market. On net, however, it excludes significantly more "bad" things than "good" things.

lower, for various time periods.[87,88,89,90] A more recent analysis by Talberth et al.[91] found annual per capita adjusted growth rate 2.5% below GDP. This data suggests that, based upon historical data alone (which may be more forgiving than the future under climate change), adjusting market interest rates for negative externalities significantly lowers the discount rate and in some instances could even imply negative discount rates.

3) Risk management: insurance versus discounting framework

Using market interest rates as discount rates assumes that investors in a market for mitigation, were it possible for one to exist,[92] would require similar returns and risk levels as those observed in asset markets today. This assumption is wrong on several counts.

First, basing climate change discount rates upon observed markets cannot possibly be correct: the worst-case scenario when investing in regular asset markets is that an individual loses all of his or her life savings. This is not comparable to the kinds of catastrophic societal risks possible from climate change.

Second, theoretically, mitigation investments are more appropriately viewed as an insurance problem, not a profit-maximizing venture. Cost-benefit analysis aims to maximize expected net returns, on contrast to mitigation as a precautionary investment that minimizes losses. Precautionary investments like climate mitigation yield their highest returns in "bad" states of nature, not when asset markets are at their peak.

These two factors point to adding a negative risk premium to any descriptive discount rate, with a correspondingly higher weighting of losses.[93] The negative "returns" individuals are willing to pay for in insurance markets, as evidenced by actuarial data, provide an example: purchasers pay to insure themselves against very bad outcomes that have very small, but positive, probabilities of occurring.

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[87] Goodstein summarizes Nordhaus & Tobin, who estimate a .7 percentage point difference in annual per capita growth between 1929-1965, and a 1.8 percentage point difference between 1947-1965; Zolatas (1981), who estimates 1.8 (1947-1965), 1.6 (1950-1965), and 1.5 percent (1965-1977) differences; and Daly and Cobb (1989), who estimate differences of 0.2 (1950-1960), 0.6 (1960-1970), 3 (1970-1980) and 3.1 (1980-1986). *See* EBAN S. GOODSTEIN, ECONOMICS AND THE ENVIRONMENT (4th ed. 2004).

[88] William Nordhaus & James Tobin, *Is Growth Obsolete?*, *in* THE MEASUREMENT OF ECONOMIC AND SOCIAL PERFORMANCE, STUDIES IN INCOME AND WEALTH 509 (1973).

[89] XENOPHON ZOLATAS, ECONOMIC GROWTH AND DECLINING SOCIAL WELFARE (1981).

[90] HERMAN H DALY & JOHN B COBB, FOR THE COMMON GOOD (1989).

[91] JOHN TALBERTH, CLIFFORD COBB & NOAH SLATTERY, THE GENUINE PROGRESS INDICATOR 2006: A TOOL FOR SUSTAINABLE DEVELOPMENT. REDEFINING PROGRESS (2007).

[92] A "mitigation investment" would be any action whose purpose is to reduce climate change impacts by reducing greenhouse gas emissions. A market for such investments could not exist, however, because mitigation is a public good (see footnote 32).

[93] JOHN H COCHRANE, ASSET PRICING (2001).

Unfortunately, the insurance analogy understates the case. With standard insurance policies:

a) Damages are often fully recoverable (i.e. not irreversible), examples being property damages resulting from fires or automobile accidents.[94]

b) The probabilities of bad outcomes generally are known. These are not known in climate change, and people are more averse to investing in risky assets if the potential losses, and the probability of those losses, are uncertain (Gollier, 2009).[95] This is called "ambiguity aversion" in the literature. Gollier shows that under certain plausible conditions,[96] aversion to ambiguity will decrease the discount rate, and could do so quite substantially.

c) The probabilities of catastrophic outcomes in climate change are higher than those observed in insurance markets. For example, the probability of a parent dying at age 35 is 0.1 percent (and exponentially smaller that both die), yet parents routinely spend thousands of dollars on life insurance. In contrast, a mid-range business-as-usual emissions projection puts the earth on track for a more than 40 percent chance of warming exceeding 4°C by 2100, well above the 2°C target scientists tell us is necessary to minimize the likelihood of catastrophic climate change), and a 10 percent possibility of this occurring already by the 2070s.[97]

In the context of cost-benefit analysis, negative discount rates implied by an insurance approach do not lead to sensible policy conclusions (cost-benefit analysis is based upon marginal changes rather than the non-linear catastrophes of the kind associated with negative discount rates). In our recommendations section, therefore, we recommend positive but low discount rates.

