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Policy Integrity  
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Union of  
**Concerned  
Scientists**



May 17, 2018

To: Bureau of Land Management

Subject: Failure to Use the Social Cost of Greenhouse Gases in the Alpine Satellite Development Plan for the Proposed Greater Mooses Tooth 2 Development

Submitted by: Environmental Defense Fund, Institute for Policy Integrity at New York University School of Law, Natural Resources Defense Council, Sierra Club, Union of Concerned Scientists, and the Wilderness Society

The Bureau of Land Management prepared a draft supplemental environmental impact statement (DSEIS) for a proposal by ConocoPhillips Alaska, Inc., to construct, operate, and maintain a drill site, pipelines, access road, and other facilities to develop and produce petroleum resources on federal managed lands within the Greater Mooses Tooth portion of the National Petroleum Reserve in Alaska.<sup>1</sup> The original draft environmental impact statement was issued in 2004, and the DSEIS was prepared to “evaluate relevant new circumstances and information that have arisen” since that time. In the DSEIS, however, BLM makes the explicit choice not to use a critical tool for assessing the climate impacts of such a project: the social cost of greenhouse gases metric. BLM calculated the project’s anticipated indirect emissions (about 41 million metric tons CO<sub>2</sub>e total, or a net increase of 2.14 million tons after energy substitution analysis<sup>2</sup>), but the agency refused to take the simple step of applying the social cost of greenhouse gases metric to monetize the costs of these emissions. In making this choice, the BLM deprives the public of information that is essential to assessing the merits of this project.

BLM makes a number of faulty arguments for not using the social cost of greenhouse gases, which we address in these comments. First, BLM cites the disbanding of the federal Interagency Working Group on the Social Cost of Greenhouse Gases (IWG). Yet the misguided disbanding of that group does not change the agency’s legal obligations under NEPA to provide informational context and consistently analyze environmental impacts. Second, BLM cites disagreement over the choice of discount rate for calculating the social cost of greenhouse gases as a reason to forego applying the metric in the DSEIS. However, there is consensus among economists and the federal experts who participated in the IWG around a

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<sup>1</sup> Bureau of Land Management, *Alpine Satellite Development Plan GMT2 Development Project Draft Supplemental Environmental Impact Statement* at i (2018) (hereinafter DSEIS).

<sup>2</sup> DSEIS at 311. BLM finds, after a substitution analysis using the MarketSim model, that the action alternatives will result in 2.14 million metric tons more of CO<sub>2</sub>e emissions compared to the no-action alternative. The substitution analysis is problematic because, among other limitations, it does not reflect changes in greenhouse gas emissions relating to the reduction in foreign oil consumption as oil imports into the United States substitute for forgone domestic production. See DSEIS Appendix H, section 2-10 (indicating that the greenhouse gas impacts associated with a reduction of as much as 6 billion barrels of foreign consumption, as well as an unquantified reduction in foreign consumption of natural gas, “are not captured in this analysis”); see also generally Appendix H, section 2 (listing other problematic assumptions, including: that demand for oil will remain nearly constant over the next 70 years, that engines will not become more efficient, and that all oil is consumed domestically).

reasonable range of discount rates and a central estimate using a 3% discount rate, as well as a consensus that certain discount rates (like 7%) are not appropriate. Third, BLM cites the Electric Power Research Institute's critiques of the IWG's methodology as proof that the tool is flawed, in particular taking issue with the three integrated assessment models. In reality, the use of multiple models is part of what makes the IWG estimates reliable and why they remain the best available figures (despite the fact that the IWG's guidance was rescinded by Executive Order 13,783). Fourth, BLM falsely claims that the social cost of greenhouse gases "does not measure the actual incremental impacts of a project,"<sup>3</sup> even though the social cost of greenhouse gases was precisely designed to do just that. Fifth, BLM says that because the social cost of greenhouse gases does not take into account "all damages or benefits from carbon emissions" or the "social benefits of energy production," using the global social cost of greenhouse gases estimates "would be unbalanced and of limited use to the decision-maker."<sup>4</sup> To the extent the social cost of greenhouse gases omits some currently unquantifiable impacts of emissions, it is widely accepted that those omissions result in a significant underestimate of the true climate damages of greenhouse gas emissions. Additionally, the market value of the natural resources recovered under the project already reflects all the benefits of energy production, in the form of consumers' willingness to pay for the resources. Whether or not BLM conducts a complete cost-benefit analysis of the project, NEPA requires the agency to provide sufficient informational context on climate damages, and an estimate of just the tons of emissions without any context or detail on the corresponding climate damages fails to satisfy BLM's obligations under NEPA.

These comments explain why each of BLM's reasons for not using the social cost of greenhouse gases in the DSEIS fails, and why the DSEIS leaves the public and decisionmakers in the dark about the climate effects of the project, in violation of NEPA. Specifically:

1. BLM refuses to use the social cost of greenhouse gases protocol, but also fails to provide a detailed accounting of the project's climate impacts. **NEPA requires a "reasonably thorough discussion" and "necessary contextual information" on climate impacts.** The social cost of greenhouse gases provides such information, while the mere recitation of so many tons of carbon that will be emitted by the project fails to provide the public and decisionmakers with the required information. Moreover, when an agency monetizes a project's economic benefits—as BLM does here—the potential climate costs must be treated with proportional rigor.
2. BLM claims that the social cost of greenhouse gases does not illuminate the incremental climate effects of emissions. However, **the social cost of greenhouse gases metric is appropriate for monetizing the climate impacts of a project-level EIS with emissions of this magnitude.** The metric can be applied to any action that significantly increases greenhouse gas emissions, not just to rulemakings. The uncertainty around factors like catastrophic outcomes that cannot currently be fully monetized is not a reason not to use the metric, but rather a reason to treat available values as lower-bound estimates of the true climate costs of emissions.
3. **The Interagency Working Group's 2016 estimates of the social cost of greenhouse gases remain the best available values for Federal Agencies to use in analyses.** Furthermore, a consensus has developed around use of the "central" 3-percent discount rate or a declining discount rate and the IWG's use of multiple models makes the estimates more reliable, rather than less.

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<sup>3</sup> *Id.*

<sup>4</sup> *Id.*

Below, we discuss each of these points in turn.

### **1. NEPA Requires a “Reasonably Thorough Discussion” and “Necessary Contextual Information” on Climate Impacts, Which the Social Cost of Greenhouse Gases Provides**

BLM fails to discuss the actual climate impacts of the project, even though it quantifies the tons of direct and indirect greenhouse gas emissions. BLM neither quantitatively nor qualitatively discusses the damages to which these additional tons of greenhouse gases would contribute. Meanwhile, BLM has monetized effects like billions of dollars’ worth in royalties.<sup>5</sup> Failing to similarly monetize the climate costs of the project is inconsistently arbitrary and deprives the public and decisionmakers of the information and context they need to weigh all the project’s potential effects.

#### ***NEPA Requires Monetizing Climate Effects If Other Costs and Benefits Are Monetized***

NEPA requires “hard look” consideration of beneficial and adverse effects of each alternative option for major federal government actions. The U.S. Supreme Court has called the disclosure of impacts the “key requirement of NEPA,” and held that agencies must “consider and disclose the actual environmental effects” of a proposed project in a way that “brings those effects to bear on [the agency’s] decisions.”<sup>6</sup> Courts have repeatedly concluded that an EIS must disclose relevant climate effects.<sup>7</sup> Though NEPA does not require a formal cost-benefit analysis,<sup>8</sup> agencies’ approaches to assessing costs and benefits must be balanced and reasonable. Courts have warned agencies that “[e]ven though NEPA does not require a cost-benefit analysis,” an agency cannot selectively monetize benefits in support of its decision while refusing to monetize the costs of its action.<sup>9</sup>

In *High Country Conservation Advocates v. Forest Service*, the U.S. District Court of Colorado found that it was “arbitrary and capricious to quantify the *benefits* of the lease modifications and then explain that a similar analysis of the *costs* was impossible when such an analysis was in fact possible.”<sup>10</sup> The court explained that, to support a decision on coal mining activity, the agencies had “weighed several specific economic benefits—coal recovered, payroll, associated purchases of supplies and services, and royalties,” but arbitrarily failed to monetized climate costs using the readily available social cost of carbon protocol.<sup>11</sup> Similarly, in *Montana Environmental Information Center v. Office of Surface Mining (MEIC v. OSM)*, the U.S. District Court of Montana followed the lead set by *High Country* and likewise held an environmental assessment to be arbitrary and capricious because it quantified the benefits of action (such as employment payroll, tax revenue, and royalties) while failing to use the social cost of carbon to quantify the costs.<sup>12</sup>

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<sup>5</sup> DSEIS at 403.

<sup>6</sup> *Baltimore Gas & Elec. Co. v. Natural Res. Def. Council*, 462 U.S. 87, 96 (1983).

<sup>7</sup> As the Ninth Circuit has held: “[T]he fact that climate change is largely a global phenomenon that includes actions that are outside of [the agency’s] control . . . does not release the agency from the duty of assessing the effects of *its* actions on global warming within the context of other actions that also affect global warming.” *Ctr. for Biological Diversity v. Nat’l Highway Traffic Safety Admin.*, 538 F.3d 1172, 1217 (9th Cir. 2008); see also *Border Power Plant Working Grp. v. U.S. Dep’t of Energy*, 260 F. Supp. 2d 997, 1028-29 (S.D. Cal. 2003) (failure to disclose project’s indirect carbon dioxide emissions violates NEPA).

<sup>8</sup> 40 C.F.R. § 1502.23 (“[T]he weighing of the merits and drawbacks of the various alternatives need not be displayed in a monetary cost-benefit analysis.”).

<sup>9</sup> *High Country Conservation Advocates v. Forest Service*, 52 F. Supp. 3d 1174, 1191 (D. Colo. 2014); accord. *MEIC v. Office of Surface Mining*, 15-106-M-DWM, at 40-46 (D. Mt., August 14, 2017) (holding it was arbitrary for the agency to quantify benefits in an EIS while failing to use the social cost of carbon to quantify costs, as well as arbitrary to imply there would be no effects from greenhouse gas emissions).

<sup>10</sup> 52 F. Supp. 3d at 1191.

<sup>11</sup> *Id.*

<sup>12</sup> 15-106-M-DWM, at 40-46, Aug. 14, 2017 (also holding that it was arbitrary to imply that there would be zero effects from greenhouse gas emissions).

Both *High Country* and *MEIC v. OSM* were in line with *Center for Biological Diversity v. National Highway Traffic Safety Administration*.<sup>13</sup> In that case, the U.S. Court of Appeals for the Ninth Circuit ruled that, because the agency had monetized other uncertain costs and benefits of its vehicle fuel efficiency standard—like traffic congestion and noise costs—its “decision not to monetize the benefit of carbon emissions reduction was arbitrary and capricious.”<sup>14</sup> Specifically, it was arbitrary to “assign[ ] no value to *the most significant benefit* of more stringent [vehicle fuel efficiency] standards: reduction in carbon emissions.”<sup>15</sup> When an agency bases a rulemaking on cost-benefit analysis, it is arbitrary to “put a thumb on the scale by undervaluing the benefits and overvaluing the costs.”<sup>16</sup>

In this DSEIS, BLM monetizes the same economic benefits as in *MEIC v. OSM*—billions of dollars of taxes, and royalties<sup>17</sup>—and so is required to be consistent in monetizing other significant effects, including climate costs. Notably, BLM touts the “benefits” of the “overall cumulative economic impacts resulting from increased development.”<sup>18</sup> It is arbitrary to fail to similarly monetize the climate costs of the increased development.

Moreover, in obligating agencies to take “hard look” at projects’ climate impacts, NEPA requires more than simply disclosing the volume of anticipated emissions.<sup>19</sup> As discussed further below, under NEPA, agencies must provide details on discrete effects of a project’s impacts within the relevant context. The social cost of greenhouse gases provides this critical information.

***The Social Cost of Greenhouse Gases Reflects the Value of Discrete Climate Damages, and Gives Necessary Context to Climate Damages***

BLM claims that “the social cost of carbon protocol does not measure the actual incremental impacts of a project on the environment”<sup>20</sup> to justify its decision not to use the metric to monetize the climate change impacts. This position reveals a misunderstanding of the design and proper application of the social cost of greenhouse gases protocol. Not only is the social cost of greenhouse gas methodology ideally suited for valuing the marginal climate damages of individual projects, but the monetization directly reflects the “actual incremental impacts” of emissions on climate change. Monetization is actually a more useful way under NEPA to present the information to decisionmakers and the public than a qualitative description of discrete effects or a mere tallying of the tons of emissions.

The social cost of greenhouse gases directly reflects the discrete effects of climate change.<sup>21</sup> The three integrated assessment models used to calculate the social cost of greenhouse gases together incorporate such damage categories as: agricultural and forestry impacts, coastal impacts due to sea level rise, impacts to the energy and water sectors, impacts from extreme weather events, vulnerable market sectors impacted by changes in energy use, human health impacts including malaria and

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<sup>13</sup> Three other cases from different courts that have declined to rule against failures to use the social cost of carbon in NEPA analyses are all distinguishable by the scale of the action or by whether other effects were quantified and monetized in the analysis. See *League of Wilderness Defenders v. Connaughton*, No. 3:12-cv-02271-HZ (D. Ore., Dec. 9, 2014); *EarthReports v. FERC*, 15-1127, (D.C. Cir. July 15, 2016); *WildEarth Guardians v. Zinke*, 1:16-CV-00605-RJ, at 23-24, (D. N.M. Feb. 16, 2017).

<sup>14</sup> 538 F.3d 1172, 1203 (9th Cir. 2008).

<sup>15</sup> *Id.* at 1199.

<sup>16</sup> *Id.* at 1198.

<sup>17</sup> DEIS at 403.

<sup>18</sup> DEIS at 384. “...the GMT2 Project will provide economic benefits for the community of Nuiqsut, for the Kuukpik Corporation, for Arctic Slope Regional Corporate, the North Slope Borough, and the State of Alaska.”

<sup>19</sup> *Supra* notes 6-7.

<sup>20</sup> DEIS at 311.

<sup>21</sup> As a comparison, while a carbon price developed for a carbon tax arguably measures the value of a constrained resource (i.e., carbon emission allowances), the integrated assessment models used to calculate the social cost of greenhouse gases directly measures climate damages.

pollution, outdoor recreation impacts and other non-market amenities, impacts to human settlements and ecosystems, and some catastrophic impacts.<sup>22</sup> Though some important damage categories are currently omitted due to insufficient data and modeling,<sup>23</sup> the integrated assessment models do a reasonable job of capturing many of the discrete climate effects that decisionmakers and the public care about.

Monetizing climate damages provides the informational context required by NEPA, while a purely quantitative estimate of tons or a qualitative description of discrete climate effects like sea-level rise provide little context. Courts review NEPA documents “under an arbitrary and capricious standard,” which requires “a reasonably thorough discussion of the significant aspects of the probable environmental consequences,” to “foster both informed decisionmaking and informed public participation.”<sup>24</sup> In particular, “the impact of greenhouse gas emissions on climate change is precisely the kind of cumulative impact analysis that NEPA requires,” and it is arbitrary to fail to “provide the necessary contextual information about the cumulative and incremental environmental impacts.”<sup>25</sup>

To “provide the necessary contextual information,” economic theory shows that one useful tool is monetization of environmental impacts. As Professor Cass Sunstein has explained, drawing from the work of recent Nobel laureate economist Richard Thaler, a well-documented mental heuristic called “probability neglect” causes people to irrationally reduce small probability risks entirely down to zero.<sup>26</sup> Yet the monetized expected cost of the climate risks associated with even relatively small increases in overall emissions, which could be hundreds of millions of dollars, is less likely overlooked. As the Environmental Protection Agency’s website explains, “abstract measurements” of so many tons of greenhouse gases can be rather inscrutable for the public, unless “translat[ed] . . . into concrete terms you can understand.”<sup>27</sup> Monetization contextualizes the significance of the additional tons of emissions. BLM is required by NEPA to provide enough context to ensure that the public and decisionmakers would not overlook the associated climate risks. Monetization is one way that BLM could provide the necessary context to foster both informed decisionmaking and informed public participation.<sup>28</sup>

Similarly, non-monetized effects are often irrationally treated as worthless.<sup>29</sup> On several occasions, courts have struck down administrative decisions for failing to give weight to non-monetized effects.<sup>30</sup> Most relevantly, in *Center for Biological Diversity v. NHTSA*, the U.S. Court of Appeals for the Ninth

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<sup>22</sup> See descriptions of the IAMs at pages 6-8 of the Interagency Working Group on the Social Cost of Carbon’s 2010 Technical Support Document.

<sup>23</sup> Peter Howard, *Omitted Damages: What’s Missing from the Social Cost of Carbon* (2014), available at [https://costofcarbon.org/files/Omitted\\_Damages\\_Whats\\_Missing\\_From\\_the\\_Social\\_Cost\\_of\\_Carbon.pdf](https://costofcarbon.org/files/Omitted_Damages_Whats_Missing_From_the_Social_Cost_of_Carbon.pdf).

<sup>24</sup> *Ctr. for Biological Diversity*, 538 F.3d at 1194 (citations omitted). See also *Montana Env’tl. Info. Ctr. v. Office of Surface Mining*, cv 15-106-M-DWM, at 12-13 (D.Mt., Aug. 14, 2017).

<sup>25</sup> *Ctr. for Biological Diversity*, 538 F.3d at 1217; see also *Montana Env’tl. Info. Ctr.*, cv 15-106-M-DWM at 45.

<sup>26</sup> Cass R. Sunstein, *Probability Neglect: Emotions, Worst Cases, and Law*, 112 Yale L. J. 61, 63, 72 (2002).

<sup>27</sup> EPA, Greenhouse Gas Equivalencies Calculator, <https://web.archive.org/web/20180212182940/https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator> (last updated Sept. 2017).

<sup>28</sup> While the regulations promulgated by the Council on Environmental Quality to implement NEPA do not require a “monetary cost-benefit analysis,” 40 C.F.R. § 1502.23, monetization nevertheless remains an available tool for contextualizing information. As the Council on Environmental Quality has explained, monetization may be “appropriate and relevant” and, in particular, “the Federal social cost of carbon . . . provides a harmonized, interagency metric that can give decision makers and the public useful information for their NEPA review.” CEQ, *Final Guidance on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews* 32-33 & fn.86 (2016), available at [https://obamawhitehouse.archives.gov/sites/whitehouse.gov/files/documents/nepa\\_final\\_ghg\\_guidance.pdf](https://obamawhitehouse.archives.gov/sites/whitehouse.gov/files/documents/nepa_final_ghg_guidance.pdf).

<sup>29</sup> Richard Revesz, *Quantifying Regulatory Benefits*, 102 Cal. L. Rev. 1424, 1434-35, 1442 (2014).

