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To: Environmental Protection Agency, via regulations.gov

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Subject: Comments on Flawed Estimates of the Social Cost of Carbon in the Proposed Repeal of Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units

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In an effort to justify its proposed repeal of the Clean Power Plan, EPA has manipulated its estimates of the social cost of greenhouse gases in ways at odds with the best available science, the best practices for economic analysis, and the legal standards for rational decisionmaking. EPA's new, so-called "interim" estimates value carbon reductions at as little as $1 per ton (through year 2035 emissions),[2] thereby negating 98% or more of benefits of carbon reductions as compared to estimates calculated by the Interagency Working Group on the Social Cost of Greenhouse Gases using the best available methodologies and data.[3] Indeed, even the Interagency Working Group's central estimate of $67 per ton (for year 2035 emissions)[4] is widely considered by economic and legal experts to reflect an extremely conservative estimate of the true costs of greenhouse gas emissions and should be treated as a lower-bound estimate.[5]

These comments detail EPA's many flaws in relying on a problematic new estimate of the social cost of carbon that arbitrarily ignores the real costs of greenhouse gas emissions:

- EPA arbitrarily attempts to limit its valuation of the social cost of carbon to purportedly domestic-only effects. Not only is a global perspective both required under principles of rational

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[1] Our organizations may separately submit other comments regarding other aspects of the proposed repeal.

[2] EPA, Regulatory Impact Analysis for the Review of the Clean Power Plan at 44, table 3-7 (2017; hereinafter "RIA") (reporting a $1 per ton interim value in 2011$ through year 2035 at a 7% discount rate). Using the CPI inflation calculator, $1 in 2011$ is just $1.12 in 2017$.

[3] In IWG's 2016 Technical Support Document Update of the Social Cost of Carbon for Regulatory Impact Analysis, *available at* https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc_tsd_final_clean_8_26_16.pdf, it reported the central estimate at a 3% discount rate for year 2035 emissions at $55 in 2007$. Using the CPI inflation calculator, that is worth $67.02 in 2017$. Compared to $67.02, $1.12 is a 98.3% reduction in value. Compared to IWG's estimate at a 2.5% discount rate ($95.05 for year 2035 emissions in 2017$), EPA's new interim estimates negate 99% of the value.

[4] IWG, 2016 Technical Support Update, *supra* note 3.

[5] *See* Richard L. Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, 508 NATURE 173 (2014); R.S. Pindyck, *The Social Cost of Carbon Revisited* (Nat'l Bureau of Econ. Res. Working Paper w22807, 2016) (estimating the social cost of carbon as between $100 and $200 per metric ton, based on expert elicitation to capture willingness to pay to avoid catastrophes). Even those estimates should be seen as lower bounds. Pindyck (2016) estimates the average SCC, and not the marginal SCC that IAMs estimate. Given that "we expect the [damage] function to be convex," R.S. Pindyck, *Coase Lecture—Taxes, Targets, and the Social Cost of Carbon*, Economica (2017), the average SCC is less than the marginal SCC.

decisionmaking and consistent with the standards of Circular A-4, but the methodology and models that EPA uses cannot calculate an accurate domestic-only value and ignore important ways in which the global impacts of climate change harm the United States. Furthermore, EPA inconsistently counts alleged cost savings that will ultimately accrue to foreign owners and foreign customers of U.S. firms, even as it excludes forgone benefits that will fall on U.S. citizens due to the global effects of climate change.

- EPA arbitrarily discounts future climate effects at a 7% discount rate in addition to a 3% rate. Applying a 7% discount rate to inter-generational effects is inconsistent with Circular A-4's requirements to distinguish social discount rates from rates based on private returns to capital; to make plausible assumptions; to adequately address uncertainty, especially over long time horizons; and to rely on the best available economic data and literature.
- EPA arbitrarily fails to follow prescribed practices for dealing with uncertainty. Specifically, EPA fails to address uncertainty over catastrophic damages, tipping points, option value, and risk aversion (by, for example, giving appropriate weight to an estimate of the social cost of carbon at the 95th percentile). By failing to run such sensitivity analyses, EPA overlooks how different (and more plausible) assumptions would change its cost-benefit calculation.
- EPA hides behind the label of "interim values" to cherry-pick only those methodological revisions that advance its predetermined goal of a lower social cost of carbon. Any update to the Interagency Working Group's 2016 estimates must fully engage with all the most up-to-date literature and with all the recommendations issued by the National Academies of Sciences.
- EPA fails to appropriately value unquantified forgone benefits from repealing the Clean Power Plan.

These critical failings completely undercut, and reverse the outcome of, the cost-benefit assessment that accompanies the proposed repeal, and underscores that the repeal is arbitrary and capricious.

Nevertheless, EPA does make a few appropriate methodological choices that it should continue applying in any future applications of the social cost of carbon. Specifically, EPA "rel[ies] on the same ensemble of three integrated assessment models (IAMs) that were used to develop the IWG [interagency working group] global SC-CH_4 (and SC-CO_2) estimates."[6] Indeed, because the Interagency Working Group on the Social Cost of Greenhouse Gases used the best available data and methodology, it is appropriate for agencies to continue to rely on its methodology. In fact, EPA should have relied more consistently on the Interagency Working Group's inputs and assumptions, and so focused on a global valuation calculation at a 3% or lower discount rate. EPA also explains the virtues of equally weighting the results of the three most peer-reviewed integrated assessment models, to balance out the limitations and omissions of any one model.[7] In any future applications of the social cost of carbon, EPA should continue to rely on the Interagency Working Group's methodology and use multiple peer-reviewed models. That said, EPA has failed to use the most up-to-date versions of those models, and should use the updated models in future calculations, including in any revised analysis of its proposed repeal.

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[6] RIA at 162.
[7] *Id*. at 164.

1. EPA Must Monetize the Full Social Cost of Carbon, Using the Best Available Data and Methodologies

Standards of rationality require attention to and consistent treatment of important factors. To the extent that EPA seeks to justify its proposed repeal, directly or indirectly, by comparing cost savings with forgone benefits, EPA's estimates of forgone benefits overlook a host of important factors like climate spillovers, international reciprocity, extraterritorial interests, intergenerational equity, uncertainty over long-term growth, uncertainty over catastrophic outcomes, risk aversion, option value, and unquantified effects to climate. Despite disbanding the Interagency Working Group, Executive Order 13,783, issued in March 2017, does not, and cannot, change EPA's legal obligations to appropriately weigh forgone benefits. Moreover, Executive Order 13,783's disbanding of the Interagency Working Group does nothing to change the fact that the IWG's 2016 estimates of the social cost of carbon reflect the best available data and methods.

Standards of Rationality Requires Attention to and Consistent Treatment of Important Factors

The Supreme Court defined the standard of rationality for agency actions under the Administrative Procedure Act as follows:

> Normally, an agency rule would be arbitrary and capricious if the agency has relied on factors which Congress has not intended it to consider, *entirely failed to consider an important aspect of the problem*, offered an explanation for its decision that runs counter to the evidence before the agency, or is so implausible that it could not be ascribed to a difference in view of the product of agency expertise.[8]

Furthermore, the Court found that the standard requires agencies to "examine the relevant data and articulate . . . a rational connection between the facts found and the choice made."[9]

Two federal courts of appeals have already applied arbitrary and capricious review to require the use of the social cost of greenhouse gases in agency decision-making. In *Center for Biological Diversity v. National Highway Traffic Safety Administration*, 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, its "decision not to monetize the benefit of carbon emissions reduction was arbitrary and capricious."[10] Specifically, it was arbitrary to "assign[ ] no value to *the most significant benefit* of more stringent [vehicle fuel efficiency] standards: reduction in carbon emissions."[11] 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."[12]

More recently, in *Zero Zone Inc. v. Department of Energy*, the U.S. Court of Appeals for the Seventh Circuit approved of the Department of Energy's use of the IWG's social cost of carbon estimates, holding that that "the expected reduction in environmental costs *needs* to be taken into account" in order for the Department "[t]o determine whether an energy conservation measure is appropriate under a cost-

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[8] *Motor Vehicle Manufacturers Assoc. v. State Farm Mutual Auto. Ins. Co.*, 463 U.S. 29, 41-43 (1983) (emphasis added); *see also id.* ("[W]e must 'consider whether the decision was based on a consideration of the relevant factors and whether there has been a clear error of judgment.'").

[9] *Id.*

[10] 538 F.3d 1172, 1203 (9th Cir. 2008).

[11] *Id.* at 1199.

[12] *Id.* at 1198.

benefit analysis."[13] Furthermore, the court specifically rejected petitioner's challenge to the Department's use of a global (rather than domestic) social cost of carbon, holding that Department had reasonably identified carbon pollution as "a global externality" and appropriately concluded that, because "national energy conservation has global effects, . . . those global effects are an appropriate consideration when looking at a national policy."[14]

Two federal district courts have also found the failure to use the social cost of carbon in NEPA analyses to be arbitrary and capricious.[15] In *High Country Conservation Advocates v. Forest Service*, the U.S. District Court for the District 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"—specifically, by applying the "social cost of carbon protocol."[16] In *Montana Environmental Information Center v. Office of Surface Mining*, the U.S. District Court for the District 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 while failing to use the social cost of carbon to quantify the costs.[17]

In short, agencies must monetize important greenhouse gas effects when analyzing the costs and benefits of their actions.[18]

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

Executive Orders 12,866 and 13,563 remain in effect[19] and continue to require agencies to weigh the costs and benefits of significant regulatory actions. In particular, Executive Order 12,866 requires agencies to "select those approaches that maximize net benefits (including potential economic, *environmental, public health* and safety, *and other advantages*; distributive impacts; and equity), unless a statute requires another regulatory approach."[20] For significant regulatory actions, agencies must quantify costs and benefits to the fullest extent feasible.[21] The Interagency Working Group on the Social Cost of Greenhouse Gases was specifically organized to develop a single, harmonized value for all agencies to use in their regulatory impact analyses under Executive Order 12,866.[22]

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[13] 832 F.3d 654, 677 (7th Cir. 2016).

[14] *Id.* at 679.

[15] Three cases from different courts have declined to find that specific failures to use the social cost of carbon in NEPA analyses rise to the level of arbitrary and capricious action, but the cases 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). More recently the U.S. Court of Appeals for the District of Columbia Circuit confirmed that NEPA requires a rigorous analysis of climate effects and, in its remand to FERC, required the agency to explain and justify its position if it decides not to use the social cost of carbon. *Sierra Club v. FERC*, No. 16-1329, 2017 WL 3597014, at *10 (D.C. Cir. Aug. 22, 2017).

[16] 52 F. Supp. 3d 1174, 1191 (D. Colo. 2014) (emphasis original).

[17] 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).

[18] *See generally* Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 COLUMBIA J. ENVTL. L. 203 (2017) for more on applying standards of rationality to the social cost of carbon.

[19] *See* Exec. Order No. 13,777 § 2 (Feb. 24, 2017) (continuing to cite the policies required under Executive Orders 12,866 and 13,563).

[20] Exec. Order 12,866 § 1(a) (Oct. 4, 1993).

[21] *Id*. § 6(a)(3)(C)(i).

[22] INTERAGENCY WORKING GROUP ON SOCIAL COST OF CARBON, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12,866 (2010). Though note the IWG's estimates are applicable in a wider range of contexts,

President Trump's Executive Order 13,783, issued March 28, 2017, officially disbanded the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) and withdrew the technical support documents that underpinned their range of estimates.[23] 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."[24] Consequently, while EPA and other federal agencies no longer have technical guidance directing them to exclusively rely on the IWG's estimates to monetize climate effects, 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.[25] The 2017 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.[26] The new 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.

As explained throughout these comments, the IWG's estimates of the social cost of greenhouse gases are, in fact, already consistent with the Circular A-4 and represent the best existing estimates of the lower bound of the range for the social cost of greenhouse gases. Therefore, the IWG estimates or those of a similar or higher value[27] should be used in regulatory analyses and environmental impact statements.

2. EPA Must Rely on a Global Estimate of the Social Cost of Greenhouse Gases

EPA claims that Circular A-4 requires a "domestic perspective in our central analysis"[28] and therefore buries its discussion of global climate damages from the repeal of the Clean Power Plan in an appendix to the Regulatory Impact Analysis. EPA is wrong. Not only is it inconsistent with Circular A-4, best economic practices, and statutory requirements to fail to estimate the global damages of U.S. greenhouse gas emissions in regulatory analyses, but existing methods for estimating a "domestic-only"

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including environmental impact statements. *See High Country and Montana Environmental,* 52 F. Supp. 3d 1174, 1191 (D. Colo. 2014).

[23] Exec. Order. No. 13,783 § 5(b), 82 Fed. Reg. 16,093 (Mar. 28, 2017).

[24] *Id.* § 5(c).

[25] OMB, Circular A-4 at 27 (2003) ("You should monetize quantitative estimates whenever possible.").

[26] 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).

[27] *See*, *e.g.*, Richard L. Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, 508 NATURE 173 (2014) (explaining that current estimates omit key damage categories and, therefore, are very likely underestimates).

[28] RIA at 43. EPA further claims that the reasons for a domestic-only perspective is (1) because authority to regulate only extends to U.S. residents, and (2) because of the assumption that most domestic policies will have negligible effects on foreign welfare. *Id.* at 168, n.83. The second reason given is patently false in the case of climate regulation. The first reason given is inapposite in the case of climate regulation: the boundaries of U.S. regulatory jurisdiction in no way changes the fact that U.S. interests in preventing climate change are inextricably bound with foreign countries, through our interconnected economy, our national security, and reciprocity.

value—including EPA's approach—are unreliable, incomplete, and inconsistent with Circular A-4. EPA's domestic-only estimate inappropriately relies on models never built for the purpose of calculating regional damages, ignores recent literature on significant U.S. climate damages, and fails to reflect international spillovers to the United States, U.S. benefits from foreign reciprocal actions, and the extraterritorial interests of U.S. citizens including financial interests and altruism. At the same time, EPA inconsistently counts in full the portion of alleged cost savings that will ultimately accrue to foreign owners or foreign customers of U.S. firms.