6. Recommendations

For the reasons discussed above, it is clear that the IWG's analysis significantly underestimates the Social Cost of Carbon. Nonetheless, we believe that the Department should continue to use the IWG's SCC value as it moves forward with the walk-in cooler and commercial refrigeration rulemakings. Although this will likely result in underestimates of the true benefits of the rule, we believe that the Department should not delay the rules, which are highly cost-effective anyway, in order to adjust the SCC. But if the Department does decide to make changes to the IWG SCC, we recommend that the Department also make the changes recommended below. These recommendations correct a number of the

[94] Minus any deductibles.
[95] Christian Gollier, Portfolio Choices and Asset Prices: The Comparative Statics of Ambiguity Aversion (Toulouse School of Economics (LERNA and IDEI) working papers 09-068, 2009).
[96] These conditions are: 1) as income rises, a person is more willing to increase investments in assets that are risky, whose risk level and size of potential loss is known; and 2) as income rises, a person is more willing to invest in assets with uncertain losses and uncertain probabilities of such losses.
[97] WORLD BANK, TURN DOWN THE HEAT: WHY A 4°C WARMER WORLD MUST BE AVOIDED 3 (2012), *available at* https://openknowledge.worldbank.org/handle/10986/11860.

errors noted previously and would result in an improved SCC estimate than the values used by DOE in the proposed rule. If the Department chooses not to make changes, we encourage it to pursue such adjustments through the IWG for use in future rulemakings.

Better account for catastrophic climate outcomes

The SCC numbers used should reflect the uncertainty range around different functional forms and standard assumptions around risk aversion in order to more accurately value potentially catastrophic climate impacts. In particular, the agencies should increase estimates of climate benefits to more accurately value the chance of catastrophic damages. Substantial economic literature supports the conclusion that current models do not place enough emphasis on catastrophic scenarios and, consequently, that some adjustment to the calculation of benefits is necessary.

In early 2010, the IWG suggested that scholarly disagreement warranted further investigation before it would be appropriate to adjust the SCC to account for catastrophic damages. However, disagreement over the exact size of that adjustment does not suggest the risk of catastrophe should be valued at zero.

Because the IWG's analysis relied heavily on IAMs that do not fully account for the possibility of catastrophic damages, the agencies should adjust SCC estimates upward to properly value expected climate damages. The IWG referred to the work of Nordhaus,[98] Pindyck,[99] and Newbold and Daigneault[100] to support its decision to delay addressing catastrophic damages. While Nordhaus' work is seminal in many ways, it is often recognized as undervaluing catastrophic outcomes. He relies heavily on one IAM (namely, DICE) that suffers from the problems explained above: it fails to fully account for the influence of catastrophic climate outcomes.[101] Newbold and Daigneault's results indicate that basing substantial SCC adjustments on catastrophic damages would depend heavily on the values assigned to model parameters. This merely shows that calculation of expected values is difficult and that extreme results such as Weitzman's[102] do not always hold. Their

[98] WILLIAM NORDHAUS, A QUESTION OF BALANCE: WEIGHING THE OPTIONS ON GLOBAL WARMING POLICIES (2008); William D. Nordhaus, *An Analysis of the Dismal Theorem* (Cowles Found., Discussion Paper No. 1686, 2009). For an update, see William D. Nordhaus, *The Economics of Tail Events with an Application to Climate Change*, 5 REV. ECON. & POL'Y 240 (2011).

[99] Robert S. Pindyck, *Uncertain Outcomes and Climate Change Policy* (NBER Working Paper No. 15,259, 2009). For more recent work, see Robert S. Pindyck, *Fat Tails, Thin Tails, and Climate Change Policy*, 5 REV. ENVTL. ECON. & POL'Y 258 (2011).