<sup>30</sup> See *id.* at 1428, 1434.

Circuit found it arbitrary and capricious to give zero value “to the most significant benefit of more stringent [fuel economy] standards: reduction in carbon emissions.”<sup>31</sup>

Finally, the social cost of greenhouse gas metric provides useful context even without a full cost-benefit analysis. BLM argues that without a complete cost-benefit analysis, including the so-called “social benefits of energy production,” applying the social cost of greenhouse gases would be inappropriate and inaccurate.<sup>32</sup> BLM is wrong. To begin, while the agency does not define what it means by “the social benefits of energy production,” basic economic theory dictates that the value of fossil fuels in the marketplace already is the best approximation of how much consumers value the welfare they derive from using the energy generated by fossil fuels. And the DSEIS already includes several monetized metrics relating to the value of coal in the marketplace. For example, BLM calculates \$1.45 billion in federal and state royalties which, at a 16.67% royalty rate on wellhead value for high oil potential areas,<sup>33</sup> would imply an approximate value in the marketplace of the fossil fuels produced at around \$8.7 billion. In short, the DSEIS already contains monetized values relating to the value to consumers of the energy production.

Regardless, whether or not an agency attempts to conduct a full cost-benefit analysis, NEPA requires that agencies disclose environmental effects with sufficient detail and context. As this section has explained, simply tallying the volume of emissions fails to give the public and decisionmakers the required information about the magnitude of discrete climate effects from those emissions. The social cost of greenhouse gas metric provides that necessary context.

## **2. The Interagency Working Group Estimates Remain the Best Available Values for Federal Agencies to Use in Analyses**

BLM makes faulty claims about the integrated assessment models underlying the IWG social cost of greenhouse gases protocol and tries to discredit the tool by asserting that there is disagreement on the appropriate discount rate to use.<sup>34</sup> However, the IWG’s social cost of greenhouse gas estimates remain the best available assessments for Federal Agencies to use in evaluating climate impacts.

In 2016, IWG published updated central estimates for the social cost of greenhouse gases: \$50 per ton of carbon dioxide, \$1440 per ton of methane, and \$18,000 per ton of nitrous oxide (in 2017 dollars for year 2020 emissions).<sup>35</sup> Notwithstanding the recent Executive Order disbanding the IWG, the estimates updated by that group in 2016 are still the best estimates of the lower bound of the social cost of greenhouse gases, reflecting current best practices and best scientific and economic literature. Agencies should continue to use estimates of a similar or higher value<sup>36</sup> in their regulatory analyses and environmental impact statements. In particular, when estimating the social cost of greenhouse gases, agencies should use multiple peer-reviewed models, a global estimate of climate damages, and a 3% or lower discount rate for the central estimate.

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<sup>31</sup> 538 F.3d at 1199.

<sup>32</sup> DSEIS at 311.

<sup>33</sup> DSEIS at 398, 403.

<sup>34</sup> DEIS at 311.

<sup>35</sup> U.S. Interagency Working Group on the Social Cost of Greenhouse Gases (IWG), “Technical support document: Technical update of the social cost of carbon for regulatory impact analysis under executive order 12866 & Addendum: Application of the methodology to estimate the social cost of methane and the social cost of nitrous oxide” (2016); <https://obamawhitehouse.archives.gov/omb/oira/social-cost-of-carbon>.

<sup>36</sup> See Richard L. Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 SCIENCE 6352 (2017) (explaining that, even after Trump’s Executive Order, the social cost of greenhouse gas estimate of around \$50 per ton of carbon dioxide is still the best estimate).

### ***New Executive Order Encourages Continued Monetization of the Social Cost of Greenhouse Gases***

Executive Order 13,783 officially disbanded the IWG and withdrew its technical support documents that underpinned their range of estimates.<sup>37</sup> Nevertheless, Executive Order 13,783 assumes that federal agencies will continue to “monetiz[e] the value of changes in greenhouse gas emissions” and instructs agencies to ensure such estimates are “consistent with the guidance contained in OMB Circular A-4.”<sup>38</sup> Consequently, while BLM and other federal agencies no longer benefit from ongoing technical support from the IWG on use of the social cost of greenhouse gases, by no means does the new Executive Order imply that agencies should not monetize important effects in their regulatory analyses or environmental impact statements. In fact, Circular A-4 instructs agencies to monetize costs and benefits whenever feasible.<sup>39</sup> The Executive Order does not prohibit agencies from relying on the same choice of models as the IWG, the same inputs and assumptions as the IWG, the same statistical methodologies as the IWG, or the same ultimate values as derived by the IWG. To the contrary, because the Executive Order requires consistency with Circular A-4, as agencies follow the Circular’s standards for using the best available data and methodologies, they will necessarily choose similar data, methodologies, and estimates as the IWG, since the IWG’s work continues to represent the best available estimates.<sup>40</sup> The Executive Order does not preclude agencies from using the same range of estimates as developed by the IWG, so long as the agency explains that the data and methodology that produced those estimates are consistent with Circular A-4 and, more broadly, with standards for rational decisionmaking.

Similarly, the Executive Order’s withdrawal of the CEQ guidance on greenhouse gases does not—and legally cannot—remove agencies’ statutory requirement to fully disclose the environmental impacts of greenhouse gas emissions. As CEQ explained in its withdrawal, the “guidance was not a regulation,” and “[t]he withdrawal of the guidance does not change any law, regulation, or other legally binding requirement.”<sup>41</sup> In other words, when the guidance originally recommended the appropriate use of the social cost of greenhouse gases in environmental impact statements,<sup>42</sup> it was simply explaining that the social cost of greenhouse gases is consistent with longstanding NEPA regulations and case law, all of which are still in effect today.

Notably, some agencies under the Trump administration have continued to use the IWG estimates even following the Executive Order. For example, in August 2017, the Bureau of Ocean Energy Management called the social cost of carbon “a useful measure” and applied it to analyze the consequences of offshore oil and gas drilling,<sup>43</sup> and in July 2017, the Department of Energy used the Interagency Working

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<sup>37</sup> Exec. Order. No. 13,783 § 5(b), 82 Fed. Reg. 16,093 (Mar. 28, 2017).

<sup>38</sup> *Id.* § 5(c).

<sup>39</sup> OMB, Circular A-4 at 27 (2003) (“You should monetize quantitative estimates whenever possible.”).

<sup>40</sup> Richard L. Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 SCIENCE 6352 (2017) (explaining that, even after Trump’s Executive Order, the social cost of greenhouse gas estimate of around \$50 per ton of carbon dioxide is still the best estimate).

<sup>41</sup> 82 Fed. Reg. 16,576, 16,576 (Apr. 5, 2017).

<sup>42</sup> See CEQ, *Revised Draft Guidance on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews* at 16 (Dec. 2014), available at [https://obamawhitehouse.archives.gov/sites/default/files/docs/nepa\\_revised\\_draft\\_ghg\\_guidance\\_searchable.pdf](https://obamawhitehouse.archives.gov/sites/default/files/docs/nepa_revised_draft_ghg_guidance_searchable.pdf) (“When an agency determines it appropriate to monetize costs and benefits, then, although developed specifically for regulatory impact analyses, the Federal social cost of carbon, which multiple Federal agencies have developed and used to assess the costs and benefits of alternatives in rulemakings, offers a harmonized, interagency metric that can provide decisionmakers and the public with some context for meaningful NEPA review. When using the Federal social cost of carbon, the agency should disclose the fact that these estimates vary over time, are associated with different discount rates and risks, and are intended to be updated as scientific and economic understanding improves.”); see also CEQ, *Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews* at 33 n.86 (Aug. 2016), available at [https://obamawhitehouse.archives.gov/sites/whitehouse.gov/files/documents/nepa\\_final\\_ghg\\_guidance.pdf](https://obamawhitehouse.archives.gov/sites/whitehouse.gov/files/documents/nepa_final_ghg_guidance.pdf).

<sup>43</sup> Draft Env’tl. Impact Statement: Liberty Development Project at 3-129, 4-246 (Aug. 2017).

Group's 2016 estimates for carbon and methane emissions to analyze energy efficiency regulation, describing the social cost of methane as having "undergone multiple stages of peer review."<sup>44</sup>

***Agencies Must Not Rely on a Single Model, but Must Use Multiple, Peer-Reviewed Models***

BLM cites a report from the industry-backed Electric Power Research Institute to cast doubt on the IWG's choice of three underlying models. In fact, as the National Academies of Sciences, the Government Accountability Office, and other reviewers have confirmed, the IWG's made a transparent selection of the most peer-reviewed models available, and the use of multiple models balances out the limitations of any single model.

Since the IWG first issued the federal social cost of carbon protocol in 2010, its methodology has relied on the three most cited, most peer-reviewed integrated assessment models (IAMs). These three IAMs—called DICE (the Dynamic Integrated Model of Climate and the Economy<sup>45</sup>), FUND (the Climate Framework for Uncertainty, Negotiation, and Distribution<sup>46</sup>), and PAGE (Policy Analysis of the Greenhouse Effect<sup>47</sup>)—draw on the best available scientific and economic data to link physical impacts to the economic damages of each marginal ton of greenhouse gas emissions. Each model translates emissions into changes in atmospheric greenhouse gas concentrations, atmospheric concentrations into temperature changes, and temperature changes into economic damages, which can then be adjusted according to a discount rate. These three models have been combined with inputs derived from peer-reviewed literature on climate sensitivity, socio-economic and emissions trajectories, and discount rates. The results of the three models have been given equal weight in federal agencies' estimates and have been run through statistical techniques like Monte Carlo analysis to account for uncertainty.

In a 2017 report, the National Academies of Sciences (NAS) recommended future improvements to this methodology. Specifically, over the next five years the NAS recommends unbundling the four essential steps in the IAMs into four separate "modules": a socio-economic and emissions scenario module, a climate change module, an economic damage module, and a discount rate module.<sup>48</sup> Unbundling these four steps into separate modules could allow for easier, more transparent updates to each individual component in order to better reflect the best available science and capture the full range of uncertainty in the literature. These four modules could be built from scratch or drawn from the existing IAMs. Either way, the integrated modular framework envisioned by NAS for the future will require significant time and resource commitments from federal agencies.

In the meantime, the NAS has supported the continued near-term use of the existing social cost of greenhouse gas estimates based on the DICE, FUND, and PAGE models, as used by federal agencies to

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<sup>44</sup> Energy Conservation Program: Energy Conservation Standards for Walk-In Cooler and Freezer Refrigeration Systems, 82 Fed. Reg. 31,808, 31,811, 31,857 (July 10, 2017).

<sup>45</sup> William D. Nordhaus, *Estimates of the social cost of carbon: concepts and results from the DICE-2013R model and alternative approaches*, 1 JOURNAL OF THE ASSOCIATION OF ENVIRONMENTAL AND RESOURCE ECONOMISTS 1 (2014).

<sup>46</sup> 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>.

<sup>47</sup> Chris Hope, *The Marginal Impact of CO<sub>2</sub> from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern*, 6 INTEGRATED ASSESSMENT J. 19 (2006).

<sup>48</sup> Nat'l Acad. Sci., Eng. & Medicine, *Valuing Climate Damages: Updating Estimates of the Social Cost of Carbon Dioxide 3* (2017) [hereinafter "NAS, Second Report"] (recommending an "integrated modular approach").



date.<sup>49</sup> In short, DICE, FUND, and PAGE continue to represent the state-of-the-art models.<sup>50</sup> The Government Accountability Office found in 2014 that the estimates derived from these models and used by federal agencies are consensus-based, rely on peer-reviewed academic literature, disclose relevant limitations, and are designed to incorporate new information via public comments and updated research.<sup>51</sup> In fact, the social cost of greenhouse gas estimates used in federal regulatory proposals and EISs have been subject to over 80 distinct public comment periods.<sup>52</sup> The economics literature confirms that estimates based on these three IAMs remain the best available estimates.<sup>53</sup> In 2016, the U.S. Court of Appeals for the Seventh Circuit held the estimates used to date by agencies are reasonable.<sup>54</sup> In 2017, the District of Montana rejected an agency's Environmental Assessment for failure to incorporate the federal social cost of carbon estimates into its cost-benefit analysis of a proposed mine expansion.<sup>55</sup>

Regardless of Executive Order 13,783's withdrawal of the guidance requiring federal agencies to rely on IWG's technical support documents to estimate the social cost of greenhouse gases, IWG's choice of DICE, FUND, and PAGE, its use of inputs and assumptions, and its statistical analysis still represent the state-of-the-art approach based on the best available, peer-reviewed literature. This approach satisfies Circular A-4's requirements for information quality and transparency. Therefore, in complying with the Executive Order's instructions to ensure that social cost of greenhouse gas estimates are consistent with Circular A-4, agencies will necessarily have to rely on models like DICE, FUND, and PAGE, to use the same or similar inputs and assumptions as the IWG, and to apply statistical analyses like Monte Carlo.

The unavoidable fact is that DICE, FUND, and PAGE are still the dominant, most peer-reviewed models,<sup>56</sup> and most estimates in the literature continue to rely on those models.<sup>57</sup> Each of these models has been developed over decades of research, and has been subject to rigorous peer review, documented in the published literature. While other models exist, they lack DICE's, FUND's, and PAGE's long history of peer review or exhibit other limitations. For example, the World Bank has created ENVISAGE, which models a more detailed breakdown of market sectors,<sup>58</sup> but unfortunately does not account for non-market

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<sup>49</sup> Specifically, NAS concluded that a near-term update was not necessary or appropriate and the current estimates should continue to be used while future improvements are developed over time. Nat'l Acad. Sci., Eng. & Medicine, *Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update 1* (2016) [hereinafter "NAS, First Report"].

<sup>50</sup> See also Robert Pindyck & James Stock, *We Don't Know What Climate Change Will Cost—That Doesn't Mean We Can Ignore It*, The Hill, May 9, 2018, <http://thehill.com/opinion/energy-environment/386952-we-dont-know-what-climate-change-will-cost-that-doesnt-mean-we-can>.

<sup>51</sup> Gov't Accountability Office, *Regulatory Impact Analysis: Development of Social Cost of Carbon Estimates* (2014).

<sup>52</sup> Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 Columbia J. Envtl. L. 203, at Appendix A (2017).

<sup>53</sup> E.g., Richard G. Newell et al., *Carbon Market Lessons and Global Policy Outlook*, 343 SCIENCE 1316 (2014); Bonnie L. Keeler et al., *The Social Costs of Nitrogen*, 2 SCIENCE ADVANCES e1600219 (2016); Richard L. Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, 508 NATURE 173 (2014) (co-authored with Nobel Laureate Kenneth Arrow, among others).

<sup>54</sup> *Zero Zone*, 832 F.3d at 678-79 (7<sup>th</sup> Cir. 2016) (finding that the agency "acted reasonably" in using global estimates of the social cost of carbon, and that the estimates chosen were not arbitrary or capricious).

<sup>55</sup> *Montana Environmental Information Center*, 2017 WL 3480262, at \*12-15, 19.

<sup>56</sup> See Interagency Working Group on the Social Cost of Carbon, *Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12,866* at 7 (July 2015) ("DICE, FUND, and PAGE are the most widely used and widely cited models in the economic literature that link physical impacts to economic damages for the purposes of estimating the SCC."), citing Nat'l Acad. Sci., Eng. & Medicine, *Hidden Cost of Energy: Unpriced Consequences of Energy Production and Use* (2010) ("the most widely used impact assessment models").

<sup>57</sup> R.S. Tol, *The Social Cost of Carbon*, 3 Annual Rev. Res. Econ. 419 (2011); T. Havranek et al., *Selective Reporting and the Social Cost of Carbon*, 51 Energy Econ. 394 (2015).

<sup>58</sup> World Bank, *The Environmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) Model* (2008), available at <http://siteresources.worldbank.org/INTPROSPECTS/Resources/334934-1193838209522/Envisage7b.pdf>.

impacts and so would omit a large portion of significant climate effects. Models like ENVISAGE are therefore not currently appropriate choices under the criteria of Circular A-4.<sup>59</sup>

An approach based on multiple, peer-reviewed models (like DICE, FUND, and PAGE) is more rigorous and more consistent with Circular A-4 than reliance on a single model or estimate. DICE, FUND, and PAGE each include many of the most significant climate effects, use appropriate discount rates and other assumptions, address uncertainty, are based on peer-reviewed data, and are transparent.<sup>60</sup> However, each IAM also has its own limitations and is sensitive to its own assumptions. No model fully captures all the significant climate effects.<sup>61</sup> By giving weight to multiple models—as the IWG did—agencies can balance out some of these limitations and produce more robust estimates.<sup>62</sup>

Finally, while agencies should be careful not to cherry-pick a single estimate from the literature, it is noteworthy that various estimates in the literature are consistent with the numbers derived from a weighted average of DICE, FUND, and PAGE—namely, with a central estimate of about \$40 per ton of carbon dioxide, and a high-percentile estimate of about \$120, for year 2015 emissions (in 2016 dollars, at a 3% discount rate). The latest central estimate from DICE’s developers is \$87 (at a 3% discount rate);<sup>63</sup> from FUND’s developers, \$12;<sup>64</sup> and from PAGE’s developers, \$123, with a high-percentile estimate of \$332.<sup>65</sup>

In fact, much of the literature suggests that a central estimate of \$40 per ton is a very conservative underestimate. A 2013 meta-analysis of the broader literature found a mean estimate of \$59 per ton of carbon dioxide,<sup>66</sup> and a soon-to-be-published update by the same author finds a mean estimate of \$108 (at a 1% discount rate).<sup>67</sup> A 2015 meta-analysis—which sought out estimates besides just those based on DICE, FUND, and PAGE—found a mean estimate of \$83 per ton of carbon dioxide.<sup>68</sup> Various studies relying on expert elicitation<sup>69</sup> from a large body of climate economists and scientists have found mean estimates of \$50 per ton of carbon dioxide,<sup>70</sup> \$96-\$144 per ton of carbon dioxide,<sup>71</sup> and \$80-\$100 per

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<sup>59</sup> Similarly, Intertemporal Computable Equilibrium System (ICES) does not account for non-market impacts. See <https://www.cmcc.it/models/ices-intertemporal-computable-equilibrium-system>. Other models include CRED, which is worthy of further study for future use. Frank Ackerman, Elizabeth A. Stanton & Ramón Bueno, *CRED: A New Model of Climate and Development*, 85 *ECOLOGICAL ECONOMICS* 166 (2013). Accounting for omitted impacts more generally, E.A. Stanton, F. Ackerman, R. Bueno, *Reason, Empathy, and Fair Play: The Climate Policy Gap*, (Stockholm Environment Inst. Working Paper 2012-02), find a doubling of the SCC using the CRED model.

<sup>60</sup> While sensitivity analysis can address parametric uncertainty within a model, using multiple models helps address structural uncertainty.