A Global Estimate of Climate Damages Is Required by the Clean Air Act[29]

Section 111 of the Clean Air Act charges EPA with protecting public health and welfare,[30] where "welfare" is defined to include "effects on . . . weather . . . and climate."[31] When interpreting similar language in Section 202 of the Clean Air Act, the Supreme Court found "there is nothing counterintuitive to the notion that EPA can curtail the emission of substances that are putting the *global* climate out of kilter."[32] When industry challenged another EPA climate program by arguing that the Clean Air Act "was concerned about local, not global effects," the U.S. Court of Appeals for the D.C. Circuit had "little trouble disposing of Industry Petitioners' argument that the [Clean Air Act's prevention of significant deterioration] program is specifically focused solely on localized air pollution," finding instead that the statute was "meant to address a much broader range of harms," including "precisely the types of harms caused by greenhouse gases."[33]

To assess the necessary protections of public welfare under Section 111 of the Clean Air Act, EPA must value not only domestic welfare changes from climate effects occurring within U.S. borders, but also other significant U.S. welfare interests affected by climate—including U.S. interests in foreign businesses and property, in global tourism, in global commons like the oceans, and in global existence values and altruism; U.S. benefits from reciprocal foreign actions on climate; and U.S. effects that spill over from foreign climate damages through our interconnected economy, national security, and public health—as well as other significant global effects. As explained below, continued use of the global estimate of climate damages—as opposed to a domestic-only value—is the only defensible way to accurately capture the full costs of climate pollution to public welfare.

Circular A-4 Requires "Different Emphases . . . Depending on the Nature" of the Regulatory Issue

Since at least 2010, and including some recent agency actions under the Trump administration,[34] federal agencies have based their regulatory decision and NEPA reviews on global estimates of the social cost of

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[29] This subsection draws from Howard & Schwartz *supra* note 18. See *id.* for additional discussion of how Section 115 of the Clean Air Act, which explicitly requires the United States to take a global perspective on the effects of its greenhouse gas emissions, interacts with Section 111.

[30] 42 U.S.C. § 7411(b)(1)(A).

[31] 42 U.S.C. § 7602(h); *Massachusetts v. EPA*, 127 S.Ct. 1438, 1447 (2007).

[32] *Mass. v. EPA,* 127 S.Ct. at 1461 (emphasis added).

[33] *Coalition for Responsible Regulation v. EPA*, 684 F.3d 102, 138 (D.C. Cir. 2012), aff'd in part *Util. Air Regulatory Grp. v. EPA*, 134 S.Ct. 2427 (2014).

[34] E.g., Dep't of Energy, Energy Conservation Program: Energy Conservation Standards for Walk-In Cooler and Freezer Refrigeration Systems, 82 Fed. Reg. 31,808, 31,812 (July 10, 2017) ("DOE maintains that consideration of global benefits is appropriate because of the global nature of the climate change problem."); U.S. Dep't of Interior, Bureau of Ocean Energy Mgmt., Draft Envtl. Impact Statement: Liberty Development Project at 3-129, 4-246 (Aug. 2017) (BOEM, Liberty Development Project), *available at* https://cdxnodengn.epa.gov/cdx-enepa-II/public/action/eis/details?eisId= 236901 (calling the global social cost of carbon estimates developed in 2016 by the Interagency Working Group "a useful measure" and applying them to analyze the consequences of offshore oil and gas drilling).

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 has been 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.[35]

Opponents of climate regulation have long challenged the global number in court and other forums, and often attempted to use Circular A-4 as support.[36] 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."[37] 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 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.[38]

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.[39]

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,"[40] suggesting that in some circumstances it is appropriate for the analysis to be global. For example, EPA and the Department of Transportation have

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[35] *See generally* Howard & Schwartz, *supra* note 18.

[36] 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).

[37] 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.

[38] *Zero Zone v. Dept. of Energy*, 832 F.3d 654, 679 (7th Cir. 2016).

[39] Circular A-4 at 3.

[40] *Id.* at 38 (counting international transfers as costs and benefits "as long as the analysis is conducted from the United States perspective").

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.[41]

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.[42] 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 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.[43] Moreover, if all countries reverted to a domestic-only SCC, U.S. industry would be placed at a competitive disadvantage internationally, since a GDP-based SCC would be higher in the U.S. than in other countries; only a global SCC puts U.S. industry on a level playing field with the rest of the world.[44]

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.[45] 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.[46] For example, Canada and Mexico have explicitly borrowed the U.S. estimates of a global social cost of carbon to set their own fuel efficiency standards.[47] For the United States to now depart from this collaborative dynamic by reverting to a domestic-only estimate would undermine the country's long-

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[41] *See* Howard & Schwartz, *supra* note 18 at 268-69.

[42] *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.").

[43] 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

[44] *See* Robert S. Pindyck, to BLM, Comments on Proposed Rule and Regulatory Impact Analysis on the Delay and Suspension of Certain Requirements for Waste Prevention and Resource Conservation (Nov. 6, 2017), at 5 ("[W]ere all countries to adopt this domestic-only scheme, the United States would be at a competitive disadvantage because it uses a higher SCC than other countries.").

[45] *See* Robert Axelrod, *The Evolution of Cooperation* 10-11 (1984) (on repeated prisoner's dilemma games).

[46] *See* Howard & Schwartz, *supra* note 18, at Appendix B.

[47] *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).

term interests and could jeopardize emissions reductions underway in other countries, which are already benefiting the United States.

For these and other reasons, reliance on a domestic-only valuation is inappropriate. In the past, some agencies have, in addition to the global estimate, also disclosed a "highly speculative" estimate of the domestic-only effects of climate change as a sensitivity analysis. 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, after first properly emphasizing the global estimates; EPA has also occasionally disclosed similar estimates as sensitivity analyses to its primary estimates of global climate damages.[48] 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, under Circular A-4, EPA should have used the global social cost of carbon in the central analysis of the costs of repealing the Clean Power Plan that was presented in the preamble to the proposed rule.

Benefits and Costs that "Accrue to U.S. Citizens" Are Much Broader Than Effects "within U.S. Borders"

To follow Circular A-4's instruction to analyze all significant effects that "accrue[s] to U.S. citizens," agencies must look beyond "U.S. borders" to a much broader range of climate effects. Circular A-4 instructs to estimate *all* important "opportunity costs," meaning "what individuals are willing to forgo to enjoy a particular benefit."[49] U.S. individuals are willing to forgo money to enjoy benefits or avoid costs from climate effects that occur beyond U.S. borders, and all such significant effects must be captured.[50]

International Spillovers: First, agencies may not ignore significant, indirect costs to trade, human health, and security likely to "spill over" to the United States as other regions experience climate change damages.[51] Due to its unique place among countries—both as the largest economy with trade- and investment-dependent links throughout the world, and as a military superpower—the United States is particularly vulnerable to effects that will spill over from other regions of the world. Spillover scenarios could entail a variety of serious costs to the United States as unchecked climate change devastates other countries. Correspondingly, mitigation or adaptation efforts that avoid climate damages to foreign countries will radiate benefits back to the United States as well.[52] While the current IAMs provide reliable but conservative estimates of global damages, they currently cannot calculate reliable region-specific estimates, in part because they do not model such spillovers.

As climate change disrupts the economies of other countries, decreased availability of imported inputs, intermediary goods, and consumption goods may cause supply shocks to the U.S. economy. Shocks to the supply of energy, technological, and agricultural goods could be especially damaging. For example, when Thailand—the world's second-largest producer of hard-drives—experienced flooding in 2011, U.S.

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[48] Howard & Schwartz, *supra* note 18, at 220-21.

[49] Circular A-4 at 18.

[50] This section draws heavily from Howard & Schwartz (2017), *supra* note 18, and includes passages taken directly from that article (which was written by co-authors of these comments).

[51] Indeed, the integrated assessment models used to develop the global SCC estimates largely ignore inter-regional costs entirely. *See* Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon* (Cost of Carbon Project Report, 2014). Though some positive spillover effects are also possible, such as technology spillovers that reduce the cost of mitigation or adaptation, *see* S. Rao et al., *Importance of Technological Change and Spillovers in Long-Term Climate Policy*, 27 ENERGY J. 123-39 (2006), overall spillovers likely mean that the U.S. share of the global SCC is underestimated, *see* Jody Freeman & Andrew Guzman, *Climate Change and U.S. Interests*, 109 COLUMBIA L. REV. 1531 (2009).

[52] *See* Freeman & Guzman, *supra* note 51, at 1563-93.

consumers faced higher prices for many electronic goods, from computers to cameras.[53] A recent economic study explored how heat stress-induced reductions in productivity worldwide will ripple through the interconnected global supply network.[54] Similarly, the U.S. economy could experience demand shocks as climate-affected countries decrease their demand for U.S. goods. Financial markets may also suffer as foreign countries become less able to loan money to the United States and as the value of U.S. firms declines with shrinking foreign profits. As seen historically, economic disruptions in one country can cause financial crises that reverberate globally at a breakneck pace.[55]

The human dimension of climate spillovers includes migration and health effects. Water and food scarcity, flooding or extreme weather events, violent conflicts, economic collapses, and a number of other climate damages could precipitate mass migration to the United States from regions worldwide, especially, perhaps, from Latin America. For example, a 10% decline in crop yields could trigger the emigration of 2% of the entire Mexican population to other regions, mostly to the United States.[56] Such an influx could strain the U.S. economy and will likely lead to increased U.S. expenditures on migration prevention. Infectious disease could also spill across the U.S. borders, exacerbated by ecological collapses, the breakdown of public infrastructure in poorer nations, declining resources available for prevention, shifting habitats for disease vectors, and mass migration.

Finally, climate change is predicted to exacerbate existing security threats—and possibly catalyze new security threats—to the United States.[57] Besides threats to U.S. military installations and operations at home and abroad from flooding, storms, extreme heat, and wildfires,[58] Secretary of Defense Mattis has explained that "Climate change is impacting stability in areas of the world where our troops are operating today."[59] The Department of Defense's 2014 Defense Review declared that climate effects "are threat multipliers that will aggravate stressors abroad such as poverty, environmental degradation, political instability, and social tensions—conditions that can enable terrorist activity and other forms of violence," and as a result "climate change may increase the frequency, scale, and complexity of future missions, including defense support to civil authorities, while at the same time undermining the capacity of our domestic installations to support training activities."[60] As an example of the climate-security-migration nexus, prolonged drought in Syria likely exacerbated the social and political tensions that

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[53] *See* Charles Arthur, *Thailand's Devastating Floods Are Hitting PC Hard Drive Supplies*, THE GUARDIAN, Oct. 25, 2011.

[54] Leonie Wenz & Anders Levermann, *Enhanced Economic Connectivity to Foster Heat Stress-Related Losses*, SCIENCE ADVANCES (June 10, 2016).

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

[56] Shuaizhang Feng, Alan B. Krueger & Michael Oppenheimer, *Linkages Among Climate Change, Crop Yields and Mexico-U.S. Cross-Border Migration*, 107 PROC. NAT'L ACAD. SCI. 14,257 (2010).

[57] *See* CNA Military Advisory Board, *National Security and the Accelerating Risks of Climate Change* (2014).

[58] U.S. Gov't Accountability Office, GAO-14-446 *Climate Change Adaptation: DOD Can Improve Infrastructure Planning and Processes to Better Account for Potential Impacts* (2014); Union of Concerned Scientists, *The U.S. Military on the Front Lines of Rising Seas* (2016).

[59] Andrew Revkin, *Trump's Defense Secretary Cites Climate Change as National Security Challenge*, ProPublica, Mar. 14, 2017.

[60] U.S. Dep't of Defense, *Quadrennial Defense Review 2014* vi, 8 (2014).; see also U.S. Dep't of Defense, *Report to Congress: 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 ("Global climate change will have wide-ranging implications for U.S. national security interests over the foreseeable future because it will aggravate existing problems—such as poverty, social tensions, environmental degradation, ineffectual leadership, and weak political institutions—that threaten domestic stability in a number of countries.")

erupted into an ongoing civil war,[61] which has triggered an international migration and humanitarian crisis.[62]

Because of these interconnections, attempts to artificially segregate a U.S.-only portion of climate damages will inevitably result in misleading underestimates. Some experts on the social cost of carbon have concluded that, given that integrated assessment models currently do not capture many of these key inter-regional costs, use of the global SCC may be further justified as a proxy to capturing all spillover effects.[63] Though not all climate damages will spill back to affect the United States, many will, and together with other justifications, the likelihood of significant spillovers makes a global valuation the better, more transparent accounting of the full range of costs and benefits that matter to U.S. policymakers and the public.

EPA even recognizes in the economic analysis of the proposed repeal that the failure to "model all relevant regional interactions—i.e., how climate change impacts in other regions of the world could affect the United States, through pathways such as global migration, economic destabilization, and political destabilization"—represents a major challenge to estimating a domestic-only social cost of methane.[64] EPA also notes that the National Academies of Sciences concluded that it "is important to consider what constitutes a domestic impact in the case of a global pollutant that could have international implications that impact the United States."[65] Yet after acknowledging the serious deficiencies in its own domestic-only estimate, EPA fails to address these shortcomings and account for spillovers in any meaningful way. EPA therefore arbitrarily ignores an important factor.

Reciprocal Foreign Actions: Second, an indirect consequence of the United States using a global social cost of greenhouse gas to justify actions that protect against climate damages is that foreign countries take reciprocal actions that benefit the United States. Circular A-4 requires that the "same standards of information and analysis quality that apply to direct benefits and costs should be applied to ancillary benefits and countervailing risks."[66] Consequently, any attempt to estimate a domestic-only value of the social cost of greenhouse gas must include indirect effects from reciprocal foreign actions.

As detailed more in Howard & Schwartz (2017), because the world's climate is a single interconnected system, the United States benefits greatly when foreign countries consider the global externalities of their greenhouse gas pollution and cut emissions accordingly. Game theory predicts that one viable strategy for the United States to encourage other countries to think globally in setting their climate policies is for the United States to do the same, in a tit-for-tat, lead-by-example, or coalition-building dynamic. In fact, most other countries with climate policies already use a global social cost of carbon or set their carbon taxes or allowances at prices above their domestic-only costs, consistent with the global perspective used to date by U.S. agencies to value the cost of greenhouse gases. Both Republican and

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[61] *See* Center for American Progress et al., *The Arab Spring and Climate Change: A Climate and Security Correlations Series* (2013); Colin P. Kelley et al., *Climate Change in the Fertile Crescent and Implications of the Recent Syrian Drought*, 112 PROC. NAT'L ACAD. SCI. 3241 (2014); Peter H. Gleick, *Water, Drought, Climate Change, and Conflict in Syria*, 6 WEATHER, CLIMATE & SOCIETY, 331 (2014).