[100] Stephen C. Newbold & Adam Daigneault, *Climate Response Uncertainty and the Benefits of Greenhouse Gas Emissions*, 44 ENVTL. & RESOURCE ECON. 351 (2009).

[101] *See, e.g.,* Martin Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 REV. ECON. & STAT. 280 (2009); Carolyn Kousky, Robert E. Kopp & Roger Cooke, *Risk Premia and the Social Cost of Carbon: A Review* 5 (Economics: The Open-Access, Open-Assessment E-Journal, Discussion Paper No. 2011-19, 2011).

[102] Martin Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 REV. ECON. & STAT. 16 (2009) (finding that, in some circumstances, the possibility of catastrophic damages will result in a theoretical infinite willingness to pay to avoid climate catastrophes).

basic conclusion that current IAMs inadequately account for catastrophic damages[103] still cuts in favor of some upward adjustment to the SCC, not waiting for further research. Pindyck finds only moderate expected utility differences when considering a wide distribution of climate outcomes.[104] However, he uses a simplified IAM with different damage and growth functions that do not assume fat tails. Yet it is fat tails and the growing possibility of extreme outcomes that drives much of the catastrophic damage analysis.

The IWG claimed that "further research in this area is needed before its practical significance can be fully understood and a reasonable approach developed to account for such risks in regulatory analysis."[105] In fact, no amount of research can lead to a "full understanding" of this problem. Nevertheless, a practical approach to treating catastrophe can be developed and implemented. Indeed, because a greater possibility of catastrophic damages exists than is included in the IAMs used by the IWG (the IWG essentially admits that this is the case[106]), the practical approach is to adjust the SCC upward. The fact that there is disagreement about the size of this catastrophic damage adjustment does not suggest that it should be zero.[107]

Moreover, a substantial amount of research has been published since the IWG's 2010 report, adding to a growing body of literature that highlights the limitations of IAMs with regard to catastrophic damages. The 2013 update did not change the IWG's approach to catastrophic damages. If the Department decides to make changes to the SCC, it should address the relevance of work by Pycroft, Vergano, Hope, Paci, and Ciscar,[108] Millner,[109] Ackerman, Stanton, and Bueno,[110] Dietz,[111] and Gerst, Howarth, and Borsuk.[112] Combined

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[103] *See generally* Stephen C. Newbold & Adam Daigneault, *Climate Response Uncertainty and the Benefits of Greenhouse Gas Emissions*, 44 ENVTL. & RESOURCE ECON. 351 (2009).

[104] Robert S. Pindyck, *Uncertain Outcomes and Climate Change Policy* (NBER Working Paper No. 15,259, 2009). For more recent work, see Robert S. Pindyck, *Fat Tails, Thin Tails, and Climate Change Policy*, 5 REV. ENVTL. ECON. & POL'Y 258 (2011).

[105] 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), *available at* http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf).

[106] *See id.* at 31.

[107] *See* Center for Biological Diversity v. National Highway Traffic Safety Admin ,538 F.3d 1172, 1200 (9th Cir. 2008) ("[W]hile the record shows that there is a range of values, the value of carbon emissions reduction is certainly not zero.").

[108] Jonathan Pycroft, Lucia Vergano, Chris W. Hope, Daniele Paci & Juan Carlos Ciscar, *A Tale of Tails: Uncertainty and the Social Cost of Carbon Dioxide* (Economics: The Open-Access, Open-Assessment E-Journal, Discussion Paper 2011-36, 2011) (finding that tail shape can change the SCC dramatically and suggesting fatter tails may be more reasonable).

[109] Antony Millner, *On Welfare Frameworks and Catastrophic Climate Risks, in* SOCIAL SCIENCE RESEARCH NETWORK (2011) (arguing that satisfactory treatment of climate modeling requires consideration of catastrophe

[110] Frank Ackerman *et al., Fat Tails, Exponents, Extreme Uncertainty: Simulating Catastrophe in DICE*, 69 ECOLOGICAL ECON. 1657 (2010) (finding that plausible increases in both the climate sensitivity and damage exponent parameters results in disastrous economic decline).

with the work of climate scholars like Weitzman and Tol,[113] the economic literature supports the proposition that IAMs do not place enough emphasis on catastrophic damages and, consequently, some adjustment should be made to account for this limitation.