<sup>61</sup> See Peter Howard, *Omitted Damages: What’s Missing from the Social Cost of Carbon* 5 (Cost of Carbon Project Report, 2014), <http://costofcarbon.org/>.

<sup>62</sup> Moore, F., Baldos, U., & Hertel, T. (2017). Economic impacts of climate change on agriculture: a comparison of process-based and statistical yield models. *Environmental Research Letters*.

<sup>63</sup> William D Nordhaus, *Revisiting the social cost of carbon*, 114 *PROC. NATL. ACAD. SCI. U. S. A.* 1518–1523 (2017) (estimate a range of \$21 to \$141).

<sup>64</sup> D. Anthoff & R. Tol, *The Uncertainty about the Social Cost of Carbon: A Decomposition Analysis Using FUND*, 177 *Climatic Change* 515 (2013).

<sup>65</sup> C. Hope, *The social cost of CO2 from the PAGE09 model*, 39 *Economics* (2011); C. Hope, *Critical issues for the calculation of the social cost of CO2*, 117 *Climatic Change*, 531 (2013).

<sup>66</sup> R. Tol, *Targets for Global Climate Policy: An Overview*, 37 *J. Econ. Dynamics & Control* 911 (2013).

<sup>67</sup> R. Tol, *Economic Impacts of Climate Change* (Univ. Sussex Working Paper No. 75-2015, 2015).

<sup>68</sup> S. Nocera et al., *The Economic Impact of Greenhouse Gas Abatement through a Meta-Analysis: Valuation, Consequences and Implications in terms of Transport Policy*. 37 *Transport Policy* 31 (2015).

<sup>69</sup> Circular A-4, at 41, supports use of expert elicitation as a valuable tool to fill gaps in knowledge.

<sup>70</sup> Scott Holladay & Jason Schwartz, *Economists and Climate Change* 43 (Inst. Policy Integrity Brief, 2009 (directly surveying experts about the SCC)).

<sup>71</sup> Peter Howard & Derek Sylvan, *The Economic Climate: Establishing Expert Consensus on the Economics of Climate Change* (Inst. Policy Integrity Working Paper 2015/1) (using survey results to calibrate the DICE-2013R damage function).

ton of carbon dioxide.<sup>72</sup> There is a growing consensus in the literature that even the best existing estimates of the social cost of greenhouse gases may severely underestimate the true marginal cost of climate damages.<sup>73</sup> Overall, a central estimate of \$40 per ton of carbon dioxide at a 3% discount rate, with a high-percentile estimate of about \$120 for year 2015 emissions, is consistent with the best available literature; if anything, the best available literature supports considerably higher estimates.<sup>74</sup>

Similarly, a comparison of international estimates of the social cost of greenhouse gases suggests that a central estimate of \$40 per ton of carbon dioxide is a very conservative value. Sweden places the long-term valuation of carbon dioxide at \$168 per ton; Germany calculates a “climate cost” of \$167 per ton of carbon dioxide in the year 2030; the United Kingdom’s “shadow price of carbon” has a central value of \$115 by 2030; Norway’s social cost of carbon is valued at \$104 per ton for year 2030 emissions; and various corporations have adopted internal shadow prices as high as \$80 per ton of carbon dioxide.<sup>75</sup>

Indeed, a number of our organizations have previously commented on ways in which the IWG’s approach could be improved to more accurately reflect the true social cost of greenhouse gases. As discussed in our Technical Appendix on Uncertainty, the IWG’s SCC estimates represents a lower bound by, for example, failing to include a risk premium and only partially modeling tipping points. We strongly encourage further efforts to address these omissions, as well as omitted climate damages more generally. Nevertheless, the IWG’s approach represents the best and most rigorous effort that the U.S. government has engaged in thus far to realistically estimate the social cost of greenhouse gases. We therefore strongly urge EPA to adopt the IWG’s approach for estimating the social cost of carbon, with the understanding that such estimates should be seen as a conservative lower-bound estimate of the true impacts of this pollutant.

### ***There Is Clear Consensus on Using a 3% or Lower (or Declining) Discount Rate as a Central Estimate***

BLM argues that the “wide range” of estimates for the social cost of greenhouse gases and the “disagreement over which discount rate to use” are reasons not to use the metric in this analysis.<sup>76</sup> Not only was this line of thinking rejected by the Ninth Circuit in *Center for Biological Diversity*—“while . . . there is a range of values, the value of carbon emissions reduction is certainly not zero”<sup>77</sup>—but the range of values recommended by the Interagency Working Group<sup>78</sup> and endorsed by the National

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<sup>72</sup> R. Pindyck, *The Social Cost of Carbon Revisited* (Nat’l Bureau of Econ. Res. No. w22807, 2016) (\$80-\$100 is the trimmed range of estimates at a 4% discount rate; without trimming of outlier responses, the estimate is \$200).

<sup>73</sup> E.g., Howard & Sylvan, *supra* note 71; Pindyck, *supra* note 72. The underestimation results from a variety of factors, including omitted and outdated climate impacts (including ignoring impacts to economic growth and tipping points), simplified utility functions (including ignoring relative prices), and applying constant instead of a declining discount rate. See Howard, *supra* note 61; Revesz et al., *supra* notes 25 and 36; J.C. Van Den Bergh & W.J. Botzen, A Lower Bound to the Social Cost of CO2 Emissions, 4 *Nature Climate Change* 253 (2014) (proposing \$125 per metric ton of carbon dioxide in 1995 dollars, or about \$200 in today’s dollars, as the lower bound estimate). See also F.C. Moore & D.B. Diaz, *Temperature Impacts on Economic Growth Warrant Stringent Mitigation Policy*, 5 *Nature Climate Change* 127 (2015) (concluding the SCC may be six times higher after accounting for potential growth impacts of climate change). Accounting for both potential impacts of climate change on economic growth and other omitted impacts, S. Dietz and N. Stern find a two- to seven-fold increase in the SCC. *Endogenous growth, convexity of damage and climate risk: how Nordhaus’ framework supports deep cuts in carbon emissions*. 125 *The Economic Journal* 574 (2015).

<sup>74</sup> Note that the various estimates cited in the paragraph have not all been converted to standard 2017\$, and may not all reflect the same year emissions. Nevertheless, the magnitude of this range suggests that \$40 per ton of year 2015 emissions is a conservative estimate.

<sup>75</sup> See Howard & Schwartz, *supra* note 52, at Appendix B. All these estimates are in 2016\$.

<sup>76</sup> DSEIS at 311.

<sup>77</sup> 538 F.3d at 1200.

<sup>78</sup> See Interagency Working Group on the Social Cost of Greenhouse Gases, *Technical Update* (2016) (hereinafter 2016 TSD).

Academies of Sciences<sup>79</sup> is rather manageable. In 2016, the IWG recommended values at discount rates from 2.5% to 5%, calculated as between \$12 and \$62 for year 2020 emissions.<sup>80</sup> Numerous federal agencies have had no difficulty either applying this range in their environmental impact statements or else focusing on the central estimate at a 3% discount rate.<sup>81</sup> Most recently, in August 2017, the Bureau of Ocean Energy Management applied the IWG's range of estimates calculated at three discount rates (2.5%, 3%, and 5%) to its environmental impact statement for an offshore oil development plan,<sup>82</sup> and called this range of estimates "a useful measure to assess the benefits of CO<sub>2</sub> reductions and inform agency decisions."<sup>83</sup>

More importantly, there is widespread consensus that a central estimate calculated at a 3% or lower discount rate, or else using a declining discount rate, is most appropriate, while a 7% discount rate would be wholly inappropriate in the context of intergenerational climate damages. Because of the long lifespan of greenhouse gases and the long-term or irreversible consequences of climate change, the effects of today's emissions changes will stretch out over the next several centuries. The time horizon for an agency's analysis of climate effects, as well as the discount rate applied to future costs and benefits, determines how an agency treats future generations. Current central estimates of the social cost of greenhouse gases are based on a 3% discount rate and a 300-year time horizon. Executive Order 13,783 disbanded the Interagency Working Group in March 2017 and instructs agencies to reconsider the "appropriate discount rates" when monetizing the value of climate effects.<sup>84</sup> By citing the official guidance on typical regulatory impact analyses (namely, Circular A-4), the Order implicitly called into question the IWG's choice not to use a 7% discount rate. However, use of a 7% discount would not only be inconsistent with best economic practices but would violate NEPA's required consideration of impacts on future generations.

NEPA requires agencies to weigh the "relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity," as well as "any irreversible and irretrievable commitments of resources."<sup>85</sup> That requirement is prefaced with a congressional declaration of policy that explicitly references the needs of future generations:

The Congress, recognizing the profound impact of man's activity on the interrelations of all components of the natural environment . . . declares that it is the continuing policy of the Federal Government . . . to use all practicable means and measures . . . to create and maintain conditions under which man and nature can exist in productive harmony, and

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<sup>79</sup> See National Academies of Sciences, *Assessment of Approaches to Updating the Social Cost of Carbon* (2016) (hereinafter First NAS Report) (endorsing continued near-term use of the IWG numbers; in 2017, the NAS recommended moving to a declining discount rate, see National Academies of Sciences, *Valuing Climate Damages* (2017) (hereinafter Second NAS Report).

<sup>80</sup> 2016 TSD. The values given here are in 2007\$. The IWG also recommended a 95<sup>th</sup> percentile value of \$123.

<sup>81</sup> BLM, *Envtl. Assessment—Waste Prevention, Prod. Subject to Royalties, and Res. Conservation* at 52 (2016); BLM, *Final Env'tl. Assessment: Little Willow Creek Protective Oil and Gas Lease*, DOI-BLM-ID-B010-2014-0036-EA, at 82 (2015); Office of Surface Mining, *Final Env'tl. Impact Statement—Four Corners Power Plant and Navajo Mine Energy Project* at 4.2-26 to 4.2-27 (2015) (explaining the social cost of greenhouse gases "provide[s] further context and enhance[s] the discussion of climate change impacts in the NEPA analysis."); U.S. Army Corps of Engineers, *Draft Env'tl. Impact Statement for the Missouri River Recovery Mgmt. Project* at 3-335 (2016); U.S. Forest Serv., *Rulemaking for Colorado Roadless Areas: Supplemental Final Env'tl. Impact Statement* at 120-123 (Nov. 2016) (using both the social cost of carbon and social cost of methane relating to coal leases); NHTSA EIS, *Available at* [http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/FINAL\\_EIS.pdf](http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/FINAL_EIS.pdf) at 9-77.

<sup>82</sup> BOEM, *Liberty Development Project: Draft Environmental Impact Statement*, at 4-247 (2017).

<sup>83</sup> *Id.* at 3-129.

<sup>84</sup> Executive Order 13,783 § 5(c).

<sup>85</sup> 42 U.S.C. § 4332(2)(C).

fulfill the social, economic, and other requirements of present and **future generations** of Americans.<sup>86</sup>

When the Congressional Conference Committee adopted that language, it reported that the first “broad national goal” under the statute is to “fulfill the responsibilities of each generation as trustee of the environment for future generations. It is recognized in this [congressional] statement [of policy] that each generation has a responsibility to improve, enhance, and maintain the quality of the environment *to the greatest extent possible for the continued benefit of future generations.*”<sup>87</sup>

Because applying a 7% discount rate to the social cost of greenhouse gases could drop the valuation essentially to \$0, use of such a rate effectively ignores the needs of future generations. Doing so would arbitrarily fail to consider an important statutory factor that Congress wrote into the NEPA requirements.

Moreover, a 7% discount rate is inconsistent with best economic practices, including under Circular A-4. In 2015, OMB explained that “Circular A-4 is a **living document**. . . . [T]he use of **7 percent is not considered appropriate** for intergenerational discounting. There is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself.”<sup>88</sup> While Circular A-4 tells agencies generally to use a 7% discount rate in addition to lower rates for typical rules,<sup>89</sup> the guidance does not intend for default assumptions to produce analyses inconsistent with best economic practices. Circular A-4 clearly supports using lower rates to the exclusion of a 7% rate for the costs and benefits occurring over the extremely long, 300-year time horizon of climate effects.

Circular A-4 clearly requires agency analysts to do more than rigidly apply default assumptions: “You cannot conduct a good regulatory analysis according to a formula. Conducting high-quality analysis requires competent professional judgment.”<sup>90</sup> As such, analysis must be “based on the best reasonably obtainable scientific, technical, and economic information available,”<sup>91</sup> and agencies must “[u]se **sound and defensible values** or procedures to monetize benefits and costs, and ensure that key analytical assumptions are defensible.”<sup>92</sup> Rather than assume a 7% discount rate should be applied automatically to every analysis, Circular A-4 requires agencies to justify the choice of discount rates for each analysis: “[S]tate in your report what assumptions were used, *such as . . . the discount rates* applied to future benefits and costs,” and explain “clearly how you arrived at your estimates.”<sup>93</sup> Based on Circular A-4’s criteria, there are numerous reasons why applying a 7% discount rate to climate effects that occur over a 300-year time horizon would be unjustifiable.

First, basing the discount rate on the **consumption rate of interest** is the correct framework for analysis of climate effects; a discount rate based on the private return to capital is inappropriate. Circular A-4 does suggest that 7% should be a “default position” that reflects regulations that primarily displace capital investments; however, the Circular explains that “[w]hen regulation primarily and directly affects private consumption . . . *a lower discount rate is appropriate.*”<sup>94</sup> The 7% discount rate is based on a

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<sup>86</sup> 42 U.S.C.A. § 4331.

<sup>87</sup> See 115 Cong. Rec. 40419 (1969) (emphasis added); see also same in Senate Report 91-296 (1969).

<sup>88</sup> Interagency Working Group on the Social Cost of Carbon, *Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12,866* at 36 (July 2015) [hereinafter, OMB 2015 Response to Comments].

<sup>89</sup> Circular A-4 at 36 (“For regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent....If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent.”).

<sup>90</sup> *Id.* at 3.

<sup>91</sup> *Id.* at 17.

<sup>92</sup> *Id.* at 27 (emphasis added).

<sup>93</sup> *Id.* at 3 (emphasis added).

<sup>94</sup> *Id.* at 33 (emphasis added).

private sector rate of return on capital, but private market participants typically have short time horizons. By contrast, climate change concerns the public well-being broadly. Rather than evaluating an optimal outcome from the narrow perspective of investors alone, economic theory requires analysts to make the optimal choices based on societal preferences and social discount rates. Moreover, because climate change is expected to largely affect large-scale consumption, as opposed to capital investment,<sup>95</sup> a 7% rate is inappropriate.

In 2013, OMB called for public comments on the social cost of greenhouse gases. In its 2015 Response to Comment document,<sup>96</sup> OMB (together with the other agencies from the IWG) explained that

the consumption rate of interest is the correct concept to use . . . as the impacts of climate change are measured in consumption-equivalent units in the three IAMs used to estimate the SCC. This is consistent with OMB guidance in Circular A-4, which states that when a regulation is expected to primarily affect private consumption—for instance, via higher prices for goods and services—it is appropriate to use the consumption rate of interest to reflect how private individuals trade-off current and future consumption.<sup>97</sup>

The Council of Economic Advisers similarly interprets Circular A-4 as requiring agencies to choose the appropriate discount rate based on the nature of the regulation: “[I]n Circular A-4 by the Office of Management and Budget (OMB) the appropriate discount rate to use in evaluating the net costs or benefits of a regulation depends on whether the regulation primarily and directly affects private consumption or private capital.”<sup>98</sup> The NAS also explained that a consumption rate of interest is the appropriate basis for a discount rate for climate effects.<sup>99</sup> For this reason, 7% is an inappropriate choice of discount rate for the impacts of climate change.

Second, **uncertainty over the long time horizon** of climate effects should drive analysts to select a lower discount rate. As an example of when a 7% discount rate is appropriate, Circular A-4 identifies an EPA rule with a 30-year timeframe of costs and benefits.<sup>100</sup> By contrast, greenhouse gas emissions generate effects stretching out across 300 years. As Circular A-4 notes, while “[p]rivate market rates provide a

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<sup>95</sup> “There are two rationales for discounting future benefits—one based on consumption and the other on investment. The consumption rate of discount reflects the rate at which society is willing to trade consumption in the future for consumption today. Basically, we discount the consumption of future generations because we assume future generations will be wealthier than we are and that the utility people receive from consumption declines as their level of consumption increases. . . . The investment approach says that, as long as the rate of return to investment is positive, we need to invest less than a dollar today to obtain a dollar of benefits in the future. Under the investment approach, the discount rate is the rate of return on investment. If there were no distortions or inefficiencies in markets, the consumption rate of discount would equal the rate of return on investment. There are, however, many reasons why the two may differ. As a result, using a consumption rather than investment approach will often lead to very different discount rates.” Maureen Cropper, *How Should Benefits and Costs Be Discounted in an Intergenerational Context?*, 183 *RESOURCES* 30, 33.

<sup>96</sup> Note that this document was not withdrawn by Executive Order 13,783.

<sup>97</sup> OMB 2015 Response to Comments, *supra* note 88, at 22.

<sup>98</sup> Council of Econ. Advisers, *Discounting for Public Policy: Theory and Recent Evidence on the Merits of Updating the Discount Rate* at 1 (CEA Issue Brief, 2017), available at [https://obamawhitehouse.archives.gov/sites/default/files/page/files/201701\\_cea\\_discounting\\_issue\\_brief.pdf](https://obamawhitehouse.archives.gov/sites/default/files/page/files/201701_cea_discounting_issue_brief.pdf). In theory, the two rates would be the same, but “given distortions in the economy from taxation, imperfect capital markets, externalities, and other sources, the SRTP and the marginal product of capital need not coincide, and analysts face a choice between the appropriate opportunity cost of a project and the appropriate discount rate for its benefits.” *Id.* at 9. The correct discount rate for climate change is the social return to capital (i.e., returns minus the costs of externalities), not the private return to capital (which measures solely the returns).

<sup>99</sup> NAS Second Report, *supra* note 79, at 28; see also Kenneth Arrow et al., *Is There a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation?*, 272 *Science* 221 (1996) (explaining that a consumption-based discount rate is appropriate for climate change).