[62] *See, e.g.*, *Ending Syria War Key to Migrant Crisis, Says U.S. General*, BBC.COM (Sept. 14, 2015).

[63] *See* Robert E. Kopp & Bryan K. Mignone, Circumspection, Reciprocity, and Optimal Carbon Prices, 120 CLIMATE CHANGE 831, 833 (2013).

[64] RIA at 45-46.

[65] *Id*. at 46.

[66] Circular A-4 at 26.

Democratic administrations have recognized that the analytical and regulatory choices of U.S. agencies can affect the actions of foreign countries, which in turn affect U.S. citizens.[67]

According to one study, over the next fifteen years, direct U.S. benefits from global climate policies already in effect could reach over $2 trillion.[68] Any attempt to estimate a domestic-only value of the social cost of greenhouse gases must include such indirect effects from reciprocal foreign actions.[69]

Accounting for U.S. benefits from global reciprocal action still understates the potential loss from failing to account for reciprocity. As noted above, other countries may select a domestic SCC in response to the U.S. selecting a domestic number. Since a GDP-based SCC would be higher for the U.S. than other nations, U.S. industry would be placed at a competitive disadvantage internationally if all countries reverted to their own domestic-only SCCs. Thus, not only should the United States account for reciprocity, but it should do so in a general equilibrium context.[70]

EPA again recognizes this shortcoming in its own domestic-only value, noting that the National Academies of Sciences recommended a thorough estimation of the potential implications of reciprocal climate actions by other countries.[71] Yet again, EPA fails to address this serious deficiency and account for reciprocity in any meaningful way. EPA therefore arbitrarily ignores another important factor.

Extraterritorial Interests: Circular A-4 requires agencies to count all significant costs and benefits, and specifically explains the importance of including "non-use" values like "bequest and existence values": "ignoring these values in your regulatory analysis may significantly understate the benefits and/or costs of regulatory action."[72] Similarly, while Circular A-4 distinguishes altruism from non-use values, the guidance instructs agencies that "if there is evidence of selective altruism, it needs to be considered specifically in both benefits and costs."[73] Many costs and benefits accrue to U.S. citizens from use values, non-use values, and altruism attached to climate effects occurring outside the U.S. borders.

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,[74] including

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[67] Howard & Schwartz, *supra* note 18, at 232-37 (citing acknowledgement of this phenomenon by both the Bush administration and the Obama administration).

[68] Policy Integrity, *Foreign Action, Domestic Windfall: The U.S. Economy Stands to Gain Trillions from Foreign Climate Action* 11 (2015), http://policyintegrity.org/files/publications/ForeignActionDomesticWindfall.pdf

[69] Kotchen shows that the optimally strategic social cost of greenhouse gas value will be strictly higher than the domestic value for all countries. Matthew J. Kotchen, *Which Social Cost of Carbon? A Theoretical Perspective* (NBER Working Paper, 2016). *See also* Pindyck, Comments to BLM, *supra* note 44, for a discussion of Kotchen (2016), and for a related discussion of why a domestic social cost of carbon is not in the United States' interest.

[70] *See* Pindyck, Comments to BLM, *supra* note 44, at 5.

[71] RIA at 46.

[72] Circular A-4 at 22.

[73] *Id.*

[74] 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).

significant U.S. ownership interests in foreign businesses, properties, and other assets, as well as consumption abroad including tourism,[75] and even the 8 million Americans living abroad.[76]

The United States also has a willingness to pay—as well as a legal obligation—to protect the global commons of the oceans and Antarctica from climate damages. For example, the Madrid Protocol on Environmental Protection to the Antarctic Treaty commits the United States and other parties to the "comprehensive protection of the Antarctic environment," including "regular and effective monitoring" of "effects of activities carried on both within and outside the Antarctic Treaty area on the Antarctic environment."[77] The share of climate damages for which the United States is responsible is not limited to our geographic borders.

Similarly, U.S. citizens value natural resources and plant and animal lives abroad, even if they never use those resources or see those plants or animals. For example, the "existence value" of restoring the Prince William Sound after the 1989 Exxon Valdez oil tanker disaster—that is, the benefits derived by Americans who would never visit Alaska but nevertheless felt strongly about preserving the existence of this pristine environment—was estimated in the billions of dollars.[78] Though the methodologies for calculating existence value remain controversial,[79] U.S. citizens certainly have a non-zero willingness to pay to protect rainforests, charismatic megafauna like pandas, coral reefs, and other life and environments existing in foreign countries. U.S. citizens also have an altruistic willingness to pay to protect foreign citizens' health and welfare.[80] This altruism is "selective altruism," consistent with Circular A-4, because the United States is directly responsible for most of the historic emissions contributing to climate change.[81]

Standards of Rational Decisionmaking Require Consideration of Important, Globally Interconnected Climate Costs

The Administrative Procedure Act, as interpreted by the Supreme Court in *State Farm*, requires agencies to consider all "important aspect[s] of the problem" and articulate a rational connection between the facts and the choice made.[82] Because international spillovers, reciprocal foreign actions, and

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[75] "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=facultyworkingpaper.

[76] Assoc. of Americans Resident Oversees, 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.

[77] Madrid Protocol on Environmental Protection to the Antarctic Treaty (1991), http://www.ats.aq/documents/recatt/Att006_e.pdf

[78] RICHARD REVESZ & MICHAEL LIVERMORE, RETAKING RATIONALITY 121 (2008).

[79] *Id.* at 129.

[80] *See* Arden Rowell, *Foreign Impacts and Climate Change*, 39 HARV. ENVT'L. L. REV. 371 (2015); Dana, *supra* note 75 (discussing U.S. charitable giving abroad and foreign aid, and how those metrics likely severely underestimate true U.S. willingness to pay to protect foreign welfare).

[81] Datablog, *A History of CO_2 Emissions*, THE GUARDIAN (Sept. 2, 2009) (from 1900-2004, the United States emitted 314,772.1 million metric tons of carbon dioxide; Russia and China follow, with only around 89,000 million metric tons each).

[82] 5 U.S.C. § 706; *see Motor Vehicle Manufacturers Assoc. v. State Farm Mutual Auto. Ins. Co.*, 463 U.S. 29, 41-42 (1983) (applying the standards of review to deregulatory action and concluding that when "rescinding a rule" an agency "is obligated to supply a reasoned analysis for the change beyond that which may be required when an agency does not act in the first instance").

extraterritorial interests are all important aspects of the problem of greenhouse gas emissions, ignoring the global consequences of climate change is arbitrary and capricious.

Two courts of appeals have already applied arbitrary and capricious review to support the use of a global social cost of carbon in setting regulatory standards. In *Center for Biological Diversity v. NHTSA*, the U.S. Court of Appeals for the Ninth Circuit not only held that it was arbitrary not to monetize the greenhouse gas benefits of vehicle efficiency standards, but also approvingly cited a partial consensus among experts around an estimate of "$50 per ton of carbon (or $13.60 per ton CO2),"[83] which, in the year 2006 when the rule was issued, would have been consistent with estimates of a global social cost of carbon.[84] More recently, in *Zero Zone v. Department of Energy*, the Court of Appeals for the Seventh Circuit found, in response to petitioners' challenge that the agency's consideration of the global social cost of carbon was arbitrary, that the agency had acted reasonably in considering the global climate effects.[85]

For more details on the justification for a global value of the social cost of greenhouse gases, including the applicable standards of rational decisionmaking, 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 Nobel laureate Kenneth Arrow.[86]

No Current Methodology for Estimating a "Domestic-Only" Value Is Consistent with Circular A-4

Even if EPA could reasonably disregard global harms caused by emissions of a global pollutant like greenhouse gases, EPA has not identified a reasonable methodology for calculating a domestic-only value. 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.[87] Yet, as the IWG itself acknowledged, this range is almost certainly an underestimate because it ignores significant, indirect 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.[88]

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,

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[83] 538 F.3d at 1199, 1201.

[84] *See* Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011-2015, 73 Fed. Reg. 24,352, 24,414 (May 2, 2008) (the National Highway Traffic Safety Administration estimated that $14 per ton of carbon dioxide approximated global benefits).

[85] 832 F.3d at 679.

[86] Richard Revesz, Kenneth Arrow et al., *The Social Cost of Carbon: A Global Imperative*, 11 REEP 172 (2017).

[87] 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).

[88] *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").

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.[89] 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.[90] 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."[91] GDP therefore does not reflect significant U.S. ownership interests in foreign businesses, properties, and other assets, as well as consumption abroad including tourism,[92] or even the 8 million Americans living abroad.[93] 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.[94] However, not only has GNI fallen out of favor as a metric used in international economic policy,[95] 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.[96] 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.[97]

As a result, in 2015, OMB concluded, along with several other agencies, that "good methodologies for estimating domestic damages do not currently exist."[98] Similarly, the NAS recently concluded that current IAMs cannot accurately estimate the domestic social cost of greenhouse gases, and that

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[89] *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.

[90] 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).

[91] 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).

[92] "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=facultyworkingpaper.

[93] Assoc. of Americans Resident Oversees, 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.

[94] *GNI, Atlas Method (Current US$)*, THE WORLD BANK, http://data.worldbank.org/indicator/NY.GNP.ATLS.CD.

[95] *Id*.

[96] 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).

[97] 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).").

[98] 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].

estimates based on U.S. share of global GDP would be likewise insufficient.[99] William Nordhaus, the developer of the DICE model, cautioned in a recent paper that "regional damage estimates are both incomplete and poorly understood," and "there is little agreement on the distribution of the SCC by region."[100] 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.

EPA Relies on Sources that Cannot Accurately Calculate a Domestic-Only Estimate and that Explicitly Caution Against Using Domestic-Only Estimates

EPA reports that its domestic-only estimates are "calculated directly" from the models FUND and PAGE; for the model DICE, EPA simply assumes that U.S. damages are 10% of global damages.[101] EPA thus uses these models in ways they were never designed for—indeed, in ways their designers specifically cautioned against. EPA furthermore fails to assess the most up-to-date literature on U.S. damages and fails to take steps to reflect spillover effects, reciprocal benefits, or U.S. interests beyond our borders. EPA's methodology is deeply flawed.

The integrated assessment models used by the agency to calculate the social cost of carbon were designed to create global estimates and are best suited for those purposes. The models are limited in how accurately and fully they can estimate domestic values of the social cost of carbon. For example, the models make simplifying assumptions about the extent of heterogeneity in crucial parameters like relative prices and discount rates.[102] The models also simplify or ignore completely global spillovers from trade, migration, and other sources.[103] These types of spillovers will not, in many cases, affect the global estimate of climate change damages, but they will change (perhaps dramatically so) the domestic estimates, as detailed below. For example, trade effects will net to zero globally. A decrease in exports by one country must correspond to a decrease in imports for another country.[104] Global estimates will also generally be more accurate than domestic estimates because aggregation of multiple values reduces the error of the overall estimate.[105]

Examining the individual models used by the agency to calculate the domestic social cost of carbon highlights the current limitations facing calculation of a domestic value of the social cost of greenhouse gases. The agency uses three models: FUND 3.8, PAGE09, and DICE 2010.[106] The FUND model generally estimates domestic damages from climate change by scaling estimates according to gross domestic product or population. For instance, forestry damages are "mapped to the FUND regions assuming that the impact is uniform [relative] to GDP."[107] Similarly, domestic energy consumption changes are a function of gross domestic product, and the authors note that "heating demand is linear in the number of people" in a FUND region.[108] Scaling damages by gross domestic product and population will fail to

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[99] National Academies of Sciences, Engineering, and Medicine, *Valuing climate damages: Updating estimation of the social cost of carbon dioxide* at 53 (2017) [hereinafter NAS Second Report].

[100] William Nordhaus, *Revisiting the Social Cost of Carbon*, 114 PNAS 1518, 1522 (2017).

[101] RIA at 162.

[102] Christian Gollier & James K. Hammitt, *The Long-Run Discount Rate Controversy*, 6 ANNU. REV. RESOUR. ECON. 273–295 (2014) at 287-289.

[103] *See generally* Howard & Schwartz, *supra* note 18 (2017).

[104] *See, e.g.* PAUL R. KRUGMAN, MAURICE OBSTFELD & MARC J. MELITZ, INTERNATIONAL ECONOMICS: THEORY AND POLICY (10 ed. 2015). Such changes could have an effect on overall levels of trade, in turn effecting global damage estimates.

[105] *See, e.g.* SIDNEY I RESNICK, A PROBABILITY PATH (2013) at 203.

[106] RIA at 162.

[107] DAVID ANTHOFF & RICHARD S. J. TOL, THE CLIMATE FRAMEWORK FOR UNCERTAINTY, NEGOTIATION, AND DISTRIBUTION (FUND), TECHNICAL DESCRIPTION, VERSION 3.8 (2014) at 8.

[108] *Id.* at 10.

capture important differences between countries like pre-existing climate, interconnectedness of trade relationships, climate change preparedness, and preferences.

These issues are readily apparent in the case of agricultural damage estimates in FUND. Agriculture is one of the most important sectors driving the relatively low damages in the FUND model. Yet, recent evidence on this sector that incorporates cutting-edge estimates of crop yield changes finds that the FUND model substantially understates the agricultural damages from climate change.[109] Particularly for domestic damages, new research shows that FUND dramatically understates the effect of warming on agricultural outcomes globally and for individual countries like the United States.[110] These higher damage estimates come from updates to the relationship between warming and crop yield but also from a more thorough modeling of international trade in agricultural products.

The PAGE09 model scales global damages estimates according to regional coastline length, with the IWG noting that, "The [domestic] scaling factor in PAGE09 is based on the length of a region's coastline relative to the EU. . . . Because of the long coastline in the EU, other regions are, on average, less vulnerable than the EU for the same sea level and temperature increase."[111] The model also uses GDP scaling, stating that "other regions lose more or less [output] depending upon their GDP per capita and weights factors."[112] Coast-line length provides a reasonable scaling factor for damages from flooding, coastal storms, and other sea-level rise issues, but it likely understates damages to the United States, where increases in mortality, agricultural losses, and other effects will likely also occur in inland, warm areas of the country.[113] Scaling by gross domestic product has the same limitations noted above in the context of the FUND model.