The studies that attempt to calculate the amount of adjustment necessary generally find it to be large. Yohe and Tol opine that increasing the SCC by 50% "is not out of the question" given the non-zero risk of catastrophic climate change.[114] In stylized conditions of structural uncertainty, Weitzman shows that the SCC might be infinite.[115] This seems implausible, and several studies react by restricting the damage function to avoid this result.[116] Pycroft, Vergano, Hope, Paci, and Ciscar find that allowing for the possibility of different tail sizes in both the climate sensitivity parameter and the damage function lead to increases in the SCC of 33% to 115%.[117] A number of other studies suggest methods for addressing the problem of catastrophic changes.

There is precedent for adjusting the IAMs to account for such risks. Both the 2010 and 2013 IWG correctly modeled the climate sensitivity parameter using a right skewed distribution. A similar model adjustment is required here for catastrophic impacts.

Adjust the SCC Estimates to Account for Risk Aversion

Climate change outcomes are uncertain because of the unprecedented nature of human interference with the climate system under way now. It is inherently difficult to measure the exact damages from each additional unit of greenhouse gas emissions. We know that GHG emissions accumulate in the atmosphere and in the case of CO_2 linger for hundreds of years. The impacts of these emissions on the climate system are cumulative and nonlinear,

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[111] Simon Dietz, *High Impact, Low Probability? An Empirical Analysis of Risk in the Economics of Climate Change*, 108 CLIMATE CHANGE 519 (2011) (discussing one method of bounding damages to avoid infinite willingness to pay for abatement).

[112] Michael D. Gerst, Richard B. Howarth & Mark E. Borsuk, *Accounting for the Risk of Extreme Outcomes in an Integrated Assessment of Climate Change*, 38 ENERGY POL'Y 4540 (2010) (finding that without aggressive abatement, the probability of catastrophic damages is high).

[113] *See* Martin Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 Rev. Econ. & Stat. 1 (2009). *See generally* Richard S. J. Tol, *Is the Uncertainty About Climate Change Too Large for Expected Cost-Benefit Analysis?*, 56 CLIMATE CHANGE 265 (2003). Participants at an EPA/DOE workshop following the interagency process likewise noted that existing research already suggests that IAMs could better assess high-end warming scenarios. ICF INT'L, DRAFT WORKSHOP REPORT: IMPROVING THE ASSESSMENT AND VALUATION OF CLIMATE CHANGE IMPACTS FOR POLICY AND REGULATORY ANALYSIS—PART 1, at 6 (2011), *available at* http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0564-50.pdf/$file/EE-0564-50.pdf.

[114] *See* Gary W. Yohe & Richard S. J. Tol, *The Stern Review and the Economics of Climate Change: An Editorial Essay*, 89 CLIMATE CHANGE 231, 237 (2008).

[115] *See* Martin Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 REV. ECON. & STAT. 1 (2009).

[116] Robert S. Pindyck, *Uncertain Outcomes and Climate Change Policy* (NBER Working Paper No. 15,259, 2009). For more recent work, see Robert S. Pindyck, *Fat Tails, Thin Tails, and Climate Change Policy*, 5 REV. ENVTL. ECON. & POL'Y 258 (2011).

[117] Jonathan Pycroft, Lucia Vergano, Chris W. Hope, Daniele Paci & Juan Carlos Ciscar, *A Tale of Tails: Uncertainty and the Social Cost of Carbon Dioxide* (Economics: The Open-Access, Open-Assessment E-Journal, Discussion Paper 2011-36, 2011).

and so too are the impacts on the economy. Consequently, each unit of emissions contributes additional risk that climate damages will very likely worsen over time, and even pose a risk of reaching catastrophic climate "tipping points."