<sup>100</sup> Circular A-4 at 34. See also OMB 2015 Response to Comments, *supra* note 88, at 21 (“While most regulatory impact analysis is conducted over a time frame in the range of 20 to 50 years”).

reliable reference for determining how society values time within a generation, but for extremely long time periods no comparable private rates exist.”<sup>101</sup>

Circular A-4 discusses how uncertainty over long time horizons drives the discount rate lower: “the longer the horizon for the analysis,” the greater the “uncertainty about the appropriate value of the discount rate,” which supports a lower rate.<sup>102</sup> Circular A-4 cites the work of renowned economist Martin Weitzman and concludes that the “certainty-equivalent discount factor corresponds to ***the minimum discount rate having any substantial positive probability***.”<sup>103</sup> The NAS makes the same point about discount rates and uncertainty.<sup>104</sup>

Third, a 7% percent discount rate would be inappropriate for climate change because it is based on **outdated data and diverges from the current economic consensus**. Circular A-4 requires that assumptions—including discount rate choices—are “based on the best reasonably obtainable scientific, technical, and economic information available.”<sup>105</sup> Yet Circular A-4’s own default assumption of a 7% discount rate was published 14 years ago and was based on data from decades ago.<sup>106</sup> Circular A-4’s guidance on discount rates is in need of an update, as the Council of Economic Advisers detailed earlier this year after reviewing the best available economic data and theory:

The discount rate guidance for Federal policies and projects was last revised in 2003. Since then a general reduction in interest rates along with a reduction in the forecast of long-run interest rates, warrants serious consideration for a reduction in the discount rates used for benefit-cost analysis.<sup>107</sup>

In addition to recommending a value below 7% as the discount factor based on private capital returns, the Council of Economic Advisers further explains that, because long-term interest rates have fallen, a discount rate based on the consumption rate of interest “should be at most 2 percent,”<sup>108</sup> which further confirms that applying a 7% rate to a context like climate change would be wildly out of step with the latest data and theory. Similarly, recent expert elicitations—a technique supported by Circular A-4 for filling in gaps in knowledge<sup>109</sup>—indicate that a growing consensus among experts in climate economics for a discount rate between 2% and 3%; 5% represents the upper range of values recommended by experts, and few to no experts support discount rates greater than 5% being applied to the costs and

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<sup>101</sup> Circular A-4 at 36.

<sup>102</sup> *Id.*

<sup>103</sup> *Id.* (emphasis added); see also CEA, *supra* note 98, at 9: “Weitzman (1998, 2001) showed theoretically and Newell and Pizer (2003) and Groom et al. (2007) confirm empirically that discount rate uncertainty can have a large effect on net present values. A main result from these studies is that if there is a persistent element to the uncertainty in the discount rate (e.g., the rate follows a random walk), then it will result in an effective (or certainty-equivalent) discount rate that declines over time. Consequently, lower discount rates tend to dominate over the very long term, regardless of whether the estimated investment effects are predominantly measured in private capital or consumption terms (see Weitzman 1998, 2001; Newell and Pizer 2003; Groom et al. 2005, 2007; Gollier 2008; Summers and Zeckhauser 2008; and Gollier and Weitzman 2010).”

<sup>104</sup> NAS Second Report, *supra* note 79, at 27.

<sup>105</sup> CEQ regulations implementing NEPA similarly require that information in NEPA documents be “of high quality” and states that “[a]ccurate scientific analysis . . . [is] essential to implementing NEPA.” 40 C.F.R. § 1500.1(b).

<sup>106</sup> The 7% rate was based on a 1992 report; the 3% rate was based on data from the thirty years preceding the publication of Circular A-4 in 2003. Circular A-4 at 33.

<sup>107</sup> CEA, *supra* note 98, at 1; *id.* at 3 (“In general the evidence supports lowering these discount rates, with a plausible best guess based on the available information being that the lower discount rate should be at most 2 percent while the upper discount rate should also likely be reduced.”); *id.* at 6 (“The Congressional Budget Office, the Blue Chip consensus forecasts, and the Administration forecasts all place the ten year treasury yield at less than 4 percent in the future, while at the same time forecasting CPI inflation of 2.3 or 2.4 percent per year. The implied real ten year Treasury yield is thus below 2 percent in all these forecasts.”).

<sup>108</sup> *Id.* at 1.

<sup>109</sup> Circular A-4 at 41.

benefits of climate change.<sup>110</sup> Tellingly, none of the integrated assessment models (DICE, FUND, and PAGE) used to build the IWG’s estimates of the social cost of greenhouse gases uses a 7% discount rate. Based on current economic data and theory, the most appropriate discount rate for climate change is 3% or lower.

Fourth, Circular A-4 requires more of analysts than giving all possible assumptions and scenarios equal attention in a sensitivity analysis; if alternate assumptions would fundamentally change the decision, Circular A-4 requires analysts to select the **most appropriate assumptions from the sensitivity analysis**.

Circular A-4 indicates that significant intergenerational effects will warrant a special sensitivity analysis focused on discount rates even lower than 3%:

Special ethical considerations arise when comparing benefits and costs across generations. . . It may not be appropriate for society to demonstrate a similar preference when deciding between the well-being of current and future generations. . . If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent.<sup>111</sup>

Elsewhere in Circular A-4, OMB clarifies that sensitivity analysis should not result in a rigid application of all available assumptions regardless of plausibility. Circular A-4 instructs agencies to depart from default assumptions when special issues “call for different emphases” depending on “the sensitivity of the benefit and cost estimates to the key assumptions.”<sup>112</sup> More specifically:

If benefit or cost estimates depend heavily on certain assumptions, you should make those assumptions explicit and carry out *sensitivity analyses using plausible alternative assumptions*. If the value of net benefits changes from positive to negative (or vice versa) or if the relative ranking of regulatory options changes with alternative plausible assumptions, you should conduct further analysis to determine **which of the alternative assumptions is more appropriate**.<sup>113</sup>

In other words, if using a 7% discount rate would fundamentally change the agency’s decision compared to using a 3% or lower discount rate, the agency must evaluate which assumption is most appropriate. Since OMB, the Council of Economic Advisers, the National Academies of Sciences, and the economic literature all conclude that a 7% rate is inappropriate for climate change, agencies should select a 3% or lower rate. Applying a 7% rate to climate effects cannot be justified “based on the best reasonably obtainable scientific, technical, and economic information available” and is inconsistent with the proper treatment of uncertainty over long time horizons.

Finally, to the extent there is uncertainty around the discount rate over long periods of time, the growing economic consensus supports shifting to a declining discount rate framework. Circular A-4 contemplates the use of declining discount rates in its reference to the work of Weitzman.<sup>114</sup> As the

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<sup>110</sup> Peter Howard & Derek Sylvan, *The Economic Climate: Establishing Expert Consensus on the Economics of Climate Change* (Inst. Policy Integrity Working Paper 2015/1); M.A. Drupp, et al., *Discounting Disentangled: An Expert Survey on the Determinants of the Long-Term Social Discount Rate* (London School of Economics and Political Science Working Paper, May 2015) (finding consensus on social discount rates between 1-3%).

<sup>111</sup> Circular A-4 at 35-36.

<sup>112</sup> *Id.* at 3.

<sup>113</sup> *Id.* at 42 (emphasis added).

<sup>114</sup> Circular A-4, at page 36, cites to Weitzman’s chapter in Portney & Weyant, eds. (1999); that chapter, at page 29, recommends a declining discount rate approach: “a sliding-scale social discounting strategy” with the rate at 3-4% through year 25; then around 2% until year 75; then around 1% until year 300; and then 0% after year 300.



Council of Economic Advisers explained earlier this year, Weitzman and others developed the foundation for a declining discount rate approach, wherein rates start relatively higher for near-term costs and benefits but steadily decline over time according to a predetermined schedule until, in the very long-term, very low rates dominate due to uncertainty.<sup>115</sup> The National Academies of Sciences’ report also strongly endorses a declining discount rate approach due to uncertainty.<sup>116</sup> In other words, the rational response to a concern about uncertainty over the discount rate is not to abandon the social cost of greenhouse gas methodology, but to apply declining discount rates and to treat the estimates calculated at a constant 3% rate as conservative lower-bound estimates.

One possible schedule of declining discount rates was proposed by Weitzman.<sup>117</sup> It is derived from a broad survey of top economists and other climate experts and explicitly incorporates arguments around interest rate uncertainty. Work by Arrow *et al*, Cropper *et al*, and Gollier and Weitzman, among others, similarly argue for a declining interest rate schedule and lay out the fundamental logic.<sup>118</sup> Another schedule of declining discount rates has been adopted by the United Kingdom.<sup>119</sup>

The technical appendix on discounting attached to these comments more thoroughly reviews the various schedules of declining discount rates available for agencies to select and explains why agencies not only can but should adopt a declining discount framework to address uncertainty. An additional technical appendix on uncertainty explains in detail why uncertainty around the social cost of greenhouse gas points toward higher values. Shifting to a declining discount rate framework would increase the social cost of greenhouse gases.<sup>120</sup> Consequently, a central estimate calculated at 3% should be considered a lower-bound of the social cost of greenhouse gases. But even providing a lower-bound estimate of the social cost of greenhouse gases helps inform decisionmakers and the public, and FERC is required by NEPA to provide some monetization of climate damages, consistent with economic best practices.

Similarly, a 300-year time horizon is required by best economic practices. In 2017, the National Academies of Sciences issued a report stressing the importance of a longer time horizon for calculating the social cost of greenhouse gases. The report states that, “[i]n the context of the socioeconomic,

<sup>115</sup> CEA, *supra* note 98, at 9 (“[A]nother way to incorporate uncertainty when discounting the benefits and costs of policies and projects that accrue in the far future—applying discount rates that decline over time. This approach uses a higher discount rate initially, but then applies a graduated schedule of lower discount rates further out in time. The first argument is based on the application of the Ramsey framework in a stochastic setting (Gollier 2013), and the second is based on Weitzman’s ‘expected net present value’ approach (Weitzman 1998, Gollier and Weitzman 2010). In light of these arguments, the governments of the United Kingdom and France apply declining discount rates to their official public project evaluations.”).

<sup>116</sup> NAS Second Report, *supra* note 79.

<sup>117</sup> Martin L. Weitzman, *Gamma Discounting*, 91 AM. ECON. REV. 260, 270 (2001). Weitzman’s schedule is as follows:

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

<sup>118</sup> Kenneth J. Arrow *et al.*, *Determining Benefits and Costs for Future Generations*, 341 SCIENCE 349 (2013); Kenneth J. Arrow *et al.*, *Should Governments Use a Declining Discount Rate in Project Analysis?*, REV ENVIRON ECON POLICY 8 (2014); Maureen L. Cropper *et al.*, *Declining Discount Rates*, AMERICAN ECONOMIC REVIEW: PAPERS AND PROCEEDINGS (2014); Christian Gollier & Martin L. Weitzman, *How Should the Distant Future Be Discounted When Discount Rates Are Uncertain?* 107 ECONOMICS LETTERS 3 (2010).

<sup>119</sup> Joseph Lowe, H.M. Treasury, U.K., *Intergenerational Wealth Transfers and Social Discounting: Supplementary Green Book Guidance 5* (2008), available at [http://www.hm-treasury.gov.uk/d/4\(5\).pdf](http://www.hm-treasury.gov.uk/d/4(5).pdf). The U.K. declining discount rate schedule that subtracts out a time preference value is as follows:

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

<sup>120</sup> This assumes the use of reasonable values in the Ramsey equation. But in general, as compared to a constant discount rate, a declining rate approach should decrease the effective discount rate.

damage, and discounting assumptions, the time horizon needs to be long enough to capture the vast majority of the present value of damages.”<sup>121</sup> The report goes on to note that the length of the time horizon is dependent “on the rate at which undiscounted damages grow over time and on the rate at which they are discounted. Longer time horizons allow for representation and evaluation of longer-run geophysical system dynamics, such as sea level change and the carbon cycle.”<sup>122</sup> In other words, after selecting the appropriate discount rate based on theory and data (in this case, 3% or below), analysts should determine the time horizon necessary to capture all costs and benefits that will have important net present values at the discount rate. Therefore, a 3% or lower discount rate for climate change implies the need for a 300-year horizon to capture all significant values. NAS reviewed the best available, peer-reviewed scientific literature and concluded that the effects of greenhouse gas emissions over a 300-year period are sufficiently well established and reliable as to merit consideration in estimates of the social cost of greenhouse gases.<sup>123</sup>

### ***Omitted Categories of Damages Should Be Discussed Qualitatively***

BLM suggests that the IWG’s social cost of greenhouse gas estimates are inappropriate to use because it “does not include all damages or benefits from carbon emissions.”<sup>124</sup> Alleged benefits of carbon emissions, such as from increased fertilization, are in fact already included in the IWG’s estimates and are probably even overstated in those estimates. Many of the assumptions about climate benefits built into the integrated assessment models used by the IWG are now outdated; for example, recent work demonstrates that the benefits to agriculture from climate change assumed by the developers of FUND are, in fact, far lower.<sup>125</sup> Other research has also shown that the predicted amenity benefits from climate change, like agricultural benefits, are also highly controversial.<sup>126</sup>

As for omitted damages, there certainly are key damages, including catastrophic outcomes, that are not yet fully monetized in the IWG’s social cost of greenhouse gas estimates. In fact, one reason that IWG published not only “central” estimates but also estimates from the 95<sup>th</sup> percentile of the distribution was to reflect that omitted damage categories could significantly increase the estimates. As noted above, the social cost of greenhouse gases should be seen as a conservative lower-bound estimate of the greenhouse gas impacts. Even while this metric represents the best and most rigorous effort that the U.S. government has engaged in thus far to realistically quantify the impacts of these emissions, it is very likely to underrepresent the true extent of those impacts. Indeed, we strongly encourage further efforts to make the social cost of greenhouse gases more robust.

Nevertheless, the fact that this metric does not capture the entire scope of greenhouse gas impacts does *not* mean that federal agencies should not use it. Rather, agencies should qualitatively discuss any significant omitted category of costs or benefits while continuing to use the IWG estimates as a lower bound of the costs of greenhouse gas emissions.<sup>127</sup>

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<sup>121</sup> NAS Second Report, *supra* note 48, at 78.

<sup>122</sup> *Id.*

<sup>123</sup> NAS First Report, *supra* note 49, at 32.

<sup>124</sup> DSEIS at 311.

<sup>125</sup> F.C. Moore et al., *New science of climate change impacts on agriculture implies higher social cost of carbon*, 8 *Nature Communications* 1607 (2017).

<sup>126</sup> Howard, *Omitted Damages*, *supra* note 23; W.M. Hannemann, *What Is the Economic Cost of Climate Change?* (2008); D. Maddison & K. Rehdanz, *The impact of climate on life satisfaction*, 70 *Ecological Economics* 2437-2445 (2011); K. Rehdanz & D. Maddison, *Climate and happiness*, 52 *Ecological Economics* 111-125 (2005).

<sup>127</sup> Howard and Sylvan (2015) and Pindyck (2016) find that the general consensus is that damages are much higher than IAMs currently show, and as a consequence, so are their corresponding SCC estimates.

## ***A Global Estimate of Climate Damages Is Required by NEPA***

BLM specifically argues that it “would be unbalanced” to apply the “global social cost of carbon” to the Greater Mooses Tooth 2 project.<sup>128</sup> However, NEPA requires BLM to take a global view in its climate analysis, and a global perspective is the appropriate framework for monetizing climate damages.

NEPA contains a provision on “International and National Coordination of Efforts” that broadly requires that “all agencies of the Federal Government *shall* . . . recognize the worldwide and long-range character of environmental problems.”<sup>129</sup> Using a global social cost of greenhouse gases to analyze and set policy fulfills these instructions. Furthermore, the Act requires agencies to, “where consistent with the foreign policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind’s world environment.”<sup>130</sup> By continuing to use the global social cost of greenhouse gases to spur reciprocal foreign actions, federal agencies “lend appropriate support” to the NEPA’s goal of “maximize[ing] international cooperation” to protect “mankind’s world environment.” Furthermore, not only is it consistent with Circular A-4 and best economic practices to estimate the global damages of U.S. greenhouse gas emissions in regulatory analyses and environmental impact statements, but no existing methodology for estimating a “domestic-only” value is reliable, complete, or consistent with Circular A-4.

From 2010 through 2016, federal agencies based their regulatory decision and NEPA reviews on global estimates of the social cost of greenhouse gases. Though agencies often also disclosed a “highly speculative” range that tried to capture exclusively U.S. climate costs, emphasis on a global value was recognized as more accurate given the science and economics of climate change, as more consistent with best economic practices, and as crucial to advancing U.S. strategic goals.<sup>131</sup>

Opponents of climate regulation challenged the global number in court and other forums, and often attempted to use Circular A-4 as support.<sup>132</sup> Specifically, opponents have seized on Circular A-4’s instructions to “focus” on effects to “citizens and residents of the United States,” while any significant effects occurring “beyond the borders of the United States . . . should be reported separately.”<sup>133</sup> Importantly, despite this language and such challenges, the U.S. Court of Appeals for the Seventh Circuit had no trouble concluding that a global focus for the social cost of greenhouse gases was reasonable:

AHRI and Zero Zone [the industry petitioners] next contend that DOE [the Department of Energy] arbitrarily considered the global benefits to the environment but only considered the national costs. They emphasize that the [statute] only concerns “national

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<sup>128</sup> DEIS at 311.

<sup>129</sup> 42 U.S.C. § 4332(2)(f) (emphasis added).

<sup>130</sup> *Id.*; see also *Environmental Defense Fund v. Massey*, 986 F.2d 528, 535 (D.C. Cir. 1993) (confirming that Subsection F is mandatory); *Natural Resources Defense Council v. NRC*, 647 F.2d 1345, 1357 (D.C. Cir. 1981) (“This NEPA prescription, I find, looks toward cooperation, not unilateral action, in a manner consistent with our foreign policy.”); cf. COUNCIL ON ENVIRONMENTAL QUALITY, GUIDANCE ON NEPA ANALYSIS FOR TRANSBOUNDARY IMPACTS (1997), available at <http://www.gc.noaa.gov/documents/transguide.pdf>; Exec. Order No. 12,114, *Environmental Effects Abroad of Major Federal Actions*, 44 Fed. Reg. 1957 §§ 1-1, 2-1 (Jan. 4, 1979) (applying to “major Federal actions . . . having significant effects on the environment outside the geographical borders of the United States,” and enabling agency officials “to be informed of pertinent environmental considerations and to take such considerations into account . . . in making decisions regarding such actions”).

<sup>131</sup> See generally Howard & Schwartz, *supra* note 52.

<sup>132</sup> Ted Gayer & W. Kip Viscusi, *Determining the Proper Scope of Climate Change Policy Benefits in U.S. Regulatory Analyses: Domestic versus Global Approaches*, 10 Rev. Envtl. Econ. & Pol’y 245 (2016) (citing Circular A-4 to argue against a global perspective on the social cost of carbon); see also, e.g., Petitioners Brief on Procedural and Record-Based Issues at 70, in *West Virginia v. EPA*, case 15-1363, D.C. Cir. (filed February 19, 2016) (challenging EPA’s use of the global social cost of carbon).