Finally, the author of DICE 2010 has explicitly warned against using a domestic-only value. In a recent article, William Nordhaus states that, "The regional estimates [of the social cost of greenhouse gases] are poorly understood, often varying by a factor of 2 across the three models. Moreover, regional damage estimates are highly correlated with output shares." He later reiterates that "the regional damage estimates are both incomplete and poorly understood."[114] These statements reinforce the conclusion of OMB that "good methodologies for estimating domestic damages do not currently exist."[115]

In conclusion, EPA's estimation of the domestic-only social cost of methane ignores "important aspect[s] of the problem" and fails to articulate a rational connection between the data and the choice made, and is therefore arbitrary and capricious in violation of the Administrative Procedure Act.[116]

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[109] Frances C Francis C Moore, Uris Lantz C Baldos & Thomas Hertel, *Economic impacts of climate change on agriculture: a comparison of process-based and statistical yield models*, 12 ENVIRON. RES. LETT. 65008 (2017).

[110] F. C. Moore et al., *New Science of Climate Change Impacts on Agriculture Implies Higher Social Cost of Carbon*, 1–43 (2017).

[111] IWG, 2013 Technical Update to the Social Cost of Carbon, at 10.

[112] Chris Hope, *Critical issues for the calculation of the social cost of CO2: why the estimates from PAGE09 are higher than those from PAGE2002*, 117 CLIM. CHANGE 531–543 (2013) at 539.

[113] Solomon Hsiang et al., *Economic Damage from Climate Change in the United States*, 1369 SCIENCE. 1362–1369 (2017).

[114] William D Nordhaus, *Revisiting the social cost of carbon*, 114 PROC. NATL. ACAD. SCI. U. S. A. 1518–1523 (2017) at 1522.

[115] OMB 2015 Response to Comments, *supra* note 98.

[116] 5 U.S.C. § 706; *see Motor Vehicle Manufacturers Assoc. v. State Farm Mutual Auto. Ins. Co.*, 463 U.S. 29, 41-42 (1983) (applying the standards of review to deregulatory action and concluding that when "rescinding a rule" an agency "is obligated to supply a reasoned analysis for the change beyond that which may be required when an agency does not act in the first instance").

EPA Inconsistently Counts in Full the Portion of Cost Savings that Will Accrue to Foreign Owners and Customers, While Ignoring Forgone Benefits from Global Climate Impacts

EPA admits that some portion of the proposed repeal's estimated cost savings will "accru[e] to entities outside U.S. borders."[117] EPA tries to downplay these benefits to foreign entities by qualifying its admission "to the extent that affected firms have some foreign ownership."[118] EPA never attempts to separate out cost effects to foreign interests or to relegate such effects to an appendix. Yet a significant portion of cost savings will ultimately accrue to foreign owners and foreign customers of U.S. firms. Consequently, EPA's choice to ignore U.S. financial interests in global forgone climate benefits is a starkly arbitrary and inconsistent treatment of costs and benefits.

A significant portion of the proposed repeal's cost savings will accrue to foreign entities. All industry compliance costs ultimately fall on the owners, employees, and customers of regulated and affected firms. At a minimum, many if not all regulated and affected firms that are public companies have significant foreign ownership of stock and corporate debt. For example, Southern Company—a major utility that has been actively litigating the Clean Power Plan[119]—is a public company. Based on its recent 13F filings and an assessment of its top 100 institutional shareholders, upwards of 15% of Southern Company stock is held by foreign governments (such as the pension plans of the governments of Canada, South Korea, Sweden, and Norway; the Central Bank of Switzerland; and Her Majesty the Queen in Right of the Province of Alberta) or by foreign-based investment banks or funds (like Sumitomo Mitsui Trust Holdings Inc. of Japan and the Commonwealth Bank of Australia).[120] Norway's Government Pension Fund holds nearly $275 million worth of Southern Company stock as of December 2017.[121] Of course, many of those foreign-based investment banks and funds will have U.S. investors, but U.S.-based funds that invest heavily in Southern Company, like BlackRock, will similarly have foreign investors. Economy-wide, between 20-30% of U.S. stocks and 35% of U.S. corporate debt are held by foreigners,[122] with significant foreign direct investment in U.S. mining and fossil fuel extraction, in U.S. utilities, and in U.S. manufacturing.[123] A significant portion of the regulatory effects passing through Southern Company and other publicly-traded regulated companies would ultimately be experienced by such foreign owners.

Furthermore, whether or not regulated utilities or other affected industries have foreign ownership, many will have direct or indirect foreign consumers. For example, the National Association of Manufacturers—another active litigant against the Clean Power Plan[124]—touts that "Manufacturers help

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[117] RIA at 46.

[118] *Id.*

[119] The Alabama Power Company, the Georgia Power Company, the Gulf Power Company, and the Mississippi Power Company are wholly-owned subsidiaries of Southern Company, a publicly held corporation traded on the New York Stock Exchange.

[120] *See, e.g.,* NASDAQ, *Southern Company Institutional Ownership*, http://www.nasdaq.com/symbol/so/institutional-holdings?page=2 (last visited Apr. 26, 2018) (listing holdings by the Commonwealth Bank of Australia, Norges Bank, Siwss National Bank, UBS Asset Management, and Sumitomo Mitsui Trust Holdings).

[121] Norges Bank, Holdings as at 31.12.2017, https://www.nbim.no/en/the-fund/holdings/?fullsize=true.

[122] Heather Long, *Foreign Investors Can't Get Enough of the U.S.*, CNN, Oct. 1, 2015, http://money.cnn.com/2015/10/01/investing/foreign-investors-buy-us-stocks-bonds/index.html.

[123] Dept. of Treasury et al., *U.S. Portfolio Holdings of Foreign Securities as of June 30, 2016* (2017), https://www.treasury.gov/press-center/press-releases/Documents/shl2016_final_20170421.pdf (see exhibit 19: market value of foreign holdings of U.S. securities, by industry, as of June 30, 2016).

[124] *See* Application of Business Associations for Immediate Stay of the Clean Power Plan, *available at* https://www.edf.org/sites/default/files/content/2016.01.27_business_assns_scotus_stay_application.pdf.

to drive the U.S. economy, with $1,403.06 billion in manufactured goods exports in 2014."[125] To the extent the Clean Power Plan would have affected manufacturing costs—a highly contested assumption—all those foreign customers of U.S. exports could have experienced some portion of the potential effects.

Yet despite counting in full these effects to foreign owners and customers of U.S. firms, EPA ignores effects caused by climate change occurring outside U.S. borders. This inconsistent treatment of costs and benefits is patently arbitrary and capricious.

EPA tries to confuse the matter by claiming that its original economic analysis of the Clean Power Plan did not "quantitatively project the full impact . . . on international trade and the location of production."[126] Nevertheless, EPA admits that the economic model it used to analysis the proposed repeal (namely, IPM) does reflect "international electricity and natural gas trade."[127] Furthermore, EPA's original analysis did thoroughly investigate whether industry would have responded to energy price increases by shifting production abroad. EPA originally concluded that it "d[id] not see evidence" of such leakage, due to "the relatively modest changes in electricity prices."[128] EPA proceeded to qualitatively assess how rising electricity prices might lead to substitution of goods, after concluding that quantitative assessment was infeasible due to uncertainties.[129] The fact that EPA could not, due to data limitations, conduct a full quantitative assessment of international trade effects in the original Clean Power Plan in no way excuses EPA now, in its proposed repeal, from ignoring readily quantifiable effects that will result due to climate change damages that happen to occur outside U.S. borders. EPA has arbitrarily drawn different geographic lines around which costs and benefits it chooses to consider. EPA should consider all significant global harms for a global pollutant like greenhouse gases, instead of inconsistently treating the costs and benefits that accrue to foreign versus domestic entities.

3. EPA Must Rely on a 3% or Lower Discount Rate for Intergenerational Effects—or a Declining Discount Rate

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. Previously, federal agencies had focused on a central estimate of the social cost of greenhouse gases calculated at a 3% discount rate. EPA now proposes to give equal consideration to estimates calculated at a 7% discount rate, alleging that this is required by Circular A-4.[130] EPA is wrong. Not only does use of a 7% discount rate violate EPA's statutorily required consideration of impacts on future generations, but a 7% rate for

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[125] NAM, *United States Manufacturing Facts* (2015), http://www.nam.org/Data-and-Reports/State-Manufacturing-Data/2014-State-Manufacturing-Data/Manufacturing-Facts--United-States/

[126] RIA at 46.

[127] RIA at 46.

[128] EPA, Responses to Public Comments on the EPA's Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units ("Comment Responses"), ch. 8, pt.2, p.77 (2015). Also note that, to the extent there were any international trade effects resulting from the Clean Power Plan, some trade effects would be distributional in nature, and transfers between the United States and other nations do not count as costs or benefit per Circular A-4 if the analysis is conducted from the global perspective. Circular A-4 at 38.

[129] EPA assessed that, while some substitutes could be imports from countries with higher emissions per production-unit, resulting in foreign emissions increases, other substitutes would be to alternate domestic goods or even to imports from countries with less intensive emissions. EPA, Regulatory Impact Analysis for the Clean Power Plan Final Rule at 5-5−5-6 (2015).

[130] RIA at 43.

intergenerational climate effects 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 <u>not</u> 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. "[131] While Circular A-4 tells agencies generally to use a 7% discount rate in addition to lower rates for typical rules,[132] 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.

EPA's Statutory Authority Requires Protecting the Needs of Future Generations; a 7% Discount Rate Ignores Those Future Needs

Section 111 of the Clean Air Act requires EPA to regulate a source category that "causes, or contributes significantly to, air pollution which may reasonably be anticipate[d] to endanger public health or welfare."[133] The Clean Air Act explicitly defines "welfare" to include "effects on . . . climate."[134] The terms "endanger" and "reasonably anticipate" are not defined, but their plain dictionary definitions include a temporal element, and legislative history confirms that this language was chosen deliberately to ensure that harms need not be imminent before EPA must act.

In the 1970 Clean Air Act amendments, EPA's authority to regulate air pollution dangers was substantially strengthened, and Congress was motivated partly by the desire to protect future generations. For example, Senator Randolph (Chair of the Environment and Public Works Committee) spoke specifically about Section 111's new provisions on performance standards for stationary sources,[135] stating that "[t]he implementation of the policies that are contained in this measure will test the determination in this country to achieve a livable environment, not only for ourselves *but for future generations*."[136] More generally, Senator Muskie—a subcommittee chair who was instrumental in passing the Clean Air Act—explained the amendments were designed to "*deal with the long-term aspects* as well as the short term,"[137] and minority leader Senator Scott spoke specifically about the legislation's importance for protecting future generations from climate change: "Unless this outpouring of contaminants is controlled, scientists tell us we may very well experience *irreversible atmospheric and climatic changes* capable of producing a snowballing adverse effect to the health and safety of our citizens….*To guarantee that future generations of Americans can live without fear* of the destruction of the very air they breathe, I urge immediate passage."[138] When he signed the Clean Air Act Amendments of 1970 into law, President Nixon pronounced that "1970 will be known as the year of the beginning, in which we really began to move on the problems of *clean air* and clean water and open spaces *for the future generations of America*."[139]

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[131] OMB 2015 Response to Comments, *supra* note 98, at 36.

[132] 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.").

[133] 42 U.S.C. § 7411(b)(1)(A).

[134] 42 U.S.C. § 7602(h).

[135] *See* Clean Air Act Amendments of 1970 Legislative History vol. 1, p.144.

[136] *Id*. at 145.

[137] *Id.* at 144.

[138] *Id.* at 349 (statement of Senator Scott).

[139] *Id.* at 106; President's Remarks upon Signing the Clean Air Amendments of 1970 Into Law, Dec. 31, 1970 https://babel.hathitrust.org/cgi/pt?id=mdp.39015077941642;view=1up;seq=245 (continuing, "We can look back and say, in the

The U.S. Court of Appeals for the District of Columbia Circuit confirmed the future-looking nature of EPA's authority when it ruled, in *Ethyl Corp v. EPA*, that the word "endanger" in the Clean Air Act made that statute "precautionary," and EPA need not wait for certain evidence of imminent harm before acting to prevent dangerous pollution.[140] Years later, that same Court of Appeals also upheld EPA's 2009 endangerment finding on greenhouse gas emissions from motor vehicles under Section 202. The endangerment finding spoke of the need to protect future generations in its very first sentence,[141] and the D.C. Circuit upheld[142] the finding as based on "evidence of current and future effects." Industry petitioners questioned the judgment on the grounds that there was "too much uncertainty" in the evidence. The Court recalled that the Act was meant to be "precautionary in nature" and warned that "[a]waiting certainty will often allow for only reactive, not preventive, regulation." The Court concluded that the language "may reasonably be anticipated to endanger" required "a precautionary, forward-looking scientific judgment."[143]

In summary, the use of the phrase "may reasonably be anticipated to endanger public health or welfare" requires EPA to consider the effects of climate change to future generations. Applying a 7% discount rate to the social cost of greenhouse gases means that, after a generation or two, future climate damages are insignificant. The use of such a rate thus effectively ignores the needs of future generations. Doing so would arbitrarily fail to consider an important statutory factor that Congress wrote into the Clean Air Act requirements.

A 7% Discount Rate Is Not "Sound and Defensible" or "Appropriate" for 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."[144] As such, analysis must be "based on the best reasonably obtainable scientific, technical, and economic information available,"[145] and agencies must "*[u]**se sound and defensible values*** or procedures to monetize benefits and costs, and ensure that key analytical assumptions are defensible."[146] 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."[147] 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

Roosevelt room on the last day of 1970, we signed a historic piece of legislation that put us far down the road toward a goal that Theodore Roosevelt, 70 years ago, spoke eloquently about, a goal of clean air, clean water, and open spaces for the future generations of America.").

140 541 F.2d 1, 13 (D.C. Cir. 1975).

141 Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 74 Fed. Reg. 18886-01 (2009).

142 Coal. for Responsible Regulation, Inc. v. E.P.A., 684 F.3d 102, 121–22 (D.C. Cir. 2012), aff'd in part, rev'd in part sub nom. Util. Air Regulatory Grp. v. E.P.A., 134 S. Ct. 2427, (2014), and amended sub nom. Coal. for Responsible Regulation, Inc. v. Envtl. Prot. Agency, 606 F. App'x 6 (D.C. Cir. 2015).

143 *Id.*

144 Circular A-4 at 3.

145 *Id.* at 17.

146 *Id.* at 27.

147 *Id.* at 3.