One way to analyze the benefits of policies that reduce emissions is by thinking of climate abatement as an investment in stabilizing the climate system which in turn reduces the risks of climate impacts by some uncertain amount.[118] Most people are naturally risk averse and where possible will take steps to insure against risk, as evidenced by the purchase of insurance policies against the risk of fires, accidents and health problems among other things. Individuals pay an insurance premium to insurance companies in return for coverage that will lower their risk of uncompensated damages.

When investments involve risk, people are willing to pay for greater certainty in returns than when only considering the expected returns of the investment.[119] For example, an investment option with less risk will typically sell at a higher price than a risky investment, even if the two alternatives have an equal expected payout. In portfolio theory, the price differential represents the risk premium that risk-averse actors demand for holding a risky asset. Investors also mitigate risk by buying investments whose risks are uncorrelated so that, ideally, when one investment performs poorly, the other performs well, increasing the likelihood that the total investment portfolio will have positive returns. Thus, when investing in a range of assets, the covariance of the assets helps determine the price investors will pay for those assets.

The lack of certainty about climate outcomes and the risk of really catastrophic, irreversible impacts, implies that a risk-averse society should make significant investments in measures that would help lower risk i.e. in measures to cut the emissions that are fueling climate change as well as in building resilience to changes already underway. In fact a risk-averse society would be willing to pay an additional amount, beyond what the expected reduction in damages would imply, to reduce the risk of these damages. Because these decisions must be made at a societal rather than individual level, public policies need to explicitly incorporate a risk premium or the market will fail to account for this. Studies that either calculate this risk premium generally, or that include a risk premium when

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[118] Martin L Weitzman, *A Review of the Stern Review on the Economics of Climate Change,* 45 J. ECON. LIT. 703 (2007).

[119] *See* Sonia Quiroga & Ana Iglesias, *A Comparison of the Climate Risks of Cereal, Citrus, Grapevine and Olive Production in Spain,* 101 AGRICULTURAL SYSTEMS 91, 98-99 (2009) (specifying risk premium in relation to risk aversion among Mediterranean agricultural producers); Howard C. Kunreuther & Erwann O. Michel-Kerjan, *Climate Change, Insurability of Large-Scale Disasters, and the Emerging Liability Challenge*, 155 U. PA. L. REV. 1795 (2007) (discussing calculations for insurance policies amid climate change); Alicia N. Rambaldi & Phil Simmons, *Response to Price and Production Risk: The Case of Australian Wheat*, 20 J. FUTURES MKTS. 345 (2000). *See also* Joseph E. Aldy *et al., Designing Climate Mitigation Policy* 14 (Res. for the Future, Discussion Paper 08-16, May 2009) (noting that proper risk premium estimate is the subject of dispute, and that it varies with estimates of the marginal utility of consumption net of climate damages); David Anthoff, Richard S. J. Tol, & Gary W. Yohe, *Risk Aversion, Time Preference, and the Social Cost of Carbon*, 4 ENVTL. RESEARCH LETTERS 1 (2009) (distilling from historical data values for the elasticity of marginal utility with respect to consumption, and identifying salience of uncertainty in SCC calculation).

estimating the SCC, generally find such premiums to be positive and could be quite substantially so.[120]

Heal finds a premium between 0.1% and 8.13% of national income.[121] Tol calculates a risk premium with "conservative assumptions" around $6-$7/ton of carbon dioxide.[122] Anthoff, Tol, and Yohe report SCCs from about $16/ton of carbon dioxide to over $5,000/ton when incorporating uncertainty into the calculation.[123] Finding that uncertainty and equity interact to increase the SCC, they report a final SCC estimate of more than $50/ton of carbon dioxide.[124] Crost and Traeger find that adding risk aversion increases SCC values by 25 to 70%.[125]

These studies constitute several ballpark examples of premium size. Other studies suggest both higher[126] and lower[127]values for risk premiums. Different assumptions about the degree of risk aversion and parameters in IAMs can radically change modeling outcomes. The point is that the values under consideration are often very large relative to current SCC estimates. The presence of many high estimates for risk premiums suggests that they should be given substantial weight in determining the SCC.