<sup>133</sup> Circular A-4 at 15. Note that A-4 slightly conflates “accrue to citizens” with “borders of the United States”: U.S. citizens have financial and other interests tied to effects beyond the borders of the United States, as discussed further below.

energy and water conservation.” In the New Standards Rule, DOE did not let this submission go unanswered. It explained that climate change “involves a global externality,” meaning that carbon released in the United States affects the climate of the entire world. According to DOE, national energy conservation has global effects, and, therefore, those global effects are an appropriate consideration when looking at a national policy. Further, AHRI and Zero Zone point to no global costs that should have been considered alongside these benefits. Therefore, DOE acted reasonably when it compared global benefits to national costs.<sup>134</sup>

Circular A-4’s reference to effects “beyond the borders” confirms that it is appropriate for agencies to consider the global effects of U.S. greenhouse gas emissions. While Circular A-4 may suggest that most typical decisions should focus on U.S. effects, the Circular cautions agencies that special cases call for different emphases:

[Y]ou cannot conduct a good regulatory analysis according to a formula. Conducting high-quality analysis requires competent professional judgment. ***Different regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues and the sensitivity of the benefit and cost estimates to the key assumptions.***<sup>135</sup>

In fact, Circular A-4 elsewhere assumes that agencies’ analyses will not always be conducted from purely the perspective of the United States, as one of its instructions only applies “as long as the analysis is conducted from the United States perspective,”<sup>136</sup> suggesting that in some circumstances it is appropriate for the analysis to be global. For example, EPA and DOT have adopted a global perspective on the analysis of potential monopsony benefits to U.S. consumers resulting from the reduced price of foreign oil imports following energy efficiency increases, and EPA assesses the global potential for leakage of greenhouse gas emissions owing to U.S. regulation.<sup>137</sup>

Perhaps more than any other issue, the nature of the issue of climate change requires precisely such a “different emphasis” from the default domestic-only assumption. To avoid a global “tragedy of the commons” that could irreparably damage all countries, including the United States, every nation should ideally set policy according to the global social cost of greenhouse gases.<sup>138</sup> Climate and clean air are global common resources, meaning they are freely available to all countries, but any one country’s use—i.e., pollution—imposes harms on the polluting country as well as the rest of the world. Because greenhouse pollution does not stay within geographic borders but rather mixes in the atmosphere and affects climate worldwide, each ton emitted by the United States not only creates domestic harms, but also imposes large externalities on the rest of the world. Conversely, each ton of greenhouse gases abated in another country benefits the United States along with the rest of the world.

If all countries set their greenhouse emission levels based on only domestic costs and benefits, ignoring the large global externalities, the aggregate result would be substantially sub-optimal climate protections and significantly increased risks of severe harms to all nations, including the United States. Thus, basic economic principles demonstrate that the United States stands to benefit greatly if all countries apply global social cost of greenhouse gas values in their regulatory decisions and project

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<sup>134</sup> Zero Zone v. Dept. of Energy, 832 F.3d 654, 679 (7th Cir. 2016),

<sup>135</sup> Circular A-4 at 3 (emphasis added).

<sup>136</sup> *Id.* at 38 (counting international transfers as costs and benefits “as long as the analysis is conducted from the United States perspective”).

<sup>137</sup> See Howard & Schwartz, *supra* note 52, at 268-69.

<sup>138</sup> See Garrett Hardin, *The Tragedy of the Commons*, 162 Science 1243 (1968) (“[E]ach pursuing [only its] own best interest . . . in a commons brings ruin to all.”).

reviews. Indeed, the United States stands to gain hundreds of billions or even trillions of dollars in direct benefits from efficient foreign action on climate change.<sup>139</sup>

In order to ensure that other nations continue to use global social cost of greenhouse gas values, it is important that the United States itself continue to do so.<sup>140</sup> The United States is engaged in a repeated strategic dynamic with several significant players—including the United Kingdom, Germany, Sweden, and others—that have already adopted a global framework for valuing the social cost of greenhouse gases.<sup>141</sup> For example, Canada and Mexico have explicitly borrowed the IWG’s global SCC metric to set their own fuel efficiency standards.<sup>142</sup> For the United States to now depart from this collaborative dynamic by reverting to a domestic-only estimate would undermine the country’s long-term interests and could jeopardize emissions reductions underway in other countries, which are already benefiting the United States.

For these and other reasons, the IWG properly relied on global estimates to develop its SCC metric, and many federal agencies have since relied on this global metric to evaluate and justify their decisions. At the same time, some agencies have, in addition to the global estimate, also disclosed a “highly speculative” estimate of the domestic-only effects of climate change. In particular, the Department of Energy always includes a chapter on a domestic-only value of carbon emissions in the economic analyses supporting its energy efficiency standards; EPA has also often disclosed similar estimates.<sup>143</sup> Such an approach is consistent with Circular A-4’s suggestion that agencies should usually disclose domestic effects separately from global effects. However, as we have discussed, reliance on a domestic-only methodology would be inconsistent with both the inherent nature of climate change and the standards of Circular A-4. Consequently, it is appropriate under Circular A-4 for agencies to continue to rely on global estimates of the social cost of greenhouses to justify their regulatory decisions or their choice of alternatives under NEPA.

Moreover, no current methodology can accurately estimate a “domestic-only” value of the social cost of greenhouse gases. OMB, the National Academies of Sciences, and the economic literature all agree that existing methodologies for calculating a “domestic-only” value of the social cost of greenhouse gases are deeply flawed and result in severe and misleading underestimates. In developing the social cost of carbon, the IWG did offer some such domestic estimates. Using the results of one economic model (FUND) as well as the U.S. share of global gross domestic product (GDP), the group generated an “approximate, provisional, and **highly speculative**” range of 7–23% of the global social cost of carbon as an estimate of the purely direct climate effects to the United States.<sup>144</sup> Yet, as the IWG itself acknowledged, this range is almost certainly an underestimate because it ignores significant, indirect

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<sup>139</sup> Policy Integrity, *Foreign Action, Domestic Windfall: The U.S. Economy Stands to Gain Trillions from Foreign Climate Action* (2015), <http://policyintegrity.org/files/publications/ForeignActionDomesticWindfall.pdf>

<sup>140</sup> See Robert Axelrod, *The Evolution of Cooperation* 10-11 (1984) (on repeated prisoner’s dilemma games).

<sup>141</sup> See Howard & Schwartz, *supra* note 52, at Appendix B.

<sup>142</sup> See Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations, SOR/2013-24, 147 Can. Gazette pt. II, 450, 544 (Can.), available at <http://canadagazette.gc.ca/rp-pr/p2/2013/2013-03-13/html/sor-dors24-eng.html> (“The values used by Environment Canada are based on the extensive work of the U.S. Interagency Working Group on the Social Cost of Carbon.”); Jason Furman & Brian Deese, *The Economic Benefits of a 50 Percent Target for Clean Energy Generation by 2025*, White House Blog, June 29, 2016 (summarizing the North American Leader’s Summit announcement that U.S., Canada, and Mexico would “align” their SCC estimates).

<sup>143</sup> Howard & Schwartz, *supra* note 52, at 220-21.

<sup>144</sup> INTERAGENCY WORKING GROUP ON SOCIAL COST OF CARBON, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12,866 at 11 (2010) (emphasis added).

costs to trade, human health, and security that are likely to “spill over” into the United States as other regions experience climate change damages, among other effects.<sup>145</sup>

Neither the existing IAMs nor a share of global GDP are appropriate bases for calculating a domestic-only estimate. The IAMs were never designed to calculate a domestic SCC, since a global SCC is the economic efficient value. FUND, like other IAMs, includes some simplifying assumptions: of relevance, FUND and the other IAMs are not able to capture the adverse effects that the impacts of climate change in other countries will have on the United States through trade linkages, national security, migration, and other forces.<sup>146</sup> This is why the IWG characterized the domestic-only estimate from FUND as a “highly speculative” underestimate. Similarly, a domestic-only estimate based on some rigid conception of geographic borders or U.S. share of world GDP will fail to capture all the climate-related costs and benefits that matter to U.S. citizens.<sup>147</sup> U.S. citizens have economic and other interests abroad that are not fully reflected in the U.S. share of global GDP. GDP is a “monetary value of final goods and services—that is, those that are bought by the final user—produced in a country in a given period of time.”<sup>148</sup> GDP therefore does not reflect significant U.S. ownership interests in foreign businesses, properties, and other assets, as well as consumption abroad including tourism,<sup>149</sup> or even the 8 million Americans living abroad.<sup>150</sup> At the same time, GDP is also over-inclusive, counting productive operations in the United States that are owned by foreigners. Gross National Income (GNI), by contrast, defines its scope not by location but by ownership interests.<sup>151</sup> However, not only has GNI fallen out of favor as a metric used in international economic policy,<sup>152</sup> but using a domestic-only SCC based on GNI would make the SCC metrics incommensurable with other costs in regulatory impact analyses, since most regulatory costs are calculated by U.S. agencies regardless of whether they fall to U.S.-owned entities or to foreign-owned entities operating in the United States.<sup>153</sup> Furthermore, both GDP and GNI are dependent on what happens in other countries, due to trade and the international flow of capital. The artificial constraints of both metrics counsel against a rigid split based on either U.S. GDP or U.S. GNI.<sup>154</sup>

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<sup>145</sup> *Id.* (explaining that the IAMs, like FUND, do “not account for how damages in other regions could affect the United States (e.g., global migration, economic and political destabilization”).

<sup>146</sup> See, e.g., Dept. of Defense, *National Security Implications of Climate-Related Risks and a Changing Climate* (2015), available at <http://archive.defense.gov/pubs/150724-congressional-report-on-national-implications-of-climate-change.pdf?source=govdelivery>.

<sup>147</sup> A domestic-only SCC would fail to “provide to the public and to OMB a careful and transparent analysis of the anticipated consequences of economically significant regulatory actions.” Office of Information and Regulatory Affairs, *Regulatory Impact Analysis: A Primer 2* (2011).

<sup>148</sup> Tim Callen, *Gross Domestic Product: An Economy’s All*, IMF, <http://www.imf.org/external/pubs/ft/fandd/basics/gdp.htm> (last updated Mar. 28, 2012).

<sup>149</sup> “U.S. residents spend millions each year on foreign travel, including travel to places that are at substantial risk from climate change, such as European cities like Venice and tropical destinations like the Caribbean islands.” David A. Dana, *Valuing Foreign Lives and Civilizations in Cost-Benefit Analysis: The Case of the United States and Climate Change Policy* (Northwestern Faculty Working Paper 196, 2009), <http://scholarlycommons.law.northwestern.edu/cgi/viewcontent.cgi?article=1195&context=facultyworkingpapers>.

<sup>150</sup> Assoc. of Americans Resident Overseas, <https://www.aaro.org/about-aaro/6m-americans-abroad>. Admittedly 8 million is only 0.1% of the total population living outside the United States.

<sup>151</sup> *GNI, Atlas Method (Current US\$)*, THE WORLD BANK, <http://data.worldbank.org/indicator/NY.GNP.ATLS.CD>.

<sup>152</sup> *Id.*

<sup>153</sup> U.S. Office of Management and Budget & Secretariat General of the European Commission, *Review of Application of EU and US Regulatory Impact Assessment Guidelines on the Analysis of Impacts on International Trade and Development* 13 (2008).

<sup>154</sup> Advanced Notice of Proposed Rulemaking on Regulating Greenhouse Gas Emissions Under the Clean Air Act, 73 Fed. Reg. 44,354, 44,415 (July 30, 2008) (“Furthermore, international effects of climate change may also affect domestic benefits directly and indirectly to the extent U.S. citizens value international impacts (e.g., for tourism reasons, concerns for the existence of ecosystems, and/or concern for others); U.S. international interests are affected (e.g., risks to U.S. national security, or the U.S. economy from potential disruptions in other nations).”).

Of course, there already are and will continue to be significant, quantifiable, localized effects of climate change. For example, a peer-reviewed EPA report, *Climate Change in the United States: Benefits of Global Action*, found that by the end of the century, the U.S. economy could face damages of \$110 billion annually in lost labor productivity alone due to extreme temperatures, plus \$11 billion annually in agricultural damages, \$180 billion in losses to key economic sectors due to water shortages, and \$5 trillion in damages U.S. coastal property.<sup>155</sup> But the existence of those examples of quantifiable estimates of localized damages does not mean that the current IAMs are able to extrapolate a U.S.-only number that accurately reflects total domestic damages—especially since, as already explained, the IAMs do not reflect spill overs.

As a result, in 2015, OMB concluded, along with several other agencies, that “good methodologies for estimating domestic damages do not currently exist.”<sup>156</sup> Similarly, the NAS recently concluded that current IAMs cannot accurately estimate the domestic social cost of greenhouse gases, and that estimates based on U.S. share of global GDP would be likewise insufficient.<sup>157</sup> William Nordhaus, the developer of the DICE model, cautioned earlier this year that “regional damage estimates are both incomplete and poorly understood,” and “there is little agreement on the distribution of the SCC by region.”<sup>158</sup> In short, any domestic-only estimate will be inaccurate, misleading, and out of step with the best available economic literature, in violation of Circular A-4’s standards for information quality.

For more details on the justification for a global value of the social cost of greenhouse gases, please see Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 Columbia J. Envtl. L. 203 (2017). Another strong defense of the global valuation as consistent with best economic practices appears in a letter published in a recent issue of *The Review of Environmental Economics and Policy*, co-authored by the late Nobel laureate economist Kenneth Arrow.<sup>159</sup>

### ***Uncertainty Supports Higher Estimates of Damages and Is Not a Reason to Abandon the Social Cost of Greenhouse Gases***

BLM vaguely argues that there is too much “uncertain[t]y” to assign a social cost of greenhouse gas value here.<sup>160</sup> However, uncertainty is *not* a reason to abandon the social cost of greenhouse gas methodologies; quite the contrary uncertainty supports higher estimates of the social cost of greenhouse gases, because most uncertainties regarding climate change entail tipping points, catastrophic risks, and unknown unknowns about the damages of climate change. Because the key uncertainties of climate change include the risk of irreversible catastrophes, applying an options value framework to the regulatory context strengthens the case for ambitious regulatory action to reduce greenhouse gas emissions. There are numerous well-established, rigorous analytical tools available to help agencies characterize and quantitatively assess uncertainty, such as Monte Carlo simulations, and the IWG’s social cost of greenhouse gas protocol incorporates those tools. For more details, please see the attached technical appendix on uncertainty.

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<sup>155</sup> EPA, *Climate Change in the United States: Benefits of Global Action* (2015).

<sup>156</sup> In November 2013, OMB requested public comments on the social cost of carbon. In 2015, OMB along with the rest of the Interagency Working Group issued a formal response to those comments. Interagency Working Group on the Social Cost of Carbon, *Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12,866* at 36 (July 2015) [hereinafter, OMB 2015 Response to Comments].

<sup>157</sup> NAS Second Report, *supra* note 48, at 53.

<sup>158</sup> William Nordhaus, *Revisiting the Social Cost of Carbon*, 114 PNAS 1518, 1522 (2017).

<sup>159</sup> Richard Revesz, Kenneth Arrow et al., *The Social Cost of Carbon: A Global Imperative*, 11 REEP 172 (2017).

<sup>160</sup> DSEIS at 311.

Sincerely,

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



## Technical Appendix: Uncertainty

Contrary to the arguments made by many opposed to strong federal climate action, uncertainty about the full effects of climate change *raises* the social cost of greenhouse gases and warrants *more* stringent climate policy.<sup>161</sup> Integrated assessment models (IAMs) currently used to calculate the SCC show that the net effect of uncertainty about economic damage resulting from climate change, costs of mitigation, future economic development, and many other parameters raises the SCC compared to the case where models simply use our current best guesses of these parameters.<sup>162</sup> Even so, IAMs still underestimate the impact of uncertainty on the SCC by not accounting for a host of fundamental features of the climate problem: the irreversibility of climate change, society's aversion to risk and other social preferences, option value, and many catastrophic impacts.<sup>163</sup> Rather than being a reason not to take action, uncertainty increases the SCC and should lead to more stringent policy to address climate change.<sup>164</sup>

### *Types of Uncertainty in the IAMs*

IAMs incorporate two types of uncertainty: parametric uncertainty and stochastic uncertainty. Parametric uncertainty covers uncertainty in model design and inputs, including the selected parameters, correct functional forms, appropriate probability distribution functions, and model structure. With learning, these uncertainties should decline over time as more information becomes available.<sup>165</sup> Stochastic uncertainty is persistent randomness in the economic-climate system, including various environmental phenomena such as volcanic eruptions and sun spots.<sup>166</sup> Uncertainties are present in each component of the IAMs: socio-economic scenarios, the simple climate model, the damage and abatement cost functions, and the social welfare function (including the discount rate).<sup>167</sup>

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<sup>161</sup> Peterson (2006) states "Most modeling results show (as can be expected) that there is optimally more emission abatement if uncertainties in parameters or the possibility of catastrophic events are considered." Peterson, S. (2006). Uncertainty and economic analysis of climate change: A survey of approaches and findings. *Environmental Modeling & Assessment*, 11(1), 1-17.

<sup>162</sup> Tol, R. S. (1999). Safe policies in an uncertain climate: an application of FUND. *Global Environmental Change*, 9(3), 221-232; Peterson, S. (2006). Uncertainty and economic analysis of climate change: A survey of approaches and findings. *Environmental Modeling & Assessment*, 11(1), 1-17; IWG, 2016 TSD, *supra*.

<sup>163</sup> Pindyck, R. S. (2007). Uncertainty in environmental economics. *Review of environmental economics and policy*, 1(1), 45-65; Golub, A., Narita, D., & Schmidt, M. G. (2014). Uncertainty in integrated assessment models of climate change: Alternative analytical approaches. *Environmental Modeling & Assessment*, 19(2), 99-109; Lemoine, D., & Rudik, I. (2017). Managing Climate Change Under Uncertainty: Recursive Integrated Assessment at an Inflection Point. *Annual Review of Resource Economics* 9:18.1-18.26.

<sup>164</sup> See *cites supra* note 163.

<sup>165</sup> Learning comes in multiple forms: passive learning of anticipated information that arrives exogenous to the emission policy (such as academic research), active learning of information that directly stems from the choice of the GHG emission level (via the policy process), and learning of unanticipated information (Kann and Weyant, 2000; Lemoine and Rudik, 2017).

<sup>166</sup> Kann, A., & Weyant, J. P. (2000). Approaches for performing uncertainty analysis in large-scale energy/economic policy models. *Environmental Modeling & Assessment*, 5(1), 29-46; Peterson (2006), *supra* note 161; Golub et al. *supra* note 163.

A potential third type of uncertainty arises due to ethical or value judgements: normative uncertainty. Peterson (2006) *supra* note 161; Heal, G., & Millner, A. (2014). Reflections: Uncertainty and decision making in climate change economics. *Review of Environmental Economics and Policy*, 8(1), 120-137. For example, there is some normative debate over the appropriate consumption discount rate to apply in climate economics, though widespread consensus exists that using the social opportunity cost of capital is inappropriate (see earlier discussion). Preference uncertainty should be modeled as a declining discount rate over time (see earlier discussion), not using uncertain parameters. Kann & Weyant, *supra* note 166.