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*.”[148] The 7% discount rate is based on a 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,[149] 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,[150] 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.[151]

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.”[152] The NAS also explained that a consumption rate of interest is the appropriate basis for a discount rate for climate effects.[153] There is also strong consensus through the

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148 *Id.* at 33.

149 “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.

150 Note that this document was not withdrawn by Executive Order 13,783.

151 OMB 2015 Response to Comments, *supra* note 98, at 22.

152 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. 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).

153 NAS Second Report, *supra* note 99, 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).

economic literature that a capital discount rate like 7% is inappropriate for climate change.[154] Finally, each of the three integrated assessment models upon which EPA bases its analysis—DICE, FUND, and PAGE—uses consumption discount rates; a capital discount rate is thus inconsistent with the underlying models. (See the technical appendix on discounting attached to these comments for more details.) For these 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.[155] By contrast, greenhouse gas emissions generate effects stretching out across 300 years. As Circular A-4 notes, while "[p]rivate market rates provide a reliable reference for determining how society values time within a generation, but for extremely long time periods no comparable private rates exist."[156]

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.[157] 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***."[158] The NAS makes the same point about discount rates and uncertainty.[159] In fact, as discussed more below and in the technical appendix on discounting, uncertainty over the discount rate is best addressed by adopting a declining discount rate framework.

Third, a 7% discount rate **ignores catastrophic risks and the welfare of future generations**. As demonstrated in EPA's graph of the frequency distribution of social cost of methane estimates, the 7% rate truncates the long right-hand tail of social costs relative to the 3% rate's distribution. The long right-hand tail represents the possibility of catastrophic damages. The 7% discount rate effectively assumes that present-day Americans are barely willing to pay anything at all to prevent medium- to long-term catastrophes. This assumption violates EPA's statutory duty to protect the future needs of Americans. At the same time, the 7% distribution also misleadingly exaggerates the possibility of negative estimates of the social cost of greenhouse gases.[160] A negative social cost of methane implies a discount rate so high that society is willing to sacrifice serious impacts to future generations for the sake of small, short-term

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[154] In addition to the CEA and NAS reports, see, for example, this article by the former chair of the NAS panel on the social cost of greenhouse gases: Richard Newell (2017, October 10). Unpacking the Administration's Revised Social Cost of Carbon. Available at http://www.rff.org/blog/2017/unpacking-administration-s-revised-social-cost-carbon. *See also* Comments from Robert Pindyck, to BLM, on the Social Cost of Methane in the Proposed Suspension of the Waste Prevention Rule (submitted Nov. 5, 2017).

[155] Circular A-4 at 34. See also OMB 2015 Response to Comments, *supra* note 98, at 21 ("While most regulatory impact analysis is conducted over a time frame in the range of 20 to 50 years").

[156] Circular A-4 at 36.

[157] *Id*.

[158] *Id.*; *see also* CEA, *supra* note 152, 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)."

[159] NAS Second Report, *supra* note 99, at 27.

[160] In the Monte Carlo simulation data, the 7% discount rate doubles the frequency of negative estimates compared to the 3% discount rate simulations, from a frequency of 4% to 8%.

benefits (such as slightly and temporarily improved fertilization for agriculture). Again, this assumption contravenes EPA's statutory responsibilities to protect the welfare of future Americans.

Fourth, a 7% 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."[161] 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.[162] 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.[163]

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."[164] The latest OMB updates to Circular A-94, the document on which Circular A-4 based its discount rates,[165] also show that more up-to-date long-run discount rates are historically low. In the February 2018 update to Circular A-94's discount rates, the OMB found that the real, 30-year discount rate is 0.6 percent,[166] the lowest rate since the OMB began tracking the number.[167] Notably, the OMB also shows that the current real interest rate is negative for maturities less than 10 years.[168]

These low interest rates further confirm 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[169]—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 benefits of climate change.[170] Based on current economic data and theory, the most appropriate discount rate for climate change is 3% or lower.

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[161] 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).

[162] 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.

[163] CEA, *supra* note 152, 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.").

[164] *Id.* at 1.

[165] Circular A-4 at 33.

[166] OMB Circular A-94 Appendix C (2018).

[167] https://obamawhitehouse.archives.gov/sites/default/files/omb/assets/a94/dischist-2017.pdf

[168] Circular A-94 Appendix C, *supra* note 166.

[169] Circular A-4 at 41.

[170] Howard and Sylvan (2015) at 33-34; 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

Fifth, 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.[171]

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."[172] 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***.[173]

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. EPA's use of a 7% discount rate as one of the discount rates featured in its central analysis of the forgone benefits of the CPP cannot be justified as "based on the best reasonably obtainable scientific, technical, and economic information available" and so is inconsistent with best practices for cost-benefit analysis under Circular A-4.

Application of a Declining Discount Rate Is Actionable Under the Current Economic Literature

Circular A-4 contemplates the use of declining discount rates in its reference to the work of Weitzman.[174] As the Council of Economic Advisers explained earlier this year, Weitzman and others

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consensus on social discount rates between 1-3%). Pindyck, in a survey of 534 experts on climate change, finds a mean discount rate of 2.9% in the climate change context and this rate drops to 2.6% when he drops individuals that lack confidence in their knowledge. Pindyck, R. S. (2016). *The social cost of carbon revisited* (No. w22807). National Bureau of Economic Research. Unlike Howard and Sylvan (2016), Pindyck (2016) combines economists and natural scientists in his survey, though the mean constant discount rate drops to 2.7% when including only economists. Again, this further supports the finding that the appropriate discount rate is between 2% and 3%.

[171] Circular A-4 at 35-36.

[172] *Id.* at 3.

[173] *Id.* at 42.

[174] 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.

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.[175] The National Academies of Sciences' report also strongly endorses a declining discount rate approach.[176] Notably, Marten et al., upon which EPA implicitly relies for developing the methodology for the social cost of methane,[177] also note the "agreement that the use of a constant discount rate over long time horizons with uncertain changes in the consumption per capita growth is not theoretically consistent."[178]

One possible schedule of declining discount rates was proposed by Weitzman.[179] 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.[180] Another schedule of declining discount rates has been adopted by the United Kingdom.[181]

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.[182]

A 300-Year Time Horizon Is Required

Related to the choice of discount rate, a 300-year time horizon for analysis of climate effects 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

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175 CEA, *supra* note 152, 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.").

176 NAS Second Report at 99.

177 We assume that EPA's starting point for analysis is the IWG's 2016 technical addendum on the social cost of methane, which in turn relies on Marten et al. IWG, Addendum to Technical Support Document: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide (2016) (citing Marten, A.L., Kopits, E.A., Griffiths, C.W., Newbold, S.C., and A. Wolverton. 2015. Incremental CH4 and N2O Mitigation Benefits Consistent with the U.S. Government's SC-CO2 Estimates. Climate Policy. 15(2): 272-298.

178 Marten, A.L., Kopits, E.A., Griffiths, C.W., Newbold, S.C., and A. Wolverton. 2015. Incremental CH4 and N2O Mitigation Benefits Consistent with the U.S. Government's SC-CO2 Estimates. Climate Policy. 15(2): 272-298.

179 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%

180 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).

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

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

182 EPA's claim that more research is necessary before implementing a declining discount rate, RIA at 167, is wrong: the methodology is actionable now.

states that, "[i]n the context of the socioeconomic, damage, and discounting assumptions, the time horizon needs to be long enough to capture the vast majority of the present value of damages."[183] 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."[184] 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.[185]

4. EPA Arbitrarily Fails to Follow Prescribed Practices for Dealing with Uncertainty

EPA notes that several important factors are incompletely or inadequately represented in the integrated assessment models, including uncertainty over catastrophic damages and extrapolation of damages to high temperatures.[186] That mere mention of significant uncertainty that could lead to much higher social cost of methane estimates hardly satisfies *Circular A-4*'s requirements for quantitative treatment of uncertainty. The IWG highlighted a 95th percentile estimate to address uncertainty over catastrophic damages, tipping points, option value, and risk aversion. EPA should have done the same, but failed to do so. EPA admits that the distributions "have long right tails"[187] and depicts a range of estimates from the 5th to 95th percentiles,[188] but by giving a 5th percentile estimate equal standing with the 95th percentile estimate, EPA obscures the significance of low-probability, high-catastrophe outcomes.[189] Under sensitivity analyses that treated such low-probability, high-catastrophe outcomes seriously, even with EPA's incorrect choices of discount rate and domestic-only perspective, the sign of net benefits for the proposed stay would have shifted from positive to sharply negative. By failing to give serious treatment to such sensitivity analyses, EPA overlooks how different (and more plausible) assumptions would change its cost-benefit calculation.

(Uncertainty in general, as well as uncertainty over the discount rate in particular, are discussed in greater detail in the technical appendices attached to these comments.)

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[183] NAS Second Report, *supra* note 99, at 78.

[184] *Id.*

[185] Nat'l Acad. Of Sci., *Assessment of Approaches to Updating the Social Cost of Carbon* 49 (2016), at 32.

[186] RIA at 45.

[187] *Id*. at 165.

[188] *Id*. at 166.

[189] The EPA's presentation of results further obscures the importance of these low-probability events by exploiting a well-documented mental heuristic called "probability neglect" that causes people to irrationally reduce small probability risks entirely down to zero. A reader of the EPA analysis might be misled to believe that these low-probability events are not important, when in fact, they would lead to substantial economic losses. *See* Cass R. Sunstein, *Probability Neglect: Emotions, Worst Cases, and Law*, 112 Yale L. J. 61, 63, 72 (2002); Valerie F. Reyna & Charles J. Brainerd, *Numeracy, ratio bias, and denominator neglect in judgments of risk and probability*, 18 LEARN. INDIVID. DIFFER. 89 (2008).

Circular A-4's Prescriptions for Uncertainty

Circular A-4 requires thorough treatment of uncertainty around both values and outcomes,[190] and for especially large or complex matters it recommends a formal probabilistic analysis.[191] Generally, Circular A-4 encourages agencies to disclose the full probability distribution of potential consequences, including both upper and lower bound estimates in addition to central estimates.[192]

However, this guidance comes with some caveats. First, this approach to central estimates and the probability distribution "is appropriate as long as society is 'risk neutral' with respect to the regulatory alternatives."[193] But if society is risk averse—as is the case with climate change[194]—different considerations need to be taken into account. Second, in 2011, the Office of Information and Regulatory Affairs interpreted Circular A-4's goal as "not to characterize the full range of *possible* outcomes . . . but rather the range of *plausible* outcomes."[195] Agency analysts must exercise judgment. Finally, as with all elements of agencies' economic analyses, Circular A-4 stresses that "Your analysis should be credible, objective, realistic, and scientifically balanced."[196]

Consequently, while it may be appropriate to disclose the full probability distribution of an uncertainty analysis, it is not appropriate under Circular A-4 to give a low-percentile estimate of the social cost of greenhouse gases equal weight in decision-making with the central and upper-percentile estimates. Giving equal attention to a low-percentile estimate is not "credible, objective, realistic, and scientifically balanced," does not reflect "plausible" scenarios, and would undermine consideration of risk aversion. Instead, a proper and plausible treatment of uncertainty in the context of climate change will support higher estimates of the social cost of greenhouse gases.

A 95th Percentile Value as a Treatment of Uncertainty over Damages

The IWG accounted for uncertainty in numerous rigorous ways. The group modeled the uncertainty over the value of the equilibrium climate sensitivity parameter using the Roe and Baker distribution calibrated to the IPCC reports. Additionally, using well-established analytic tools to capture and reflect uncertainty, including a Monte Carlo simulation to randomly select the equilibrium climate sensitivity parameter and other uncertainty parameters selected by the model developers, the IWG quantitatively modeled the uncertainty underlying how greenhouse gas emissions affect temperature.

To further deal with uncertainty, the IWG recommended to agencies a range of four estimates: three central or mean-average estimates at a 2.5%, 3%, and 5% discount rate respectively, and a 95th percentile value at the 3% discount rate. While the IWG's technical support documents disclosed fuller probabilities distributions, these four estimates were chosen by agencies to be the focus for

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190 Circular A-4, at 42, requires probability distributions for "values as well for each of the outcomes"; the social cost of greenhouse gases is a value with a probability distribution.

191 *Id.* at 41.

192 Circular A-4 at 18, 40; *id.* at 45 ("When you provide only upper and lower bounds (in addition to best estimates), you should, if possible, *use the 95 and 5 percent* confidence bounds.").

193 *Id.* at 42.

194 *See* 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).

195 Office of Information and Regulatory Affairs, *Regulatory Impact Analysis: A Primer* 2 (2011). This is best understood as drawing the line at insignificant or scientifically unsupported outcomes. By contrast, the low-probability but catastrophic potential outcomes of climate change are highly significant and the scientific literature demands giving them due attention. EPA acknowledges that Circular A-4 requires quantitative sensitivity analysis when estimates depend heavily on assumptions, RIA at 166 n.82, but fails to follow the guidance to make plausible conclusions based on such analyses.

196 Circular A-4 at 39.

decisionmaking. In particular, application of the 95th percentile value was not part of an effort to show the probability distribution around the 3% discount rate; rather, the 95th percentile value serves as a methodological shortcut to approximate the uncertainties around low-probability but high-damage, catastrophic, or irreversible outcomes that are currently omitted or undercounted in the economic models.

The shape of the distribution of climate risks and damages includes a long tail of lower-probability, high-damage, irreversible outcomes due to "tipping points" in planetary systems, inter-sectoral interactions, and other deep uncertainties. Climate damages are not normally distributed around a central estimate, but rather feature a significant right skew toward catastrophic outcomes. In fact, a 2015 survey of economic experts concludes that catastrophic outcomes are increasingly likely to occur.[197] Because the three integrated assessment models that the IWG's methodology relied on are unable to systematically account for these potential catastrophic outcomes, a 95th percentile value was selected instead to account for such uncertainty. There are no similarly systematic biases pointing in the other direction which might warrant giving weight to a low-percentile estimate.

Additionally, the 95th percentile value addresses the strong possibility of widespread risk aversion with respect to climate change. The integrated assessment models do not reflect that individuals likely have a higher willingness to pay to reduce low-probability, high-impact damages than they do to reduce the likelihood of higher-probability but lower impact damages with the same expected cost. Beyond individual members of society, governments also have reasons to exercise some degree of risk aversion to irreversible outcomes like climate change.