The wealth of studies on this subject provides the agencies with sufficient know-how to incorporate a risk premium into the SCC estimates. If the Department makes changes to the SCC, it should analyze the range of approaches toward risk and implement the best method for incorporating a defensible risk premium into the SCC. In particular, the agencies should consider including either a "risk adder" or a downward adjustment of the discount rate.[128]

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[120] Carolyn Kousky, Robert E. Kopp, & Roger M. Cooke, *Risk Premia and the Social Cost of Carbon: A Review,* ECONOMICS EJOURNAL (2011), *available at* http://dx.doi.org/10.5018/economics-ejournal.ja.2011-21.
[121] Geoffrey Heal, *The Economics of Climate Change: A Post-Stern Perspective,* 96 CLIMATIC CHANGE 275 (2009).
[122] Richard S. J. Tol, The Social Cost of Carbon: Trends, Outliers and Catastrophes (Economics Discussion Papers, No 2007-44, Kiel Institute for the World Economy (2007)), *available at* http://www.economics-ejournal.org/economics/discussionpapers/2007-44
[123] David Anthoff, Richard S. J. Tol, & Gary W. Yohe, *Risk Aversion, Time Preference, and the Social Cost of Carbon*, 4 ENVTL. RESEARCH LETTERS 1 (2009).
[124] David Anthoff, Richard S. J. Tol & Gary W. Yohe, *Risk Aversion, Time Preference, and the Social Cost of Carbon*, 4 ENVTL. RESEARCH LETTERS 1, 6 (2009) (distilling from historical data values for the elasticity of marginal utility with respect to consumption, and identifying salience of uncertainty in SCC calculation).
[125] Benjamin Crost & Christian P. Traeger (2013), *available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2270482*
[126] Simon Dietz, *High Impact, Low Probability? An Empirical Analysis of Risk in the Economics of Climate Change*, 108 CLIMATE CHANGE 519 (2011) (discussing one method of bounding damages to avoid infinite willingness to pay for abatement).
[127] Robert Mendelsohn, Is the Stern Review an Economic Analysis?, 2 *Rev. Envtl. Econ. & Pol'y* 45 (2008).
[128] Reducing the discount rate is one way to account for risk aversion. *See* Carolyn Kousky, Robert E. Kopp & Roger Cooke, *Risk Premia and the Social Cost of Carbon: A Review* 5 (Economics: The Open-Access, Open-Assessment E-Journal, Discussion Paper No. 2011-19, 2011). However, the effect of emissions abatement investments on the overall level of risk in the economy does not affect the discount rate as described by modern portfolio theory. There are also independent reasons for lowering the discount rates used by the IWG, *see* Letter from Institute for Policy Integrity & Environmental Defense Fund, to Lisa P. Jackson, Administrator, EPA, 15 (Nov. 27, 2009), *available at* http://www.policyintegrity.org. Any downward adjustment to the discount rate to account for risk should not diminish those independent reasons to also lower the discount rate.

Without a risk premium, the SCC estimates will be too low and the rule will undervalue benefits from greenhouse gas reductions, setting a precedent for future emissions standards to be inefficiently lenient.

Risk Aversion and Catastrophic Damages Likely Interact, Necessitating Even Larger SCC Values

The combination of risk aversion and uncertainty about catastrophic damages implies an even greater upward adjustment to SCC estimates may be necessary. Millner, Deitz, and Heal argue that differences among complex climate change models expose large gaps in our knowledge regarding climate damages.[129] Substantial uncertainty remains for a variety of IAM parameters.[130] In the presence of risk aversion, this deep uncertainty coupled with the possibility of catastrophic climate damages implies that the risk adjustment may need to be very large to account for society's desire to avoid catastrophic climate damages. Each unit of emissions reduction not only decreases the average expected future damages, but also thins the fat tails in damage probability distributions, thereby reducing the likelihood of catastrophic outcomes.[131] If the government is risk averse, the SCC should include a large risk premium to account for all of these effects.