<sup>167</sup> Peterson (2006), *supra* note 161; Pindyck (2007), *supra* note 163; Heal & Millner, *supra* note 166.

When modeling climate change uncertainty, scientists and economists have long emphasized the importance of accounting for the potential of catastrophic climate change.<sup>168</sup> Catastrophic outcomes combine several overlapping concepts including unlucky states of the world (i.e., bad draws), deep uncertainty, and climate tipping points and elements.<sup>169</sup> Traditionally, IAM developers address uncertainty by specifying probability distributions over various climate and economic parameters. This type of uncertainty implies the possibility of an especially bad draw if multiple uncertain parameters turn out to be lower than we expect, causing actual climate damages to greatly exceed expected damages.

Our understanding of the climate and economic systems is also affected by so-called “deep uncertainty,” which can be thought of as uncertainty over the true probability distributions for specific climate and economic parameters.<sup>170</sup> The mean and variance of many uncertain climate phenomena are unknown due to lack of data, resulting in “fat-tailed distributions”—i.e., the tail of the distributions decline to zero slower than the normal distribution. Fat-tailed distributions result when the best guess of the distribution is derived under learning.<sup>171</sup> Given the general opinion that bad surprises are likely to outweigh good surprises in the case of climate change,<sup>172</sup> modelers capture deep uncertainty by selecting probability distributions with a fat upper tail which reflects the greater likelihood of extreme events.<sup>173</sup> The possibility of fat tails increases the likelihood of a “very” bad draw with high economic costs, and can result in a very high (and potentially infinite) expected cost of climate change (a phenomenon known as the dismal theory).<sup>174</sup>

Climate tipping elements are environmental thresholds where a small change in climate forcing can lead to large, non-linear shifts in the future state of the climate (over short and long periods of time) through positive feedback (i.e., snowball) effects.<sup>175</sup> Tipping points refer to economically relevant thresholds after which change occurs rapidly (i.e., Gladwellian tipping points), such that opportunities for adaptation and intervention are limited.<sup>176</sup> Tipping point examples include the reorganization of the Atlantic meridional overturning circulation (AMOC) and a shift to a more persistent El Niño regime in the

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<sup>168</sup> Nordhaus, W. D. (2008). *A question of balance: Weighing the options on global warming policies*. Yale University Press; Kopp, R. E., Shwom, R. L., Wagner, G., & Yuan, J. (2016). Tipping elements and climate–economic shocks: Pathways toward integrated assessment. *Earth's Future*, 4(8), 346-372.

<sup>169</sup> Kopp et al. (2016), *supra* note 168.

<sup>170</sup> *Id.*

<sup>171</sup> Nordhaus, W. D. (2009). *An Analysis of the Dismal Theorem* (No. 1686). Cowles Foundation Discussion Paper; Weitzman, M. L. (2011). Fat-tailed uncertainty in the economics of catastrophic climate change. *Review of Environmental Economics and Policy*, 5(2), 275-292; Pindyck, R. S. (2011). Fat tails, thin tails, and climate change policy. *Review of Environmental Economics and Policy*, 5(2), 258-274.

<sup>172</sup> Mastrandrea, M. D. (2009). Calculating the benefits of climate policy: examining the assumptions of integrated assessment models. *Pew Center on Global Climate Change Working Paper*; Tol, R. S. (2012). On the uncertainty about the total economic impact of climate change. *Environmental and Resource Economics*, 53(1), 97-116.

<sup>173</sup> Weitzman (2011), *supra* note 171, makes clear that “deep structural uncertainty about the unknown unknowns of what might go very wrong is coupled with essentially unlimited downside liability on possible planetary damages. This is a recipe for producing what are called ‘fat tails’ in the extreme of critical probability distributions.”

<sup>174</sup> Weitzman, M. L. (2009). On modeling and interpreting the economics of catastrophic climate change. *The Review of Economics and Statistics*, 91(1), 1-19; Nordhaus (2009), *supra* note 171; Weitzman (2011), *supra* note 171.

<sup>175</sup> Tipping elements are characterized by: (1) deep uncertainty, (2) absence from climate models, (3) larger resulting changes relative to the initial change crossing the relevant threshold, and (4) irreversibility. Kopp et al. (2016), *supra* note 168.

<sup>176</sup> *Id.*

Pacific Ocean.<sup>177</sup> Social tipping points—including climate-induced migration and conflict—also exist. These various tipping points interact, such that triggering one tipping point may affect the probabilities of triggering other tipping points.<sup>178</sup> There is some overlap between tipping point events and fat tails in that the probability distributions for how likely, how quick, and how damaging tipping points will be are unknown.<sup>179</sup> Accounting fully for these most pressing, and potentially most dramatic, uncertainties in the climate-economic system matter because humans are risk averse and tipping points—like many other aspects of climate change—are, by definition, irreversible

#### *How IAMs and the IWG Account for Uncertainty*

Currently, IAMs (including all of those used by the IWG) capture uncertainty in two ways: deterministically and through uncertainty propagation. For the deterministic method, the modeler assumes away uncertainty (and thus the possibility of bad draws and fat tails) by setting parameters equal to their most likely (median) value. Using these values, the modeler calculates the median SCC value. Typically, the modeler conducts sensitivity analysis over key parameters—one at a time or jointly—to determine the robustness of the modeling results. This is the approach employed by Nordhaus in the preferred specification of the DICE model<sup>180</sup> used by the IWG.

Uncertainty propagation is most commonly carried out using Monte Carlo simulation. In these simulations, the modeler randomly draws parameter values from each of the model's probability distributions, calculates the SCC for the draw, and then repeats this exercise thousands of times to calculate a mean social cost of carbon.<sup>181</sup> Tol, Anthoff, and Hope employ this technique in FUND and PAGE—as did the IWG (2010, 2013, and 2016)—by specifying probability distributions for the climate and economic parameters in the models. These models are especially helpful for assessing the net effect of different parametric and stochastic uncertainties. For instance, both the costs of mitigation and the damage from climate change are uncertain. Higher costs would warrant less stringent climate policies, while higher damages lead to more stringent policy, so theoretically, the effect of these two factors on climate policy could be ambiguous. Uncertainty propagation in an IAM calibrated to empirically motivated distributions, however, shows that climate damage uncertainty outweighs the effect of cost uncertainty, leading to a stricter policy when uncertainty is taken into account than when it is ignored.<sup>182</sup>

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<sup>177</sup> *Id.*; Kriegler, E., Hall, J. W., Held, H., Dawson, R., & Schellnhuber, H. J. (2009). Imprecise probability assessment of tipping points in the climate system. *Proceedings of the national Academy of Sciences*, 106(13), 5041-5046; Diaz, D., & Keller, K. (2016). A potential disintegration of the West Antarctic Ice Sheet: Implications for economic analyses of climate policy. *The American Economic Review*, 106(5), 607-611. See Table 1 of Kopp et al. (2016) *supra* note 168, for a full list of known tipping elements and points.

<sup>178</sup> Kriegler et al. (2009), *supra* note 177; Cai, Y., Lenton, T. M., & Lontzek, T. S. (2016). Risk of multiple interacting tipping points should encourage rapid CO<sub>2</sub> emission reduction; Kopp et al. (2016) *supra* note 168.

<sup>179</sup> Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon 5* (Cost of Carbon Project Report, 2014), <http://costofcarbon.org/>; Kopp et al. (2016) *supra* note 168.

<sup>180</sup> Nordhaus, W. & Sztorc, P. (2013). DICE 2013: Introduction & User's Manual. Retrieved from Yale University, Department of Economics website: <http://www.econ.yale.edu/~nordhaus/homepage/documents/Dicemanualfull>

<sup>181</sup> In alternative calculation method, the modeler “performs optimization of policies for a large number of possible parameter combinations individually and estimates their probability weighted sum.” Golub et al. *supra* note 163. In more recent DICE-2016, Nordhaus conducts a three parameter analysis using this method to determine a SCC confidence interval. Given that PAGE and FUND model hundred(s) of uncertainty parameters, this methodology appears limited in the number of uncertain variables that can be easily specified.

<sup>182</sup> Tol (1999), *supra* note 162, in characterizing the FUND model, states, “Uncertainties about climate change impacts are more serious than uncertainties about emission reduction costs, so that welfare-maximizing policies are stricter under uncertainty than under certainty.”

This can be seen in the resulting right-skewed distribution of the SCC (see Figure 1 in IWG (2016)) where the mean (Monte Carlo) SCC value clearly exceeds the median (deterministic) SCC value.

The IWG was rigorous in addressing uncertainty. First, it conducted Monte Carlo simulations over the above IAMs specifying different possible outcomes for climate sensitivity (represented by a right skewed, fat tailed distribution to capture the potential of higher than expected warming). It also used scenario analysis: five different emissions growth scenarios and three discount rates. Second, the IWG (2016) reported the various moments and percentiles—including the 95<sup>th</sup> percentile—of the resulting SCC estimates. Third, the IWG put in place an updating process, e.g., the 2013 and 2016 revisions, which updates the models as new information becomes available.<sup>183</sup> As such, the IWG used the various tools that economists have developed over time to address the uncertainty inherent in estimating the economic cost of pollution: reporting various measures of uncertainty, using Monte Carlo simulations, and updating estimates as evolving research advances our knowledge of climate change. Even so, the IWG underestimate the SCC by failing to capture key features of the climate problem.

#### *Current IAMs Underestimate the SCC by Failing to Sufficiently Model Uncertainty*

Given the current treatment of uncertainty by the IWG (2016) and the three IAMs that they employ, the IWG (2016) estimates represent an underestimate of the SCC. DICE clearly underestimates the true value of the SCC by effectively eliminating the possibility of bad draws and fat tails through a deterministic model that relies on the median SCC value. Even with their calculation of the mean SCC, the FUND and PAGE also underestimate the metric's true value by ignoring key features of the climate-economic problem. Properly addressing the limitations of these models' treatment of uncertainty would further increase the SCC.

First, current IAMs insufficiently model catastrophic impacts. DICE fails to model both the possibility of bad draws and fat tails by applying the deterministic approach. Alternatively, FUND and PAGE ignore deep uncertainty by relying predominately on the thin-tailed triangular and gamma distributions.<sup>184</sup> The IWG (2010) only partially addresses this oversight by replacing the ECS parameter in DICE, FUND, and PAGE with a fat-tailed, right-skewed distribution calibrated to the IPCC's assumptions (2007), even though many other economic and climate phenomenon in IAMs are likely characterized by fat tails, including climate damages from high temperature levels, positive climate feedback effects, and tipping points.<sup>185</sup> Recent work in stochastic dynamic programming tends to better integrate fat tails – particularly with respect to tipping points (see below) – and address additional aversion to this type of uncertainty (also known as ambiguity aversion); doing so can further increase the SCC under uncertainty.<sup>186</sup>

In contrast to their approach to fat tails, the IAMs used by the IWG (2010; 2013; 2016) sometimes address climate tipping points, though they do not apply state-of-the-art methods for doing so. In early

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<sup>183</sup> IWG (2010).

<sup>184</sup> Howard (2014), *supra* note 179. While both FUND and PAGE employ thin tailed distributions, the resulting distribution of the SCC is not always thin-tailed. In PAGE09, the ECS parameter is endogenous, such that the distribution of the ECS has a long tail following the IPCC (2007). See Chen, Z., Marquis, M., Averyt, K. B., Tignor, M., & Miller, H. L. (2007). Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. *Cambridge, UK and New York: Cambridge University Press, 996p*. Similarly, while Anthoff and Tol do not explicitly utilize fat-tail distributions, the distribution of net present welfare from a Monte Carlos simulation is fat tailed. Anthoff, D., & Tol, R. S. (2014). The Climate Framework for Uncertainty, Negotiation and Distribution (FUND): Technical description, Version 3.8. Available at [www.fund-model.org](http://www.fund-model.org). Explicitly modeling parameter distributions as fat tailed may further increase the SCC.

<sup>185</sup> Weitzman (2011), *supra* note 171; Kopp et al. (2016) *supra* note 168.

<sup>186</sup> Lemoine, D., & Traeger, C. P. (2016a). Ambiguous tipping points. *Journal of Economic Behavior & Organization*, 132, 5-18; Lemoine & Rudik (2017), *supra* note 163. IAM modelers currently assume that society is equally averse to known unknown and known unknowns. Lemoine & Traeger, *id*.

versions of DICE (DICE-2010 and earlier), Nordhaus implicitly attributes larger portions of the SCC to tipping points by including certainty equivalent damages of catastrophic events - representing two-thirds to three-quarter of damages in DICE – calibrated to an earlier Nordhaus (1994) survey of experts.<sup>187</sup> In PAGE09, Hope also explicitly models climate tipping points as a singular, discrete event (of a 5% to 25% loss in GDP) that has a probability (which grows as temperature increases) of occurring in each time period.<sup>188</sup> Though not in the preferred versions of the IAMs employed by the IWG, some research also integrates specific tipping points into these IAMs finding even higher SCC estimates.<sup>189</sup> Despite the obvious methodological basis for addressing tipping points, the latest versions of DICE<sup>190</sup> and FUND exclude tipping points in their preferred specifications. Research shows that if these models were to correctly account for the full range of climate impacts—including tipping points—the resulting SCC estimates would increase.<sup>191</sup>

The IWG approach also fails to include a risk premium—that is, the amount of money society would require in order to accept the uncertainty (i.e., variance) over the magnitude of warming and the resulting damages from climate change relative to mean damages (IWG, 2010; IWG, 2015)). The mean of a distribution, which is a measure of a distribution’s central tendency, represents only one descriptor or “moment” of a distribution’s shape. Each IAM parameter and the resulting SCC distributions have differing levels of variance (i.e., spread around the mean), skewness (i.e., a measure of asymmetry), and kurtosis (which, like skewness, is another descriptor of a distribution’s tail) as well as means.<sup>192</sup> It is generally understood that people are risk averse in that they prefer input parameter distributions and

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<sup>187</sup> Nordhaus, W. D., & Boyer, J. (2000). *Warning the World: Economic Models of Global Warming*. MIT Press (MA); Nordhaus, W. D. (2008). *A question of balance: Weighing the options on global warming policies*. Yale University Press; Howard (2014), *supra* note 179; Kopp et al. (2016) *supra* note 168.

<sup>188</sup> Hope (2006) also calibrated a discontinuous damage function in PAGE-99 used by IWG (2010). Howard (2014), *supra* note 179.

<sup>189</sup> Kopp et al. (2016) *supra* note 168.

<sup>190</sup> For DICE-2013 and DICE-2016, Nordhaus calibrates the DICE damage function using a meta-analysis based on estimates that mostly exclude tipping point damages. Howard, P. H., & Sterner, T. (2016). Few and Not So Far Between: A Meta-analysis of Climate Damage Estimates. *Environmental and Resource Economics*, 1-29.

<sup>191</sup> Using FUND, Link and Tol (2010) find that a collapse of the AMOC would decrease GDP (and thus increase the SCC) by a small amount. Earlier modeling of this collapse in DICE find a more significance increase. Keller, K., Tan, K., Morel, F. M., & Bradford, D. F. (2000). Preserving the ocean circulation: implications for climate policy. *Climatic Change*, 47, 17-43; Mastrandrea, M. D., & Schneider, S. H. (2001). Integrated assessment of abrupt climatic changes. *Climate Policy*, 1(4), 433-449; Keller, K., Bolker, B. M., & Bradford, D. F. (2004). Uncertain climate thresholds and optimal economic growth. *Journal of Environmental Economics and management*, 48(1), 723-741. With respect to thawing of the permafrost, Hope and Schaefer (2016), Economic impacts of carbon dioxide and methane released from thawing permafrost. *Nature Climate Change*, 6(1), 56-59, and Gonzalez-Eguino and Neumann (2016), González-Eguino, M., & Neumann, M. B. (2016). Significant implications of permafrost thawing for climate change control. *Climatic Change*, 136(2), 381-388, find increases in damages (and thus an increase in the SCC) when integrating this tipping element into the PAGE09 and DICE-2013R, respectively. Looking at the collapse of the West Antarctic Ice sheet, Nicholls et al. (2008) find a potential for significant increases in costs (and thus the SCC) in FUND. Nicholls, R. J., Tol, R. S., & Vafeidis, A. T. (2008). Global estimates of the impact of a collapse of the West Antarctic ice sheet: an application of FUND. *Climatic Change*, 91(1), 171-191. Ceronsky et al. (2011) model three tipping points (collapse of the Atlantic Ocean Meridional Overturning Circulation, large scale dissociation of oceanic methane hydrates; and a high equilibrium climate sensitivity parameter), and finds a large increase in the SCC in some cases. Ceronsky, M., Anthoff, D., Hepburn, C., & Tol, R. S. (2011). *Checking the price tag on catastrophe: The social cost of carbon under non-linear climate response* (No. 392). ESRI working paper.

<sup>192</sup> Golub, A., & Brody, M. (2017). Uncertainty, climate change, and irreversible environmental effects: application of real options to environmental benefit-cost analysis. *Journal of Environmental Studies and Sciences*, 1-8; see Figure 1 in IWG (2016).

(the resulting) SCC distributions with lower variances, holding the mean constant.<sup>193</sup> While the IWG assumes a risk-neutral central planner by using a constant discount rate (setting the risk premium to zero), this assumption does not correspond with empirical evidence,<sup>194</sup> current IAM assumptions,<sup>195</sup> the NAS (2017) recommendations, nor with the IWG's own discussion (2010) of the possible values of the elasticity of the marginal utility of consumption. Evidence from behavioral experiments indicate that people and society are also averse to other attributes of parameter distributions – specifically to the thickness of the tails of distributions – leading to an additional ambiguity premium (Heal and Millner, 2014).<sup>196</sup> Designing IAMs to properly account for the risk and ambiguity premiums from uncertain climate damages would increase the resulting SCC values they generate.

Even under the IWG's current assumption of risk neutrality, the mean SCC from uncertainty propagation excludes the (real) option value of preventing marginal CO<sub>2</sub> emissions.<sup>197</sup> Option value reflects the value of future flexibility due to uncertainty and irreversibility; in this case, the irreversibility of CO<sub>2</sub> emissions due to their long life in the atmosphere.<sup>198</sup> If society exercises the option of emitting an additional unit of CO<sub>2</sub> emissions today, “we will lose future flexibility that the [mitigation] option gave” leading to possible “regret and...a desire to ‘undo’” the additional emission because it “constrains future behavior.”<sup>199</sup> Given that the SCC is calculated on the Business as Usual (BAU) emission pathway, option value will undoubtedly be positive for an incremental emission because society will regret this emission in most possible futures.

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<sup>193</sup> In other words, society prefers a narrow distribution of climate damages around mean level of damages X to a wider distribution of damages also centered on the same mean of X because they avoid the potential for very high damages even at the cost of eliminating the chance of very low damages.