In short, the 95th percentile estimate attempts to capture risk aversion and uncertainties around lower-probability, high-damage, irreversible outcomes that are currently omitted or undercounted by the models. There is no need to balance out this estimate with a low-percentile value, because the reverse assumptions are not reasonable:

- There is no reason to believe the public or the government will be systematically risk seeking with respect to climate change.[198]
- The consequences of overestimating the risk of climate damages (i.e., spending more than we need to on mitigation and adaptation) are not nearly as irreversible as the consequences of underestimating the risk of climate damage (i.e., failing to prevent catastrophic outcomes).
- Though some uncertainties might point in the direction of lower social cost of greenhouse gas values, such as those related to the development of breakthrough adaptation technologies, the models already account for such uncertainties around adaptation; on

[197] Policy Integrity, *Expert Consensus on the Economics of Climate Change* 2 (2015), *available at* http://policyintegrity.org/files/publications/ExpertConsensusReport.pdf [hereinafter *Expert Consensus*] ("Experts believe that there is greater than a 20% likelihood that this same climate scenario would lead to a 'catastrophic' economic impact (defined as a global GDP loss of 25% or more)."). *See also* Robert Pindyck, *The Social Cost of Carbon Revisited* (National Bureau of Economic Research, No. w22807, 2016).

[198] As a 2009 survey revealed, the vast majority of economic experts support the idea that "uncertainty associated with the environmental and economic effects of greenhouse gas emissions increases the value of emission controls, assuming some level of risk-aversion." *See Expert Consensus, supra* note 197, at 3 (citing 2009 survey).

balance, most uncertainties strongly point toward higher, not lower, social cost of greenhouse gas estimates.[199]

- There is no empirical basis for any "long tail" of potential benefits that would counteract the potential for extreme harm associated with climate change.

Moreover, even the best existing estimates of the social cost of greenhouse gases are likely underestimated because the models currently omit many significant categories of damages—such as depressed economic growth, pests, pathogens, erosion, air pollution, fire, dwindling energy supply, health costs, political conflict, and ocean acidification—and because of other methodological choices.[200] There is little to no support among economic experts to give weight to any estimate lower than the 5% discount rate estimate.[201] Rather, even a discount rate at 3% or below likely continues to underestimate the true social cost of greenhouse gases.

The National Academies of Sciences did recommend that the IWG document its full treatment of uncertainty in an appendix and disclose low-probability as well as high-probability estimates of the social cost of greenhouse gases.[202] However, that does not mean it would be appropriate for individual agencies to rely on low-percentile estimates to justify decisions. While disclosing low-percentile estimates as a sensitivity analysis may promote transparency, relying on such an estimate for decisionmaking—in the face of contrary guidance from the best available science and economics on uncertainty and risk—would not be a "credible, objective, realistic, and scientifically balanced" approach to uncertainty.

By giving only a scant graphical presentation of the 95th percentile value, and by misleadingly placing that value on equal footing with a 5th percentile estimate, EPA has failed to address uncertainties over catastrophic outcomes, tipping points, risk aversion, and option value, and so has violated the prescriptions of Circular A-4. The IWG emphasized the 95th percentile (not the 5th percentile) to address this systematic downward bias in the social cost of greenhouse gases. By giving equal weight to

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[199] *See* Richard L. Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, 508 NATURE 173 (2014). R. Tol, *The Social Cost of Carbon*, 3 Annual Rev. Res. Econ. 419 (2011) ("[U]ndesirable surprises seem more likely than desirable surprises. Although it is relatively easy to imagine a disaster scenario for climate change—for example, involving massive sea level rise or monsoon failure that could even lead to mass migration and violent conflict—it is not at all easy to imagine that climate change will be a huge boost to human welfare.").

[200] *See* Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, *supra* note 27; Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon* (Cost of Carbon Project Report, 2014); Frances C. Moore & Delavane B. Diaz, *Temperature Impacts on Economic Growth Warrant Stringent Mitigation Policy*, 5 NATURE CLIMATE CHANGE 127 (2015) (demonstrating SCC may be biased downward by more than a factor of six by failing to include the climate's effect on economic growth).

[201] The existing estimates based on the 5% discount rate already provides a lower-bound; indeed, if anything the 5% discount rate is already far too conservative as a lower-bound. A recent survey of 365 experts on the economics of climate change found that 90% of experts believe a 3% discount rate or lower is appropriate for climate change; a 5% discount rate falls on the extremely high end of what experts would recommend. *Expert Consensus, supra* note 197, at 21; *see also* Drupp, M.A., 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%). Only 8% of the experts surveyed believe that the central estimate of the social cost of carbon is below $40, and 69% of experts believed the value should be at or above the central estimate of $40. *Expert Consensus, supra* note 197, at 18.

[202] Nat'l Acad. Of Sci., *Assessment of Approaches to Updating the Social Cost of Carbon* 49 (2016) ("[T]he IWG could identify a high percentile (e.g., 90th, 95th) and corresponding low percentile (e.g., 10th, 5th) of the SCC frequency distributions on each graph.").

the 5th and 95th percentiles, the EPA is ignoring this systematic bias and failing to consider the accepted logic that climate change is likely to bring with it more bad surprises than good surprises.

Uncertainty over Climate Damages Points Toward a Higher Social Cost of Methane

Uncertainty about the full effects of climate change actually *raises* the social cost of greenhouse gases and warrants *more* stringent climate policy.[203] The integrated assessment models (IAMs) currently used to calculate the social cost of greenhouse gases 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 social cost of greenhouse gases compared to the case where models simply use our current best guesses of these parameters.[204] Even so, IAMs still underestimate the impact of uncertainty 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.[205] Rather than being a reason not to take action, uncertainty increases the social cost of greenhouse gases and should lead to more stringent policy to address climate change.

A technical appendix attached to these comments more fully details how uncertainty on the whole points toward an even higher social cost of methane. The appendix covers such topics as insufficient modeling of catastrophic outcomes (including unlucky states of the world, deep uncertainty over the probability distributions for specific climate parameters, and tipping points), failure to include a risk premium, exclusion of the real option value of preventing irreversible greenhouse gas emissions, and how the social cost of greenhouse gases would increase with improved modeling of uncertainty.

5. EPA Has Cherry-Picked Methodological Revisions to Advance a Predetermined Goal, Without Engaging in a Holistic Update

EPA explains that its estimates of the social cost of carbon are simply "interim values" until an improved estimate can be developed.[206] The revisions to the Interagency Working Group's 2016 estimates that EPA made to produce these interim values are all methodologically unsound: ignoring the global values in EPA's central analysis in favor of an inaccurate and incomplete domestic-only estimate; applying the inappropriate 7% discount rate alongside the 3% discount rate in EPA's central analysis; and failing to disclose a 95th percentile estimate. What links these select revisions together is a common, predetermined goal: artificially lowering the social cost of carbon to support deregulation.

This is an arbitrary approach to updating the social cost of carbon. EPA does not engage with any of the most recent literature on damages (see the technical appendix attached to these comments on damage

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[203] 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.

[204] 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, Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis (2016).

[205] 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.

[206] RIA at 42.

literature), does not update the underlying models (EPA continues to use DICE-2010, even though DICE-2016R has been published[207]), does not move toward a declining discount rate, and does not implement any of the recommendations for improving the social cost of greenhouse gas methodology as articulated by the National Academies of Sciences. EPA notes, but then does nothing about, the National Academies of Sciences' warning that domestic-only numbers fail to account for spillovers and reciprocity.[208] Agencies should pursue a holistic update of the social cost of greenhouse gas methodology, but EPA's revisions all appear cherry-picked to lower the valuation. As such, EPA's interim values are biased and should not be used in analysis.

To ensure that the agency is using the best available data and methodologies to monetize the full social cost of greenhouse gases, a thorough review of the relevant economics and scientific literature is critical. Specifically, the agency should consider the data, assumptions, and methods applied in the latest peer-reviewed publications with special attention applied to consensus-type documents, such as the Intergovernmental Panel on Climate Change. The agency should adopt such consensus findings as their central assumptions; alternative views with significant support should be considered through sensitivity analysis. An agency should undergo such a thorough review at frequent intervals—such as every three years (as undertaken by the IWG) or every five years (as recommended by the NAS panel).

The now-disbanded Interagency Working Group undertook such a process of regular and systematic revisions. In 2010—and again in the 2013 and 2016 updates—the IWG's analytic process was science-based, open, and transparent. The IWG hosted a thorough public comment period in 2013.[209] The 2010 Technical Support Document (TSD) set out in detail the IWG's decision-making process with respect to how it assessed and employed the models.[210] The Government Accountability Office (GAO) found that "the working group's processes and methods reflected the following three principles: Used consensus-based decision making, Relied on existing academic literature and models, and Took steps to disclose limitations and incorporate new information."[211]

To ensure social cost of greenhouse gases reflect the best available science, agencies should not cherry pick modeling-assumptions. Instead, any update of the social cost of greenhouse gases requires a thorough review of peer-reviewed research to develop consensus-based modeling assumptions. In particular, the review process allows for the development of pre-specified frameworks and criteria upon which assumptions can be assessed. In fact, the NAS recently conducted such a review—and developed these frameworks and criteria—to enable a thorough near-term update of social cost of greenhouse gas estimates by agencies. The National Academies of Sciences' reports are attached to these comments, so that EPA might review their recommendations for a holistic update to the methodology.

6. EPA Fails to Appropriately Consider Unquantified Benefits

In Appendix B, EPA makes a cursory list of unquantified forgone climate benefits, including "other climate impacts (e.g., other GHGs such as methane, aerosols, and other impacts)."[212] EPA mentions a

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[207] William D Nordhaus, *Revisiting the social cost of carbon*, 114 PROC. NATL. ACAD. SCI. U. S. A. 1518–1523 (2017).

[208] RIA at 46.

[209] Notice of Availability and Request for Comments: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order No. 12866, 78 Fed. Reg. 70,586 (Nov. 26, 2013); IWG, *Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866* (July 2015), https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc-response-to-comments-final-july-2015.pdf.

[210] *See generally* 2010 TSD, *supra* note 21.

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

[212] RIA at 156.

few other important, unquantified climate effects, like ocean acidification, scattered throughout the analysis.[213] This treatment fails Circular A-4's requirements for adequate consideration of the many significant but unquantified effects of climate change.

Experts widely acknowledge that even the best existing estimates of the social cost of greenhouse gases are almost certainly underestimates of true global damages—perhaps severe underestimates.[214] Using different discount rates; selecting different models; applying different treatments to uncertainty, climate sensitivity, and the potential for catastrophic damages; and making other reasonable assumptions could yield very different, and much larger estimates.[215] For example, a 2014 report found current social cost of carbon estimates omit or poorly quantify damages to the following sectors:

> agriculture, forestry, and fisheries (including pests, pathogens, and weeds, erosion, fires, and ocean acidification); ecosystem services (including biodiversity and habitat loss); health impacts (including Lyme disease and respiratory illness from increased ozone pollution, pollen, and wildfire smoke); inter-regional damages (including migration of human and economic capital); inter-sector damages (including the combined surge effects of stronger storms and rising sea levels); exacerbation of existing non-climate stresses (including the combined effect of the over pumping of groundwater and climate-driven reductions in regional water supplies); socially contingent damages (including increases in violence and other social conflict); decreasing growth rates (including decreases in labor productivity and increases in capital depreciation); weather variability (including increased drought and inland flooding); and catastrophic impacts (including unknown unknowns on the scale of the rapid melting of Arctic permafrost or ice sheets).[216]

Circular A-4 requires that "When there are important non-monetary values at stake, you should also identify them in your analysis."[217] Specifically, agencies must "Include a summary table that lists all the unquantified benefits and costs, and use your professional judgment to highlight (e.g., with categories or rank ordering) those that you believe are most important."[218] The Circular cautions that "the most efficient alternative will not necessarily be the one with the largest quantified and monetized net-benefit estimate."[219] EPA must therefore fully disclose the limitations of its social cost of greenhouse gas estimates and include detailed charts of all important, unquantified climate effects. EPA's cursory references to a few unquantified effects is insufficient. The agency does not use, or even explain why it is not using, the social cost of methane to quantify the proposed repeal's effects on methane.

EPA must then explain why, after giving appropriate weight to all the unquantified climate effects, the proposed repeal's cost savings justify its forgone benefits.

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213 RIA at 12.

214 *See* Richard L. Revesz, Peter H. Howard, Kenneth Arrow, Lawrence H. Goulder, Robert E. Kopp, Michael A. Livermore, Michael Oppenheimer & Thomas Sterner, *Global Warming: Improve Economic Models of Climate Change*, 508 NATURE 173 (2014).

215 *Id.*; *see also* Joint Comments from Institute for Policy Integrity et al., to Office of Information and Regulatory Affairs, on the Technical Update of the Social Cost of Carbon, OMB-2013-0007-0085, Feb. 26, 2014.

216 Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon* 5 (Cost of Carbon Project Report, 2014), http://costofcarbon.org/.

217 Circular A-4 at 3.

218 *Id.* at 27.

219 *Id.* at 2.

7. EPA Appropriately Gives Equal Weight to the Three Most Peer-Reviewed Models, but Should Use the Updated Models

EPA explains the virtues of equally weighting the results of the three most peer-reviewed integrated assessment models in order to balance out the limitations and omissions of any one model.[220] In any future applications of the social cost of carbon, EPA should continue to rely on the Interagency Working Group's methodology and use multiple peer-reviewed models. That said, EPA has failed to use the most up-to-date versions of those models, and should use the updated models in future calculations, including in any revised analysis of its proposed suspension.

Agencies Should Continue to Rely on the Interagency Working Group's Methodology and Estimates

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).[221] 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[222] 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.

Any departure from IWG's most recent estimates would require agencies to engage with the complex integrated assessment models and ensure consistency with the most current scientific and economic literature, which overwhelmingly supports a global estimate based on a 3% or lower discount rate. Indeed, since the IWG's estimates omit important damage categories and so are best treated as a lower bound, if anything the social cost of greenhouse gas values used by agencies should be even higher.

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

Circular A-4 requires agencies to use "the best reasonably obtainable scientific, technical, and economic information available. To achieve this, you should rely on peer-reviewed literature, where available."[223]

Since the IWG first issued the federal social cost of carbon protocol in 2010, this 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[224]), FUND (the Climate Framework for Uncertainty, Negotiation, and Distribution[225]), and PAGE (Policy Analysis of the Greenhouse Effect[226])—draw on the best available scientific and economic data to link physical impacts

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[220] RIA at 164.

[221] 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).

[222] *See supra* note 27.

[223] OMB, Circular A-4, at 17.