Another improvement would be to modify the DICE and FUND models to allow for Monte Carlo simulations that include catastrophic damage function and outcome specifications, as is done in PAGE.

Adopt a declining discount rate

Given the problems with the constant market interest rates discussed above, and the economic consensus on using declining discount rates for climate damages, we urge DOE to develop a declining discount rate schedule and discard its 3 and 5% rates. This schedule should reflect to the best extent possible a zero rate of time preference for damages to future generations, and a level of risk aversion commensurate with catastrophic risks. Ideally it would also adjust for negative market externalities.

While we commend the Agency's use of the Newell-Pizer 2.5% estimate as a first step, in our opinion it is still too high for valuing future climate damages. Because it is derived from historical market interest rates, the Newell-Pizer estimate: 1) penalizes future generations from embedded positive rates of time preference; 2) reflects historical growth rates that may be overly optimistic, given an increasingly disrupted climate; 3) incorporates only modest market risks that do not adequately capture catastrophic risks associated with climate change; and 4) exclude general negative production externalities.

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[129] Antony S Millner, Simon Dietz and Geoffrey Heal, *Scientific Ambiguity and Climate Policy*, 55 ENVTL. & RESOURCE ECON. 21 (2010).
[130] Robert S. Pindyck, *Uncertain Outcomes and Climate Change Policy* (NBER Working Paper No. 15,259, 2009).
[131] Carolyn Kousky, Robert E. Kopp & Roger Cooke, *Risk Premia and the Social Cost of Carbon: A Review* 5 (Economics: The Open-Access, Open-Assessment E-Journal, Discussion Paper No. 2011-19, 2011).

The closest available estimates consistent with low rates of time preference and aversion to catastrophic risk that we are aware are one used by the United Kingdom (cite), and another derived from a broad survey of top economists and the profession at large in a climate change context (Weitzman, 2001). The UK schedule explicitly subtracts out an estimated time preference[132] the Weitzman schedule[133] may come closest to both incorporating a low rate of time preference and concerns over catastrophic risks. France's schedule is roughly similar to the UK's. All of these discount rate schedules yield lower present values than the constant 2.5% Newell-Pizer rate, which is based solely on observed market interest rate uncertainty, with no adjustments for time preference or catastrophic risk aversion. Using the IWG's 2010 SCC model, Johnson and Hope find that the UK and Weitzman schedules yield SCCs of $55 and $175 per ton of CO_2, respectively, compared to $35 at a 2.5% discount rate.

Consider option values

Option value should properly be accounted for in estimating the damages of increased emissions, and will most likely raise the damage estimates from climate change. The EPA has argued that "available information did not support rigorous inclusion of an option value" in the light duty vehicle café standards.[134] Still, as suggested by Fisher (2000, 2005)[135] the option value concept in the environmental preservation literature is not logically different from the option value concept in the theory of investment under uncertainty, the latter of which the OMB recommends should be considered by agencies when performing cost-benefit analyses. It would therefore be in the vein of this OMB recommendation, in the estimates of the SCC, to consider the option value of delaying the decision to emit a ton of carbon dioxide today.

Continual updating of damage estimates

We commend the IWG for revising its SCC estimates by incorporating the most recent versions of the models used in its calculation, and suggest that that DOE develop its own means by which to update the damage estimates in the three IAMs when a consensus is reached in the literature. Along with other agencies, the DOE should continually revise

[132] The UK 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%	.86%

Joseph Lowe, Intergenerational Wealth Transfers and Social Discounting: Supplementary Green Book Guidance (2008), *available at* http://www.hm-treasury.gov.uk/d/4(5).pdf.

[133] The Weitzman schedule is as follows:

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

Martin Weitzman, *Gamma Discounting*, 91 AM. ECON. REV. 260 (2011).

[134] Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, EPA Response to Comments Document for Joint Rulemaking. EPA-420-R-10-012a, April 2010, at 57.