<sup>194</sup> IWG, 2010, at fn 22; Cai et al., 2016, *supra* note 178, at 521.

<sup>195</sup> The developers of each of the three IAMs used by the IWG (2010; 2013; 2016) assume a risk aversion society. Nordhaus and Sztorc, 2013, *supra*; Anthoff, D., & Tol, R. S. (2010). The Climate Framework for Uncertainty, Negotiation and Distribution (FUND): Technical description, Version 3.5. Available at [www.fund-model.org](http://www.fund-model.org); Anthoff, D., & Tol, R. S. (2014). The Climate Framework for Uncertainty, Negotiation and Distribution (FUND): Technical description, Version 3.8. Available at [www.fund-model.org](http://www.fund-model.org); Hope, C. (2013). Critical issues for the calculation of the social cost of CO<sub>2</sub>: why the estimates from PAGE09 are higher than those from PAGE2002. *Climatic Change*, 117(3), 531-543.

<sup>196</sup> According to Heal and Millner (2014), *supra*, there is an ongoing debate of whether ambiguity aversion is rational or a behavioral mistake. Given the strong possibility that this debate is unlikely to be resolved, the authors recommend exploring both assumptions.

<sup>197</sup> Arrow, K. J., & Fisher, A. C. (1974). Environmental preservation, uncertainty, and irreversibility. *The Quarterly Journal of Economics*, 312-319; Dixit, A.K., Pindyck, R.S., 1994. *Investment Under Uncertainty*. Princeton University Press, Princeton, NJ; Traeger, C. P. (2014). On option values in environmental and resource economics. *Resource and Energy Economics*, 37, 242-252.

In the discrete emission case, there are two overlapping types of option value: real option value and quasi-option value. Real option value is the full value of future flexibility of maintaining the option to mitigate, and mathematically equals the maximal value that can be derived from the option to [emit] now or later (incorporating learning) less the maximal value that can be derived from the possibility to [emit] now or never. Traeger, C. P. (2014). On option values in environmental and resource economics. *Resource and Energy Economics*, 37, 242-252, equation 5. Quasi-option value is the value of future learning conditional on delaying the emission decision, which mathematically equals the value of mitigation to the decision maker who anticipates learning less the value of mitigation to the decision maker who anticipates only the ability to delay his/her decision, and not learning. *Id.* The two values are related, such that real option value can be decomposed into:

$$DPOV = \text{Max}\{QOV + SOV - \text{Max}\{NPV, 0\}, 0\} = \text{Max}\{QOV + SOV - SCC, 0\}$$

where DPOV is the real option value, QOV is quasi-option value, SOV is simple option value (the value of the option to emit in the future condition on mitigating now), and NPV is the expected net present value of emitting the additional unit or the mean SCC in our case. *Id.*

<sup>198</sup> Even if society drastically reduced CO<sub>2</sub> emissions, CO<sub>2</sub> concentrations would continue to rise in the near future and many impacts would occur regardless due to lags in the climate system. Pindyck, R. S. (2007). Uncertainty in environmental economics. *Review of environmental economics and policy*, 1(1), 45-65.

<sup>199</sup> Pindyck (2007).

Though sometimes the social cost of carbon and a carbon tax are thought of as interchangeable ways to value climate damages, agencies should be careful to distinguish two categories of the literature. The first is the economic literature that calculates the optimal carbon tax in a scenario where the world has shifted to an optimal emissions pathway. The second is literature that assesses the social cost of carbon on the business-as-usual (BAU) emissions pathway; the world is currently on the BAU pathway, since optimal climate policies have not been implemented. There are currently no numerical estimates of the risk premium and option value associated with an incremental emission on the BAU emissions path. Although there are stochastic dynamic optimization models that implicitly account for these two values, they analyze *optimal*, sequential decision making under climate uncertainty.<sup>200</sup> By nature of being optimization models (instead of policy models), these complex models focus on calculating the optimal tax and not the social cost of carbon, which differ in that the former is the present value of marginal damages on the optimal emissions path rather than on the BAU emissions path.<sup>201</sup> While society faces the irreversibility of emissions on the BAU emissions path when abatement is essentially near zero (i.e., far below the optimal level even in the deterministic problem),<sup>202</sup> the stochastic dynamic optimization model must also account for a potential counteracting abatement cost irreversibility – the sunk costs of investing in abatement technology if we learn that climate change is less severe than expected – by the nature of being on the optimal emissions path that balances the cost of emissions and abatement. In the optimal case, uncertainty and irreversibility of abatement *can theoretically* lead to a lower optimal emissions tax, unlike the social cost of carbon. The difference in the implication for the optimal tax and the SCC means that the stochastic dynamic modeling results are less applicable to the SCC.

#### *What can we learn from new literature on stochastic dynamic programming models?*

Bearing in mind the limitations of stochastic dynamic modeling, some new research provides valuable insights that are relevant to calculation of the social cost of greenhouse gases. The new and growing stochastic dynamic optimization literature implies that the IWG's SCC estimates are downward biased. The literature is made up of three models – real option, finite horizon, and infinite horizon models – of which the infinite time horizon (i.e., stochastic dynamic programming (SDP)) models are the most comprehensive for analyzing the impact of uncertainty on optimal sequential abatement policies.<sup>203</sup> Recent computational advancements in SDP are helping overcome the need for strong simplifying assumptions in this literature for purpose of tractability. Traditionally, these simplifications led to unrealistically fast rates of learning – leading to incorrect outcomes – and difficulty in comparing results across papers (due to differing uncertain parameters, models of learning, and model types). Even so, newer methods still only allow for a handful of uncertain parameters compared to the hundreds of

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<sup>200</sup> Kann & Weyant, *supra*; Pindyck (2007), *supra*; Golub et al. (2014), *supra*.

<sup>201</sup> Nordhaus (2014) makes this difference clear when he clarifies that “With an optimized climate policy...the SCC will equal the carbon price...In the more realistic case where climate policy is not optimized, it is conventional to measure the SCC as the marginal damage of emissions along the actual path. There is some inconsistency in the literature on the definition of the path along which the SCC should be calculated. This paper will generally define the SCC as the marginal damages along the baseline path of emissions and output and not along the optimized emissions path.” Nordhaus, W. (2014). Estimates of the social cost of carbon: concepts and results from the DICE-2013R model and alternative approaches. *Journal of the Association of Environmental and Resource Economists*, 1(1/2), 273-312.

<sup>202</sup> On the BAU path, emissions far exceed their optimal level even without considering uncertainty. As a consequence, society is likely to regret an additional emission of CO<sub>2</sub> in most future states of the world. Alternatively, society is unlikely to regret current abatement levels unless the extremely unlikely scenarios that there is little to no warming and/or damages from climate change.

<sup>203</sup> Kann and Weyant, 2000, *supra*; Pindyck, 2007, *supra*; Golub et al., 2014, *supra*.

uncertain parameters in FUND and PAGE. Despite these limitations, the literature supports the above finding that the SCC, if anything, increases under uncertainty.<sup>204</sup>

First, uncertainty increases the optimal emissions tax under realistic parameter values and modeling scenarios. While the impact of uncertainty on the optimal emissions tax (relative to the deterministic problem) depends on the uncertain parameters considered, the type of learning, and the model type (real option, finite horizon, and infinite horizon), the optimal tax clearly increases when tipping points or black swan events are included in stochastic optimization problems.<sup>205</sup> For SDP models, uncertainty tends to strengthen the optimal emissions path relative to the determinist case even without tipping points,<sup>206</sup> and these results are strengthened under realistic preference assumptions.<sup>207</sup> Given that there is no counter-balancing tipping abatement cost,<sup>208</sup> the complete modeling of climate uncertainty – which fully accounts for tipping points and fat tails – increases the optimal tax. Uncertainty leads to a stricter optimal emissions policy even if with irreversible mitigation costs, highlighting that the SCC would also increase when factoring in risk aversion and irreversibility given that abatement costs are very low on the BAU emissions path.

Second, given the importance of catastrophic impacts under uncertainty (as shown in the previous paragraph), the full and accurate modeling of tipping points and unknown knowns is critical when modeling climate change. The most sophisticated climate-economic models of tipping points – which include the possibility of multiple correlated tipping points in stochastic dynamic IAMs – find an increase in the optimal tax by 100%<sup>209</sup> to 800%<sup>210</sup> relative to the deterministic case without them. More realistic modeling of tipping points will also increase the SCC.

Finally, improved modeling of preferences will amplify the impact of uncertainty on the SCC. Adopting Epstein-Zin preferences that disentangle risk aversion and time preferences can significantly increase the SCC under uncertainty.<sup>211</sup> Recent research has shown that accurate estimation of decisions under

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<sup>204</sup> Kann and Weyant, 2000, *supra*; Pindyck, 2007, *supra*; Golub et al., 2014, *supra*; Lemoine and Rudik, 2017, *supra*. Comparing the optimal tax to the mean SCC is made further difficult by the frequent use of DICE as the base from which most stochastic dynamic optimization models are built. As a consequence, deterministic model runs are frequently the base of comparison for these models (Lemoine and Rudik, 2017).

<sup>205</sup> The real options literature tends to find an increase in the optimal emissions path under uncertainty relative to the deterministic case (Pindyck, 2007), though the opposite is true when modelers account for the possibility of large damages (i.e., tipping point or black swan events) even with a risk-neutral society (Pindyck, 2007; Golub et al., 2014). Solving finite horizon models employing non-recursive methods, modelers find that the results differ depending on the model of learning – the research demonstrates stricter emission paths under uncertainty without learning (with emission reductions up to 30% in some cases) and the impact under passive learning has a relatively small impact due the presence of sunken mitigation investment costs - except when tipping thresholds are included (Golub et al., 2014).

<sup>206</sup> Using SDP, modelers find that uncertainty over the equilibrium climate sensitivity parameter generally increases the optimal tax by a small amount, though the magnitude of this impact is unclear (Golub et al., 2014; Lemoine and Rudik, 2017). Similarly, non-catastrophic damages can have opposing effects dependent on the parameters changed, though emissions appear to decline overall when you consider their uncertainty jointly.

<sup>207</sup> Pindyck, 2007; Golub et al., 2017; Lemoine and Rudik, 2017

<sup>208</sup> Pindyck, 2007

<sup>209</sup> Lemoine, D., & Traeger, C. P. (2016b). Economics of tipping the climate dominoes. *Nature Climate Change*.

<sup>210</sup> Cai et al., 2016

<sup>211</sup> Cai et al., 2016; Lemoine and Rudik, 2017. The standard utility function adopted in IAMs with constant relative risk version implies that the elasticity of substitution equals the inversion of relative risk aversion. As a consequence, the society's preferences for the intra-generational distribution of consumption, the intergenerational distribution of consumption, and risk aversion hold a fixed relationship. For purposes of stochastic dynamic programming, this is problematic because this assumption conflates intertemporal consumption smoothing and risk aversion. Botzen, W. W., & van den Bergh, J. C. (2014). Specifications of social welfare in economic studies of climate policy: overview of criteria and related policy



uncertainty crucially depends on distinguishing between risk and time preferences.<sup>212</sup> By conflating risk and time preferences, current models substantially understate the degree of risk aversion exhibited by most individuals, artificially lowering the SCC. Similarly, adopting ambiguity aversion increase the SCC, but to a much lesser extent than risk aversion.<sup>213</sup> Finally, allowing for the price of non-market goods to increase with their relative scarcity can amplify the positive effect that even small tipping points have on the SCC if the tipping point impacts non-market services.<sup>214</sup> Including more realistic preference assumptions in IAMs would further increase the SCC under uncertainty.

Introducing stochastic dynamic modeling (which captures option value and risk premiums), updating the representation of tipping points, and including more realistic preference structures in traditional IAMs will – as in the optimal tax – further increase the SCC under uncertainty

### *Conclusion: Uncertainty Raises the Social Cost of Greenhouse Gases*

Overall, the message is clear: climate uncertainty is *never* a rationale for ignoring the SCC or shortening the time horizon of IAMs. Instead, our best estimates suggest that increased variability implies a higher SCC and a need for more stringent emission regulations.<sup>215</sup> Current omission of key features of the climate problem under uncertainty (the risk and climate premiums, option value, and fat tailed probability distributions) and incomplete modeling of tipping points imply that the SCC will further increase with the improved modeling of uncertainty in IAMs.

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insights. *Environmental and Resource Economics*, 58(1), 1-33. By adopting the Epstein-Zinn utility function which separates these two parameters, modelers can calibrate them according to empirical evidence. For example, Cai et al. (2016) replace the DICE risk aversion of 1.45 and elasticity parameter of 1/1.45 with values of 3.066 and 1.5, respectively.

<sup>212</sup> James Andreoni & Charles Sprenger, *Risk Preferences Are Not Time Preferences*, 102 AM. ECON. REV. 3357–3376 (2012).

<sup>213</sup> Lemoine, D., & Traeger, C. P. (2016b). Economics of tipping the climate dominoes. *Nature Climate Change*; Lemoine and Rudik, 2017

<sup>214</sup> Typically, IAMs assume constant relative prices of consumption goods. Gerlagh, R., and B.C.C. Van der Zwaan. 2002. “Long-term substitutability between environmental and man-made goods.” *Journal of Environmental Economics and Management* 44(2):329-345; Sterner, T., and U.M. Persson. 2008. “An Even Sterner Review: Introducing Relative Prices into the Discounting Debate.” *Review of Environmental Economics and Policy* 2(1):61-76. By replacing the standard isoelastic utility function in IAMs with a nested CES utility function following Sterner and Persson (2008), Cai et al. (2015) find that even a relatively small tipping point (i.e., a 5% loss) can substantially increase the SCC in the stochastic dynamic setting. Cai, Y., Judd, K. L., Lenton, T. M., Lontzek, T. S., & Narita, D. (2015). Environmental tipping points significantly affect the cost–benefit assessment of climate policies. *Proceedings of the National Academy of Sciences*, 112(15), 4606-4611.

<sup>215</sup> Golub et al. (2014) states “The most important general policy implication from the literature is that despite a wide variety of analytical approaches addressing different types of climate change uncertainty, none of those studies supports the argument that no action against climate change should be taken until uncertainty is resolved. On the contrary, uncertainty despite its resolution in the future is often found to favor a stricter policy.”

## Technical Appendix: Discounting

### *The Underlying IAMs All Use a Consumption Discount Rate*

Employing a consumption discount rate would also ensure that the U.S. government is consistent with the assumptions employed by the underlying IAM models: DICE, FUND, and PAGE. Each of these IAMs employs consumption discount rates calibrated using the standard Ramsey formula (Newell, 2017). In DICE-2010, the elasticity of the pure rate of time preference is 1.5 and an elasticity of the marginal utility of consumption ( $\eta$ ) of 2.0. Together with its assumed per capita consumption growth path, the average discount rate over the next three hundred years is 2.4%.<sup>216</sup> However, more recent versions of DICE (DICE-2013R and DICE-2016) update  $\eta$  to 1.45; this implies an increase of the average discount rate over the timespan of the models to between 3.1% and 3.2% depending on the consumption growth path.<sup>217</sup> In FUND 3.8 and (the mode values in) PAGE09, both model parameters are equal to 1.0. Based on the assumed growth rate of the U.S. economy (without climate damages), the average U.S. discount rate in FUND 3.8 is 2.0% over the timespan of the model (without considering climate damages). Unlike FUND 3.8, PAGE09 specifies triangular distributions for both parameters with a pure rate of time preference of between 0.1 and 2 with a mean of 1.03 and an elasticity of the marginal utility of consumption of between 0.5 and 2 with a mean 1.17. Using the PAGE09's mode values (without accounting for climate damages), the average discount rate over the timespan of the models is approximately 3.3% with a range of 1.2% to 6.5%. Rounding up the annual growth rate over the last 50 years to approximately 2%,<sup>218</sup> the range of best estimates of the SDR implied in the short-run by these three models is approximately 3% (PAGE09's mode estimate and FUND 3.8) to 4.4% (DICE-2016), though the PAGE09 model alone implies a range of 1.1% to 6.0% with a central estimate of 3%. The range of potential consumption discount rates in these IAMs is relatively consistent with IWG (2010; 2013; 2016) in the short-run, though the discount rates of the IAMs employed by the IWG decline over time (due to declining growth rates over time) implying a potential upward bias to the IWG consumption discount rates.

### *A Declining Discount Rate is Justified to Address Discount Rate Uncertainty*

A strong consensus has developed in economics that the appropriate way to discount intergenerational benefits is through a declining discount rate (Arrow et al., 2013; Arrow et al., 2014; Gollier & Hammitt, 2014; Cropper et al., 2014).<sup>219</sup> Not only are declining discount rate theoretically correct, they are actionable (i.e., doable given our current knowledge) and consistent with OMB's *Circular A-4*. Perhaps the best reason to adopt a declining discount rate is the simple fact that there is considerable uncertainty around which discount rate to use. The uncertainty in the rate points directly to the need to use a declining rate, as the impact of the uncertainty grows exponentially over time such that the

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<sup>216</sup> Due to a slowing of global growth, DICE-2010 implies a declining discount rate schedule of 5.1% in 2015, 3.9% from 2015 to 2050; 2.9% from 2055 to 2100; 2.2% from 2105 to 2200, and 1.9% from 2205 to 2300. This would be a steeper decline if Nordhaus accounted for the positive and normative uncertainty underlying the SDR.

<sup>217</sup> Due to a slowing of global growth, DICE-2016 implies a declining discount rate schedule of 5.1% in 2015, 4.7% from 2015 to 2050; 4.1% from 2055 to 2100; 3.1% from 2105 to 2200, and 2.5% from 2205 to 2300.

<sup>218</sup> According to the World Bank, the average global and United States per capita growth rates were 1.7% and 1.9%, respectively.

<sup>219</sup> Arrow et al. (2014) at 160-161 states that "We have argued that theory provides compelling arguments for using a declining certainty-equivalent discount rate," and concludes the paper by stating "Establishing a procedure for estimating a [declining discount rate] for project analysis would be an improvement over the OMB's current practice of recommending fixed discount rates that are rarely updated."

correct discount rate is not an arithmetic average of possible discount rates.<sup>220</sup> Uncertainty about future discount rates could stem from a number of sources particularly salient in the context of climate change, including uncertainty about future economic growth, consumption, the consumption rate of interest, and preferences. Additionally, economic theory shows that if there is debate or disagreement over which discount rate to use, this should lead to the use of a declining discount rate (Weitzman, 2001; Heal & Millner, 2014). Though, the range of potential discount rates is limited by theory to potential consumption discount rates (see earlier discussion), which is certainly less than 7%.