[224] 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).

[225] 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.

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

to the economic damages of each marginal ton of greenhouse gas emissions. As noted previously, 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.[227] 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 date.[228] In short, DICE, FUND, and PAGE continue to represent the state-of-the-art models. 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.[229] 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.[230] The economics literature confirms that estimates based on these three IAMs remain the best available estimates.[231] In 2016, the U.S. Court of Appeals for the Seventh Circuit held the estimates used to date by agencies are reasonable.[232] 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.[233]

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

[227] 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").

[228] 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"].

[229] Gov't Accountability Office, *Regulatory Impact Analysis: Development of Social Cost of Carbon Estimates* (2014).

[230] Howard & Schwartz, *supra* note 18 at Appendix A.

[231] *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).

[232] *Zero Zone*, 832 F.3d at 678-79 (7th 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).

[233] *Montana Environmental Information Center*, 2017 WL 3480262, at *12-15, 19.

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,[234] and most estimates in the literature continue to rely on those models.[235] 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,[236] but unfortunately does not account for non-market 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.[237]

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.[238] However, each IAM also has its own limitations and is sensitive to its own assumptions. No model fully captures all the significant climate effects.[239] By giving weight to multiple models—as the IWG did—agencies can balance out some of these limitations and produce more robust estimates.[240]

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

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[234] *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").

[235] 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).

[236] 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.

[237] 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.

[238] While sensitivity analysis can address parametric uncertainty within a model, using multiple models helps address structural uncertainty.

[239] *See* Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon* 5 (Cost of Carbon Project Report, 2014), http://costofcarbon.org/.

[240] 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*.

rate);[241] from FUND's developers, $12;[242] and from PAGE's developers, $123, with a high-percentile estimate of $332.[243]

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,[244] and a soon-to-be-published update by the same author finds a mean estimate of $108 (at a 1% discount rate).[245] 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.[246] Various studies relying on expert elicitation[247] from a large body of climate economists and scientists have found mean estimates of $50 per ton of carbon dioxide,[248] $96-$144 per ton of carbon dioxide,[249] and $80-$100 per ton of carbon dioxide.[250] 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.[251] 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.[252]

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

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[241] 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).

[242] D. Anthoff & R. Tol, *The Uncertainty about the Social Cost of Carbon: A Decomposition Analysis Using FUND*, 177 Climatic Change 515 (2013).

[243] 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).

[244] R. Tol, *Targets for Global Climate Policy: An Overview*, 37 J. Econ. Dynamics & Control 911 (2013).

[245] R. Tol, *Economic Impacts of Climate Change* (Univ. Sussex Working Paper No. 75-2015, 2015).

[246] 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).

[247] Circular A-4, at 41, supports use of expert elicitation as a valuable tool to fill gaps in knowledge.

[248] Scott Holladay & Jason Schwartz, *Economists and Climate Change* 43 (Inst. Policy Integrity Brief, 2009 (directly surveying experts about the SCC).

[249] 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).

[250] 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).

[251] *E.g.,* Howard & Sylvan, *supra* note 249; Pindyck, *supra* note 250. 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 239; Revesz et al., *supra* notes 25 and 27; 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).

[252] 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.

$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.[253]

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.

EPA Should Use the Most Updated Models

EPA explains it uses DICE 2010, FUND 3.8, and PAGE 2009.[254] However, not only is DICE 2010 not considered to be a major update of the DICE model,[255] but two major updates have occurred more recently: DICE-2013R[256] and DICE-2016R.[257] In using the outdated DICE 2010, EPA has failed to use the "best available science and economics" as required by Executive Order 13,783, and failed to follow the recommendations of the National Academies of Sciences on updating the integrated assessment models.[258] Updating from DICE 2010 to the most recent model would increase the social cost of greenhouse gases and enable a Monte Carlo simulation (as in FUND and PAGE) to better specify uncertainty.[259]

Sincerely,

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[253] *See* Howard & Schwartz, *supra* note 18, at Appendix B. All these estimates are in 2016$.

[254] RIA at 162.

[255] *See* Nordhaus, W., & Sztorc, P. (2013). DICE 2013R: Introduction and user's manual.

[256] Nordhaus (2014) *supra* note 220.

[257] William D Nordhaus, *Revisiting the social cost of carbon*, 114 PROC. NATL. ACAD. SCI. U. S. A. 1518–1523 (2017).

[258] *See* National Academies of Sciences, Engineering, and Medicine. (2017). *Valuing climate damages: Updating estimation of the social cost of carbon dioxide*. National Academies Press. Note that the Interagency Working Group was incorrect in 2016 in failing to update the DICE model from DICE-2010 to DICE-2013R, which was available at the time. *Cf.* IWG, 2013 Technical Update (updating the models). *See also* Marten, A.L., Kopits, E.A., Griffiths, C.W., Newbold, S.C., and A. Wolverton. 2015. Incremental CH4 and N2O Mitigation Benefits Consistent with the U.S. Government's SC-CO2 Estimates. Climate Policy. 15(2): 272-298 (anticipating that the models will be continually updated).

[259] The update would also increase EPA's calculation of the domestic-only share from 10% to 15%, *see* William D Nordhaus, *Revisiting the social cost of carbon*, 114 PROC. NATL. ACAD. SCI. U. S. A. 1518–1523 (2017). But, as explained *supra* in these comments, a domestic-only value is the wrong framework and is inaccurate.

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

Appendices:

- Technical Appendix on Uncertainty
- Technical Appendix on Discounting

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Christian P. Traeger, *On option values in environmental and resource economics*, 37 RESOUR. ENERGY ECON. 242 (2014).

Martin L Weitzman, *Gamma discounting*, 91 AM. ECON. REV. 260-271 (2001).

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

Martin L Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 REV. ECON. STAT. 1–19 (2009).

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.[260] 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.[261] 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.[262] Rather than being a reason not to take action, uncertainty increases the SCC and should lead to more stringent policy to address climate change.[263]

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.[264] Stochastic uncertainty is persistent randomness in the economic-climate system, including various environmental phenomena such as volcanic eruptions and sun spots.[265] 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).[266]

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[260] Sonja Peterson, *Uncertainty and economic analysis of climate change: A survey of approaches and findings*, 11 Environmental Modeling & Assessment 1-17 (2006) ("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.").

[261] Richard SJ Tol, Safe policies in an uncertain climate: an application of FUND, 9 *Global Environmental Change* 221-232 (1999); Peterson 2006 *supra* note 221.

[262] Robert S Pindyck, *Uncertainty in environmental economics*, 1 Review of environmental economics and policy 45-65 (2007); Alexander Golub, Daiju Narita, and Matthias GW Schmidt, *Uncertainty in integrated assessment models of climate change: Alternative analytical approaches*, 19 Environmental Modeling & Assessment 99-109 (2014); Lemoine, Derek, and Ivan Rudik, *Managing Climate Change Under Uncertainty: Recursive Integrated Assessment at an Inflection Point*, 9 Annual Review of Resource Economics 18.1-18.26 (2017).

[263] *See* cites *supra* note 262.

[264] 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. Antje Kann & John P. Weyant, *Approaches for performing uncertainty analysis in large-scale energy/economic policy models*, 5 Environmental Modeling & Assessment 29-46 (2000); Derek Lemoine & Ivan Rudik, *Managing Climate Change Under Uncertainty: Recursive Integrated Assessment at an Inflection Point*, 9 *Annual Review of Resource Economics* 18.1-18.26 (2017).

[265] A potential third type of uncertainty arises due to ethical or value judgements: normative uncertainty. Peterson (2006) *supra* note 260; Geoffrey Heal & Antony Millner, *Reflections: Uncertainty and decision making in climate change economics*, 8 Review of Environmental Economics and Policy 120-137 (2014). 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 261 and Golub et al. *supra* note 262.

[266] Peterson (2006), *supra* note *257*; Pindyck (2007), *supra* note 262; Heal & Millner 2014, *supra* note 265.

When modeling climate change uncertainty, scientists and economists have long emphasized the importance of accounting for the potential of catastrophic climate change.[267] Catastrophic outcomes combine several overlapping concepts including unlucky states of the world (i.e., bad draws), deep uncertainty, and climate tipping points and elements.[268] 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.[269] 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.[270] Given the general opinion that bad surprises are likely to outweigh good surprises in the case of climate change,[271] modelers capture deep uncertainty by selecting probability distributions with a fat upper tail which reflects the greater likelihood of extreme events.[272] 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).[273]

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.[274] 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.[275] 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 Pacific Ocean.[276] Social tipping points—including climate-induced migration and conflict—also exist.

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[267] William Nordhaus, A Question of Balance: Weighing the Options on Global Warming Policies (2008); Robert E. Kopp, Rachael L. Shwom, Gernot Wagner, and Jiacan Yuan, Tipping elements and climate–economic shocks: Pathways toward integrated assessment, 4 *Earth's Future* 346-372 (2016).

[268] Kopp et al. (2016), *supra* note 267.

[269] *Id.*

[270] William Nordhaus, *An Analysis of the Dismal Theorem* (Cowles Foundation Discussion Paper No. 1686, 2009); Martin L. Weitzman, *Fat-tailed uncertainty in the economics of catastrophic climate change*, 5 Review of Environmental Economics and Policy 275-292 (2011). Robert S Pindyck, *Fat tails, thin tails, and climate change policy*, 5 Review of Environmental Economics and Policy 258-274 (2011).

[271] Michael D Mastrandrea, Calculating the benefits of climate policy: examining the assumptions of integrated assessment models (Pew Center on Global Climate Change Working Paper, 2009); Richard SJ Tol, On the uncertainty about the total economic impact of climate change, 53 Environmental and Resource Economics 97-116 (2012).

[272] Weitzman (2011), *supra* note 270, 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."

[273] Martin L Weitzman, *On modeling and interpreting the economics of catastrophic climate change*, 91 The Review of Economics and Statistics 1-19 (2009); Nordhaus (2009), *supra* note 270; Weitzman (2011), *supra* note 270.

[274] 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 267.

[275] *Id.*

[276] *Id.*; Elmar Kriegler, Jim W. Hall, Hermann Held, Richard Dawson, and Hans Joachim Schellnhuber, Imprecise probability assessment of tipping points in the climate system, 106 *Proceedings of the national Academy of Sciences* 5041-5046 (2009);

These various tipping points interact, such that triggering one tipping point may affect the probabilities of triggering other tipping points.[277] 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.[278] 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[279] 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.[280] Tol, Anthoff, and Hope employ this technique in FUND and PAGE—as did the IWG (2010, 2013, and 2016)[281]—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.[282]

Delavane Diaz & Klaus Keller, A potential disintegration of the West Antarctic Ice Sheet: Implications for economic analyses of climate policy, 106 *The American Economic Review* 607-611 (2016). See Table 1 of Kopp et al. (2016) *supra* note 267, for a full list of known tipping elements and points.

277 Kriegler et al. (2009), *supra* note 276; Cai, Yongyang, Timothy M. Lenton, and Thomas S. Lontzek, *Risk of multiple interacting tipping points should encourage rapid CO2 emission reduction*, 6 Nature Climate Change 520-525 (2016); Kopp et al. (2016) *supra* note 267.

278 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 267.

279 *See* Nordhaus, W., & Sztorc, P. (2013). DICE 2013R: Introduction and user's manual.

280 In alternative calculation method, the modeler "performs optimization of polices for a large number of possible parameter combinations individually and estimates their probability weighted sum." Golub et al. *supra* note 262. 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.

281 Interagency Working Group on Social Cost of Carbon, Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12,866 (2010). Interagency Working Group on Social Cost of Carbon, Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12,866 (2013). Interagency Working Group on Social Cost of Carbon, Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12,866 (2016).

282 Tol (1999), *supra* note 261, 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)[283] reported the various moments and percentiles—including the 95th 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.[284] 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.[285] 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.[286] 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.[287]

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[283] IWG (2016) *supra* note 278.

[284] IWG (2010) *supra* note 278.

[285] Howard (2014), *supra* note 278. 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* Z Chen, M Marquis, KB Averyt, M Tignor, & HL Miller, Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change (2007). 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. DAVID ANTHOFF & RICHARD S. J. TOL, THE CLIMATE FRAMEWORK FOR UNCERTAINTY, NEGOTIATION, AND DISTRIBUTION (FUND), TECHNICAL DESCRIPTION, VERSION 3.8 (2014). Explicitly modeling parameter distributions as fat tailed may further increase the SCC.

[286] Weitzman (2011), *supra* note 270; Kopp et al. (2016) *supra* note 267.

[287] Derek Lemoine & Christian P. Traeger, *Ambiguous tipping points*, 132 Journal of Economic Behavior & Organization 5-18 (2016); Lemoine & Rudik (2017), *supra* note 262. IAM modelers currently assume that society is equally averse to known unknown and known unknowns. Lemoine & Traeger, *id*.

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 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.[288] 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.[289] 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.[290] Despite the obvious methodological basis for addressing tipping points, the latest versions of DICE[291] 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.[292]

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

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[288] William Nordhaus & Joseph Boyer, Warning the World: Economic Models of Global Warming (2000); Nordhaus (2008) *supra* note 264; Howard (2014), *supra* note 278; Kopp et al. (2016) *supra* note 267.

[289] Hope (2006) also calibrated a discontinuous damage function in PAGE-99 used by IWG (2010); see Chris Hope, *The Marginal Impact of CO_2 from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern*, 6 INTEGRATED ASSESSMENT J. 19 (2006). Howard (2014), *supra* note 278.

[290] Kopp et al. (2016) *supra* note 267.

[291] 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. Peter H Howard & Thomas Sterner, *Few and Not So Far Between: A Meta-analysis of Climate Damage Estimates*, 68 Environmental and Resource Economics 1-29 (2016).