[135] Anthony C Fisher, *Investment Under Uncertainty and Option Value in Environmental Economics,* 22 RESOURCE & ENERGY ECON. 197 (2000); Anthony C Fisher, *Investment Under Uncertainty and Option Value in Environmental Economics: Reply,* 27 RESOURCE & ENERGY ECON. 89 (2005).

estimates of climate benefits to reflect the most recent scientific and economic knowledge. The agencies should take the lead on adjusting estimates to account for risk and catastrophic damages, as well as the latest climate science. Even if a better estimate of benefits will not change the stringency or structure of the proposed rule, accuracy remains important. Professional and legal norms for economic analysis require it; accurate benefits estimates will increase confidence in the justifications for the rule and inform the public debate; and the agencies' impact analysis will set a precedent for future rulemakings. Developing the most accurate estimates of climate benefits and the appropriate stringency for emissions standards will set a valuable precedent for all future rulemakings that affect greenhouse gas emissions. This is particularly necessary for outdated damage estimates in the IAMs, such as CO_2 fertilization benefits, and omitted damages, such as ocean acidification.

CO_2 fertilization benefits

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, fertilization benefits may be cancelled out by negative impacts on agriculture (e.g. extreme heat, pests, and weeds).[136] If the agency is not able to adequately model all agricultural impacts it should, at a minimum, remove CO_2 fertilization benefits.

Clearly enumerating included and excluded damages

In the NSPS rulemaking for oil and gas, comments were submitted by NRDC requesting that the EPA list all of the damages and associated underlying research papers included and not included in each of the three IAMs, with a table for each model. The EPA rejected this suggestion, noting that the complexities of the models and aggregated nature of some of the damage functions within them did not lend themselves to a simple enumeration along NRDC's suggested lines.

We acknowledge the difficulty in carrying out NRDC's suggestion, and for this rulemaking therefore suggest an alternative which may be more feasible: DOE should include in a support document to this rulemaking a detailed list of studies available in the literature that *directly* estimate a *specific* damage from climate events, and that it indicate which of these studies are utilized in the three IAMs, and which are not. For example, FUND uses estimates of changes in agricultural yields with changes in temperature. This is a *direct* and *specific* impact, as opposed to a proxy for all impacts on agriculture. DOE should provide a table with all these studies, noting what specific damages were estimated in them.

In addition to a table of all current damage estimates that highlights which of these estimates were utilized by DICE, FUND, and PAGE (and thus what damage are excluded),

[136] FRANK ACKERMAN & ELIZABETH A. STANTON, CLIMATE ECONOMICS: THE STATE OF THE ART (2013); William Schlenker, W. Michael Hanemann & Anthony C Fisher, *Will US Agriculture Really Benefit From Global Warming? Accounting for Irrigation in the Hedonic Approach*, 95 AM. ECON. REV. 395 (2005).

DOE should provide an exhaustive list of climate impacts for which there are no direct damage estimates in the literature that could be used in the models.

Implementing this recommendation would be consistent with OMB's A-4 (2003), which recognizes that some costs and benefits will be difficult to monetize, but directs agencies to consider other means of quantification.

7. Concluding remarks

The Department should use move forward to finalize these important proposed rules with the current IWG estimate of the SCC. For the reasons discussed, the current SCC estimates are biased downwards and more can (and will) be done to improve the SCC and ensure through regular updates that it reflects the latest science and economics. But the necessary process of improving the accuracy of the SCC cannot hold up the Department's rulemaking efforts, particularly its efforts to set efficiency standards for walk-in coolers and commercial refrigeration. The SCC provides an important, if very conservative, estimate of the costs of climate change and the benefits of reducing carbon pollution. The costs of climate change are all too real already for communities across America. To ignore these costs and costs to future generations would be detrimental to the health and well-being of Americans 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 is the best available means to factor those costs into the benefits-cost analysis of our pollution mitigation choices.

We also suggest that the Department work with the IWG to continuously update the SCC, as occurred in 2013, as new economic and scientific consensus emerges. This approach is in line with the stated intentions of the IWG, which stated in the 2010 TSD that the IWG is committed to "updating these estimates as the science and economic understanding of climate change . . . improves."

Accordingly, the Department should affirm the current IWG SCC and move forward with these important rules.

Sincerely,

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