*There is a consensus that declining discount rates are appropriate for intergenerational discounting*

Since the IWG undertook its initial analysis and before the most recent estimates of the SCC, a large and growing majority of leading climate economists consensus (Arrow et al., 2013) has come out in favor of using a declining discount rate for climate damages to reflect long-term uncertainty in interest rates. This consensus view is held whether economists favor descriptive (i.e., market) or prescriptive (i.e., normative) approaches to discounting (Freeman et al., 2015). Several key papers (Arrow et al., 2013; Arrow et al., 2014; Gollier & Hammitt, 2014; Cropper et al., 2014) outline this consensus and present the arguments that strongly support the use of declining discount rates for long-term benefit-cost analysis in both the normative and positive contexts. Finally, in a recent survey of experts on the economics of climate change, Howard and Sylvan (2015), found that experts support using a declining discount rate relative to a constant discount rate at a ratio of approximately 2 to 1.

Economists have recently highlighted two main motivations for using a declining discount rate, which we elaborate on in what follows. First, if the discount rate for a project is fixed but uncertain, then the certainty-equivalent discount rate will decline over time, meaning that benefits should be discounted using a declining rate.<sup>221</sup> Second, uncertainty about the growth rate of consumption or output also implies that a declining discount rate should be used, so long as shocks to consumption are positively correlated over time.<sup>222</sup> In addition to these two arguments, other motivations for declining discount rates have long been recognized. For instance, if the growth rate of consumption declines over time, the Ramsey rule<sup>223</sup> for discounting will lead to a declining discount rate.<sup>224</sup>

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<sup>220</sup> Karp (2005) states that mathematical “intuition for this result is that as [time] increases, smaller values of  $r$  in the support of the distribution are relatively more important in determining the expectation of  $e^{-rt}$ ” where  $r$  is the constant discount rate.” Or as Hepburn et al. (2003) puts it, “The intuition behind this idea is that scenarios with a higher discount rate are given less weight as time passes, precisely because their discount factor is falling more rapidly” over time.

<sup>221</sup> This argument was first developed in Weitzman (1998) and Weitzman (2001).

<sup>222</sup> See, e.g., Gollier (2009).

<sup>223</sup> The Ramsey discount rate equation for the social discount rate is  $r = \delta + \eta * g$  where  $r$  is the social discount rate,  $\delta$  is the pure rate of time preference,  $\eta$  is the aversion to inter-generational inequality, and  $g$  is the growth rate of per capita consumption. For the original development, see, Ramsey, F. P. (1928). A Mathematical Theory of Saving. *The Economic Journal*, 38(152).

<sup>224</sup> Higher growth rates lead to higher discounting of the future in the Ramsey model because growth will make future generations wealthier. If marginal utility of consumption declines in consumption, then, one should more heavily discount consumption gains by wealthier generations. Thus, if growth rates decline over time, then the rate at which the future is discounted should also decline. See, e.g., Arrow et al. (2014) at 148. It is standard in IAMs to assume that the growth rate of consumption will fall over time. See, e.g., Nordhaus (2017) at 1519, “Growth in global per capita output over the 1980–2015 period was 2.2% per year. Growth in global per capita output from 2015 to 2050 is projected at 2.1% per year, whereas that to 2100 is projected at 1.9% per year.” Similarly, Hope (2011) at 22 assumes that growth will decline. For instance, in the U.S., growth is 1.9% per year in 2008 and declines to 1.7% per year by 2040. Using data provided by Dr. David Anthoff (one of the founders of FUND), FUND assumes that the global growth rate was 1.8% per year from 1980–2015 period, 1.4% per year from 2015 to 2050 and 2015 to 2100, and then dropping to 1.0% from 2100 to 2200 and then 0.7% from 2200 to 2300.

In the descriptive setting adopted by the IWG (2010), economists have demonstrated that calculating the expected net present value of a project is equivalent to discounting at a declining certainty equivalent discount rate when (1) discount rates are uncertain, and (2) discount rates are positively correlated (Arrow et al., 2014 at 157). Real consumption interest rates are uncertain given that there are no multi-generation assets to reflect long-term discount rates and the real returns to all assets—including government bonds—are risky due to inflation and default risk (Gollier & Hammitt, 2014). Furthermore, recent empirical work analyzing U.S. government bonds demonstrates that they are positively correlated over time; this empirical work has estimated several declining discount rate schedules that the IWG can use (Cropper et al., 2014; 2014; Arrow et al., 2013; Arrow et al., 2014; Jouini and Napp, 2014; Freeman et al. 2015).

Currently when evaluating projects, the U.S. government applies the descriptive approach using constant rates of 3% and 7% based on the private rates of return on consumer savings and capital investments. As discussed previously, applying a capital discount rate to climate change costs and benefits is inappropriate (Newell, 2017). Instead, analysis should focus on the uncertainty underlying the future consumption discount rate (Newell, 2017). Past U.S. government analyses (IWG, 2010; IWG, 2013; IWG, 2016) modeled three consumption discount rates reflecting this uncertainty. If the U.S. government correctly returns its focus on multiple consumption discount rates, then the expected net present value argument given above implies that a declining discount rate is the appropriate way to perform discounting. As an alternative, given that the Ramsey discount rate approach is the appropriate methodology in intergenerational settings, the U.S. government could use a fixed, low discount rate as an approximation of the Ramsey equation following the recommendation of Marten et al. (2015); see our discussion on Martin et al. 2015). This is roughly IWG (2010)’s goal for using the constant 2.5% discount rate.

If the normative approach to discounting is used in the future (i.e., the current approach of IAMs), economists have demonstrated that an extended Ramsey rule<sup>225</sup> implies a declining discount rate when (1) the growth rate of per capita consumption is stochastic,<sup>226</sup> and (2) consumption shocks are positively correlated over time (or their mean or variances are uncertain) (Arrow et al., 2013; Arrow et al., 2014; Gollier & Hammitt, 2014; Cropper et al., 2014).<sup>227</sup> While a constant adjustment downwards (known as the precautionary effect<sup>228</sup>) can be theoretically correct when growth rates are independent and

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<sup>225</sup> If the future growth of consumption is uncertainty with mean  $\mu$  and variance  $\sigma^2$ , an extended Ramsey equation  $r = \delta + \eta * \mu - 0.5\eta^2\sigma^2$  applies where  $r$  is the social discount rate,  $\delta$  is the pure rate of time preference,  $\eta$  is the aversion to inter-generational inequality, and  $g$  is the growth rate of per capita consumption. Gollier (2012, Chapter 3) shows that we can rewrite the extended discount rate as  $r = \delta + \eta * g - 0.5\eta(\eta + 1)\sigma^2$  where  $g$  is the growth rate of expected consumption and  $\eta + 1$  is prudence.

<sup>226</sup> The IWG assumption of five possible socio-economic scenarios implies an uncertain growth path.

<sup>227</sup> The intuition of this result requires us to recognize that the social planner is prudent in these models (i.e., saves more when faces riskier income). When there is a positive correlation between growth rates in per capita consumption, the representative agent faces more cumulative risk over time with respect to the “duration of the time spent in the bad state.” (Gollier et al., 2008). In other words, “the existence of a positive correlation in the changes in consumption tends to magnify the long-term risk compared to short-term risks. This induces the prudent representative agent to purchase more zero-coupon bonds with a long maturity, thereby reducing the equilibrium long-term rate.” (Gollier, 2007). Mathematically, the intuition is that under prudence, the third term in the extended Ramsey equation (see footnote 323) is negative, and a “positive [first-degree stochastic] correlation in changes in consumption raises the riskiness of consumption at date  $T$ , without changing its expected value. Under prudence, this reduces the interest rate associated to maturity  $T$ ” (Gollier et al., 2007) by “increasing the strength of the precautionary effect” in the extended Ramsey equation (Arrow et al., 2014; Cropper et al., 2014).

<sup>228</sup> The precautionary effect measures aversion to future “wiggles” in consumption (i.e., preference for consumption smoothing) (Traeger, 2014).

identically distributed (Cropper et al., 2014), empirical evidence supports the two above assumptions for the United States, thus implying a declining discount rate (Cropper et al., 2014; Arrow et al., 2014; IPCC, 2014).<sup>229</sup> We should further expect this positive correlation to strengthen over time due to the negative impact of climate change on consumption, as climate change causes an uncertain permanent reduction in consumption (Gollier, 2009).<sup>230</sup>

Several papers have estimated declining discount rate schedules for specific values of the pure rate of time preference and elasticity of marginal utility of consumption (e.g., Arrow et al., 2014), though recent work demonstrates that the precautionary effect increases and discount rates decrease further when catastrophic economic risks (such as the Great Depression and the 2008 housing crisis) are modeled (Gollier & Hammitt, 2014; Arrow et al., 2014). It should be noted that this decline in discount rates due to uncertainty in the global growth path is in addition to that resulting from a declining central growth path over time (Nordhaus, 2014; Marten, 2015).<sup>231</sup>

Additionally, a related literature has developed over the last decade demonstrating that normative uncertainty (i.e., heterogeneity) over the pure rate of time preference ( $\delta$ )—a measure of impatience—also leads to a declining social discount rate (Arrow et al., 2014; Cropper et al., 2014; Freeman and Groom, 2016). Despite individuals differing in their pure rate of time preference (Gollier and Zeckhauser, 2005), an equilibrium (consumption) discount exists in the economy. In the context of IAMs, modelers aggregate social preferences (often measured using surveyed experts) by calibrating the preferences of a representative agent to this equilibrium (Millner and Heal, 2015; Freeman and Groom, 2016). The literature generally finds a declining social discount rate due to a declining collective pure rate of time preference (Gollier and Zeckhauser, 2005; Jouini et al., 2010; Jouini and Napp, 2014; Freeman and Groom, 2016).<sup>232</sup> The heterogeneity of preferences and the uncertainty surrounding economic growth hold simultaneously (Jouini et al., 2010; Jouini and Napp, 2014), leading to potentially two sources of declining discount rates in the normative context.

#### *Declining Rates are Actionable and Time-Consistent*

There are multiple declining discount rate schedules from which the U.S. government can choose, of which several are provided in Arrow et al. (2014) and Cropper et al. (2014). One possible declining

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<sup>229</sup> Essentially, the precautionary effect increases over time when shocks to the growth rate are positively correlated, implying that future societies require higher returns to face the additional uncertainty (Cropper et al., 2014; Arrow et al., 2014; IPCC, 2014).

<sup>230</sup> Due to the deep uncertainty characterizing future climate damages, some analysts argue that the stochastic processes underlying the long-run consumption growth path cannot be econometrically estimated (Weitzman, 2007; Gollier, 2012). In other words, economic damages, and thus future economic growth, are ambiguous. Agents must then form subjectivity probabilities, which may be better interpreted as a belief (Cropper et al., 2014). Again, theory shows that ambiguity leads to a declining discount rate schedule by Jensen's inequality (Cropper et al., 2014).

<sup>231</sup> A common assumption in IAMs is that global growth will slow over time leading to a declining discount rate schedule over time; see footnote 7. Uncertainty over future consumption growth and heterogeneous preferences (discussed below) would lead to a more rapid decline in the social discount rate.

<sup>232</sup> The intuition for declining discount rates due to heterogeneous pure rates of time preference is laid out in Gollier and Zeckhauser (2005). In equilibrium, the least patient individuals trade future consumption to the most patient individuals for current consumption, subject to the relative value of their tolerance for consumption fluctuations. Thus, while public policies in the near term mostly impact the most impatient individuals (i.e., the individuals with the most consumption in the near term), long-run public policies in the distant future are mostly going to impact the most patient individuals (i.e., the individuals with the most consumption in the long-run).

interest rate schedule for consideration by the IWG is the one proposed by Weitzman (2001).<sup>233</sup> It is derived from a broad survey of top economists in context of climate change, and explicitly incorporates arguments around interest rate uncertainty.<sup>234</sup> Other declining discount rate schedule include Newell and Pizer (2003); Groom et al. (2007); Freeman et al. (2015). Many leading economists support the United States government adopting a declining discount rate schedule (Arrow et al., 2014; Cropper et al., 2014). Moreover, the United States would not be alone in using a declining discount rate. It is standard practice for the United Kingdom and French governments, among others (Gollier & Hammitt, 2014; Cropper et al., 2014). The U.K. schedule explicitly subtracts out an estimated time preference.<sup>235</sup> France's schedule is roughly similar to the United Kingdom's. Importantly, all of these discount rate schedules yield lower present values than the constant 2.5% discount rate employed by IWG (2010), suggesting that even the lowest discount rate evaluated by the IWG is too high.<sup>236</sup> The consensus of leading economists is that a declining discount rate schedule should be used, harmonious with the approach of other countries like the United Kingdom. Adopting such a schedule would likely increase the SCC substantially from the administration's 3% estimate, potentially up to two to three fold (Arrow et al., 2013; Arrow et al., 2014; Freeman et al., 2015).

A declining discount rate motivated by discount rate or growth rate uncertainty avoids the time inconsistency problem that can arise if a declining pure rate of time preference ( $\delta$ ) is used. *Circular A-4* cautions that "[u]sing the same discount rate across generations has the advantage of preventing time-inconsistency problems."<sup>237</sup> A time inconsistent decision is one where a decision maker changes his or her plan over time, solely because time has passed. For instance, consider a decision maker choosing whether to make an investment that involves an up-front payment followed by future benefits. A time consistent decision maker would invest in the project if it had a positive net-present value, and that decision would be the same whether it was made 10 years before investment or 1 year before investment. A time inconsistent decision maker might change his or her mind as the date of the investment arrived, despite no new information becoming available. Consider a decision maker who has a declining pure rate of time preference ( $\delta$ ) trying to decide whether to invest in a project that has large up-front costs followed by future benefits. 10 years prior to the date of investment, the decision maker will believe that this project is a relatively unattractive investment because both the benefits and costs would be discounted at a low rate. Closer to the date of investment, however, the costs would be relatively highly discounted, possibly leading to a reversal of the individual's decision. Again, the discount rate schedule is time consistent as long as  $\delta$  is constant.

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<sup>233</sup> Weitzman (2001)'s schedule is as follows: 4% for 1-5 years; 3% for 6-25 years; 2% for 26-75 years; 1% for 76-300 years; and 0% for 300+ years.

<sup>234</sup> Freeman and Groom (2014) demonstrate that this schedule only holds if the heterogeneous responses to the survey were due to differing ethical interpretations of the corresponding discount rate question. A recent survey by Drupp et al. (2015) – which includes Freeman and Groom as co-authors – supports the Weitzman (2001) assumption.

<sup>235</sup> The U.K. declining discount rate schedule that subtracts out a time preference value is as follows (Lowe, 2008): 3.00% for 0-30 years; 2.57% for 31-75 years; 2.14% for 76-125 years; 1.71% for 126-200 years; 1.29% for 201-300 years; and 0.86% for 301+ years.

<sup>236</sup> Using the IWG's 2010 SCC model, Johnson and Hope (2012) find that the U.K. and Weitzman schedules yield SCCs of \$55 and \$175 per ton of CO<sub>2</sub>, respectively, compared to \$35 at a 2.5% discount rate. Because the 2.5% discount rate was included by the IWG (2010) to proxy for a declining discount rate, this result indicates that constant discount rate equivalents may be insufficient to address declining discount rates.

<sup>237</sup> *Circular A-4* at 35.

The arguments provided here for using a declining consumption discount rate are not subject to this time inconsistency critique. First, time inconsistency occurs if the decision maker has a declining pure rate of time preference, not due to a decreasing discount rate term structure.<sup>238</sup> Second, uncertainty about growth or the discount rate avoids time inconsistency because uncertainty is only resolved in the future, after investment decisions have already been made. As the NAS (2017) notes, “One objection frequently made to the use of a declining discount rate is that it may lead to problems of time inconsistency....This apparent inconsistency is not in fact inconsistent....At present, no one knows what the distribution of future growth rates...will be; it may be different or the same as the distribution in 2015. Even if it turns out to be the same as the distribution in 2015, that realization is new information that was not available in 2015.”<sup>239</sup>

We should note that time-inconsistency is not a reason to ignore heterogeneity (i.e., normative uncertainty) over the pure rate of time preference ( $\delta$ ). If the efficient declining discount rate schedule is time-inconsistent, the appropriate solution is to select the best time-consistent policy. Millner and Heal (2014) do just this by demonstrating that a voting procedure – whereby the median voter determines the collective preference – is: (1) time consistent, (2) welfare enhancing relative to the non-commitment, time-inconsistent approach, and (3) preferred by a majority of agents relative to all other time-consistent plans. Due to the right skewed distribution of the pure rate of time preference and the social discount rate as shown in all previous surveys (Weitzman, 2001; Drupp et al., 2015; Howard and Sylvan, 2015), the median is less than the mean social discount rate (and pure rate of time preference); the mean social discount rate is what holds in the very short-run under various aggregation methods, such as Weitzman (2001) and Freeman and Groom (2015). Combining an uncertain growth rate and heterogeneous preference together implies a declining discount rate starting at a lower value in the short-run. In addition to the reasons discussed earlier in the comments, this is another reason to exclude a discount rate as high as 7%.

*There is an economic consensus on the appropriateness of employing a consumption discount rate (and the inappropriateness of a capital discount rate) in the context of climate change*

There is a strong consensus among economists that it is theoretically correct to use consumption discount rates in the intergenerational setting of climate change, such as in the calculation of the SCC. Similarly, there is a strong consensus that a capital discount rate is inappropriate according to “good economics” (Newell, 2017).<sup>240</sup> This consensus holds across panels of experts on the social cost of carbon (NAS, 2017); surveys of experts on climate change and discount rates (Weitzman, 2001; Drupp et al., 2015; Howard and Sylvan, 2015; and Pindyck, 2016); the three most commonly cited IAMs employed in calculating the federal SCC; and the government’s own analysis (IWG, 2010; CEA, 2017). For more

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<sup>238</sup> Gollier (2012) states “It is often suggested in the literature that economic agents are time inconsistent if the term structure of the discount rate is decreasing. This is not the case. What is crucial for time consistency is the constancy of the rate of impatience, which is a cornerstone of the classic analysis presented in this book. We have seen that this assumption is compatible with a declining monetary discount rate.”

<sup>239</sup> NAS Second Report, *supra* note 48, at 182.

<sup>240</sup> The former co-chair of the National Academy of Sciences’ Committee on Assessing Approaches to Updating the Social Cost of Carbon – Richard Newell (2017) – states that “[t]hrough the addition of an estimate calculated using a 7 percent discount rate is consistent with past regulatory guidance under OMB Circular A-4, there are good reasons to think that such a high discount rate is inappropriate for use in estimating the SCC...It is clearly inappropriate, therefore, to use such modeling results with OMB’s 7 percent discount rate, which is intended to represent the historical before-tax return on private capital...This is a case where unconsidered adherence to the letter of OMB’s simplified discounting approach yields results that are inconsistent with and ungrounded from good economics.”

analysis of this issue, see the discussion in the main body our Comments on the inappropriateness using a discount rate premised on the return to capital in intergenerational settings.