[292] Using FUND, Link and Tol (2011) 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. P. Michael Link & Richard SJ Tol, Estimation of the economic impact of temperature changes induced by a shutdown of the thermohaline circulation: an application of FUND, 104 *Climatic Change* 287-304 (2011); Klaus Keller, Kelvin Tan, François MM Morel, & David F. Bradford*, Preserving the Ocean Circulation: Implications for Climate Policy*, 47 Climatic Change 17-43 (2000); Michael D Mastrandrea & Stephen H. Schneider*, Integrated assessment of abrupt climatic changes*, 1 Climate Policy 433-449 (2001); Klaus Keller, Benjamin M. Bolker, & David F. Bradford, *Uncertain climate thresholds and optimal economic growth*, 48 Journal of Environmental Economics and management 723-741 (2004). With respect to thawing of the permafrost, Hope and Schaefer (2016) and Gonzalez-Eguino and Neumann (2016) find increases in damages (and thus an increase in the SCC) when integrating this tipping element into the PAGE09 and DICE-2013R, respectively. Chris Hope & Kevin Schaefer. *Economic impacts of carbon dioxide and methane released from thawing permafrost*, 6 Nature Climate Change 56-59 (2016); Mikel González-Eguino & Marc B. Neumann, *Significant implications of permafrost thawing for climate change control*, 136 Climatic Change 381-388 (2016). 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. Robert J Nicholls, Richard SJ Tol, & Athanasios T. Vafeidis, Global estimates of the impact of a collapse of the West Antarctic ice sheet: an application of FUND, 91 *Climatic Change* 171-191 (2008). 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. Megan Ceronsky, David Anthoff, Cameron Hepburn, and Richard SJ Tol, *Checking the price tag on catastrophe: The social cost of carbon under non-linear climate response* (ESRI working paper No. 392, 2011).

kurtosis (which, like skewness, is another descriptor of a distribution's tail) as well as means.[293] It is generally understood that people are risk averse in that they prefer input parameter distributions and (the resulting) SCC distributions with lower variances, holding the mean constant.[294] 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,[295] current IAM assumptions,[296] 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).[297] 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_2 emissions.[298] Option value reflects the value of future flexibility due to uncertainty and irreversibility; in this case, the irreversibility of CO2 emissions due to their long life in the atmosphere.[299] If society exercises the option of emitting an additional unit of CO2 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

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[293] Alexander Golub & Michael Brody, *Uncertainty, climate change, and irreversible environmental effects: application of real options to environmental benefit-cost analysis*, 7 Journal of Environmental Studies and Sciences 7 519-526 (2017); see Figure 1 in IWG (2016) supra note 278.

[294] 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.

[295] IWG, 2010 *supra* note 278, at fn 22; Cai et al., 2016, *supra* note 277, at 521.

[296] 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* note 276; Anthoff & Tol (2013) *supra* note 282; DAVID ANTHOFF & RICHARD S. J. TOL, THE CLIMATE FRAMEWORK FOR UNCERTAINTY, NEGOTIATION, AND DISTRIBUTION (FUND), TECHNICAL DESCRIPTION, VERSION 3.5 (2010); Chris Hope, *Critical issues for the calculation of the social cost of CO2: why the estimates from PAGE09 are higher than those from PAGE2002*, 117 CLIM. CHANGE 531–543 (2013) at 539.

[297] According to Heal and Millner (2014) *supra* note 262, 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.

[298] Kenneth J Arrow & Anthony C. Fisher*, Environmental preservation, uncertainty, and irreversibility*, 88 The Quarterly Journal of Economics 312-319 (1974); Avinash K Dixit and Robert S Pindyck, Investment under uncertainty (1994); Christian P Traeger, On option values in environmental and resource economics, 37 Resource and Energy Economics 242-252 (2014).

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 (2014) *supra* note 295, 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:

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

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.*

[299] Even if society drastically reduced CO_2 emissions, CO_2 concentrations would continue to rise in the near future and many impacts would occur regardless due to lags in the climate system. Robert S Pindyck, *Uncertainty in environmental economics*, 1 Review of environmental economics and policy 45-65 (2007).

behavior."[300] 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.

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.[301] 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.[302] 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),[303] 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.[304] 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

[300] Pindyck (2007) *supra* note 296.

[301] Kann & Weyant *supra* note 261; Pindyck (2007) *supra* note 296; Golub et al. (2014) *supra* note *259*.

[302] 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." William D. Nordhaus, *Estimates of the Social Cost of Carbon: Concepts and Results from the DICE-2013R Model and Alternative Approaches*, 1 J. ASSOC. ENVIRON. RESOUR. ECON. 1 (2014).

[303] 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 CO2 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.

[304] Kann & Weyant *supra* note 261; Pindyck (2007) *supra* note 296; Golub et al. (2014) *supra* note *259*.

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 uncertain parameters in FUND and PAGE. Despite these limitations, the literature supports the above finding that the SCC, if anything, increases under uncertainty.[305]

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.[306] For SDP models, uncertainty tends to strengthen the optimal emissions path relative to the determinist case even without tipping points,[307] and these results are strengthened under realistic preference assumptions.[308] Given that there is no counter-balancing tipping abatement cost,[309] 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%[310] to 800%[311] 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.[312] Recent research has shown that accurate estimation of decisions under

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[305] Kann & Weyant *supra* note 261; Pindyck (2007) *supra* note 296; Golub et al. (2014) *supra* note *259*; Lemoine & Rudik 2017 supra note *259*. 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 & Rudik, *id*).

[306] The real options literature tends to find an increase in the optimal emissions path under uncertainty relative to the deterministic case (Pindyck 2007 *supra* note 296), 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 *supra* note 296; Golub et al 2014 *supra* note *259*). 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 *supra* note *259*).

[307] 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) *supra* note *259*; Lemoine & Rudik 2017 supra note *259*). 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.

[308] Pindyck (2007) *supra* note 296; Golub et al. (2014) *supra* note *259*; Lemoine & Rudik 2017 supra note *259*.

[309] Pindyck (2007) *supra* note 296.

[310] Derek Lemoine & Christian P. Traeger, *Economics of tipping the climate dominoes*. 6 NAT. CLIM. CHANG. 514-519 (2016).

[311] Cai et al. 2016 *supra* note 277.

[312] Cai et al. 2016 *supra* note 277; Lemoine & Rudik 2017 supra note *259*. 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

uncertainty crucially depends on distinguishing between risk and time preferences.[313] 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.[314] 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.[315] 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.[316] 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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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. WJ Wouter Botzen & Jeroen CJM van den Bergh, *Specifications of social welfare in economic studies of climate policy: overview of criteria and related policy insights*, 58 Environmental and Resource Economics 1-33 (2014). 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) *supra* note 277 replace the DICE risk aversion of 1.45 and elasticity parameter of 1/1.45 with values of 3.066 and 1.5, respectively.

[313] James Andreoni & Charles Sprenger, *Risk Preferences Are Not Time Preferences*, 102 AM. ECON. REV. 3357–3376 (2012).

[314] Lemoine & Traeger (2016) *supra* note 307.

[315] Typically, IAMs assume constant relative prices of consumption goods. Reyer Gerlagh & B. C. C. Van der Zwaan, *Long-term substitutability between environmental and man-made goods*, 44 Journal of Environmental Economics and Management 329-345 (2002); Thomas Sterner & U. Martin Persson, *An even sterner review: Introducing relative prices into the discounting debate*, 2 Review of Environmental Economics and Policy 61-76 (2008). 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. Yongyang Cai, Kenneth L. Judd, Timothy M. Lenton, Thomas S. Lontzek, & Daiju Narita, *Environmental tipping points significantly affect the cost− benefit assessment of climate policies*, 112 PROC. NATL. ACAD. SCI. 4606-4611 (2015).

[316] Golub et al. (2014) *supra* note *259* 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." *See also* Comments from Robert Pindyck, to BLM, on the Social Cost of Methane in the Proposed Suspension of the Waste Prevention Rule (submitted Nov. 5, 2017) ("Specifically, my expert opinion about the uncertainty associated with Integrated Assessment Models (IAMs) was used to justify setting the SC-CH4 to zero until this uncertainty is resolved. That conclusion does not logically follow and I have rejected it in the past, and I reiterate my rejection of that view again here. While at this time we do not know the Social Cost of Carbon (SCC) or the Social Cost of Methane with precision, we do know that the correct values are well above zero…Because of my concerns about the IAMs used by the now-disbanded Interagency Working Group to compute the SCC and SC-CH4, I have undertaken two lines of research that do not rely on IAMs…[They lead] me to believe that the SCC is larger than the value estimated by the U.S. Government."

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.[317] In DICE-2010, the elasticity of the pure rate of time preference is 1.5 and an elasticity of the marginal utility of consumption (η) 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%.[318] However, more recent versions of DICE (DICE-2013R and DICE-2016) update η 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.[319] 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%,[320] 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[321] 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.[322] Not only are declining discount rate theoretically

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[317] Richard Newell (2017, October 10). Unpacking the Administration's Revised Social Cost of Carbon. Available at http://www.rff.org/blog/2017/unpacking-administration-s-revised-social-cost-carbon.

[318] 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.

[319] 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.

[320] According to the World Bank, the average global and United States per capita growth rates were 1.7% and 1.9%, respectively.

[321] INTERAGENCY WORKING GROUP ON SOCIAL COST OF CARBON, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12,866 (2010). INTERAGENCY WORKING GROUP ON SOCIAL COST OF CARBON, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12,866 (2013). INTERAGENCY WORKING GROUP ON SOCIAL COST OF CARBON, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12,866 (2016).

[322] 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). 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 that "Establishing a procedure for estimating a [declining discount

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 correct discount rate is not an arithmetic average of possible discount rates.[323] 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.[324] 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[325] 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.[326] Several key papers[327] 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)[328], 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.[329] 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

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rate] for project analysis would be an improvement over the OMB's current practice of recommending fixed discount rates that are rarely updated."

323 Larry Karp, Global warming and hyperbolic discounting, 89 Journal of Public Economics 261-282 (2005) (The 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 Cameron Hepburn, *Hyperbolic Discounting And Resource Collapse*, 103 *Royal Economic Society Annual Conference 2004* (2004) 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.

324 Martin L Weitzman, Gamma discounting, 91 AM. ECON. REV. 260-271 (2001). Geoffrey M. Heal, & Antony Millner, Agreeing to disagree on climate policy, 111 PROC. NATL. ACAD. SCI. 3695-3698 (2014).

325 *See generally* Arrow et al. (2013), *supra* note 317.

326 Mark C. Freeman, Ben Groom, Ekaterini Panopoulou, & Theologos Pantelidis, Declining discount rates and the Fisher Effect: Inflated past, discounted future?, 73 J. ENVIRON. ECON. MANAGE. 32-49 (2015).

327 *See generally* Arrow et al., 2013; Arrow et al., 2014;; Cropper et al., 2014, *supra* note 317. *See also* Christian Gollier, & James K. Hammitt, The long-run discount rate controversy, 6 ANNU. REV. RESOUR. ECON. 273-295 (2014).

328 Peter Howard & Derek Sylvan, *The Economic Climate: Establishing Expert Consensus on the Economics of Climate Change,* INST. POLICY INTEGRITY WORKING PAPER (2015).

329 This argument was first developed in Weitzman (1998) and Weitzman (2001). Martin L Weitzman, Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate, 36 J. ENVIRON. ECON. MANAGE. 201–208 (1998). Martin L Weitzman, Gamma discounting, 91 AM. ECON. REV. 260-271 (2001). *See* Weitzman (2001) *supra* note 319.

correlated over time.[330] 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[331] for discounting will lead to a declining discount rate.[332]

In the descriptive setting adopted by the IWG (2010),[333] 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.[334] 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.[335] 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.[336]

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. Instead, analysis should focus on the uncertainty underlying the future consumption discount rate.[337] Past U.S. government analyses[338] 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

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[330] *See* Christian Gollier, Should we discount the far-distant future at its lowest possible rate?, 3 *Economics: The Open-Access, Open-Assessment E-Journal* 1-14 (2009).

[331] The Ramsey discount rate equation for the social discount rate is $r = \delta + \eta * g$ where r is the social discount rate, δ is the pure rate of time preference, η is the aversion to inter-generational inequality, and *g* is the growth rate of per capita consumption. For the original development, *see*, Frank Plumpton Ramsey, *A mathematical theory of saving*, 38 The Economic Journal 543-559 (1928).

[332] 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) supra note 317 at 148. It is standard in IAMs to assume that the growth rate of consumption will fall over time. *See*, *e.g.,* William D. Nordhaus, Revisiting the social cost of carbon, 114 PROC. NATL. ACAD. SCI. 1518-1523 (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, Chris Hope, The social cost of CO2 from the PAGE09 model, Economics The Open-Access, Open-Assessment E-Journal Discussion Paper No. 2011-39 (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. *See* David Anthoff, & Richard SJ Tol, The Climate Framework for Uncertainty, Negotiation and Distribution (FUND): Technical description, Version 3.8." Discussion paper. URL http://www.fund-model.org.

[333] 333 *See* IWG (2010), *supra* note 316.

[334] *See* Arrow et al. (2014) *supra* note 317 at 157.

[335] *See generally* Gollier and Hammitt 2014, *supra* note 322.

[336] *See generally* Arrow et al., 2013; Arrow et al., 2014;; Cropper et al., 2014, *supra* note 317. *See also* Freeman et al. (2015), *supra* note 321. Finally, see Elyès Jouini, & Clotilde Napp, How to aggregate experts' discount rates: An equilibrium approach, 36 ECON. MODELLING 235-243 (2014).

[337] *See generally* Newell (2017) *supra* note 312.

[338] *See* IWG (2010; 2013; 2016) *supra* note 316.

the recommendation of Marten et al. (2015);[339] see our discussion on Martin et al. (2015). This is roughly IWG (2010)[340]'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[341] implies a declining discount rate when (1) the growth rate of per capita consumption is stochastic,[342] and (2) consumption shocks are positively correlated over time (or their mean or variances are uncertain).[343] While a constant adjustment downwards (known as the precautionary effect[344]) can be theoretically correct when growth rates are independent and identically distributed,[345] 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).[346] 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).[347]

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[339] *See* Alex L.Marten, Elizabeth A. Kopits, Charles W. Griffiths, Stephen C. Newbold, & Ann Wolverton, Incremental CH4 and N2O mitigation benefits consistent with the US Government's SC-CO2 estimates, 15 CLIMATE POL'Y 272-298 (2015).

[340] *See* IWG (2010) *supra* note 316.

[341] If the future growth of consumption is uncertainty with mean μ and variance σ^2, an extended Ramsey equation $r = \delta + \eta * \mu - 0.5\eta^2\sigma^2$ applies where r is the social discount rate, δ is the pure rate of time preference, η 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. Christian Gollier, Pricing the Planet's Future: The Economics of Discounting in an Uncertain World, Princeton University Press (2012) at Chapter 3.

[342] The IWG assumption of five possible socio-economic scenarios implies an uncertain growth path.

[343] *See generally* Arrow et al., 2013; Arrow et al., 2014; Gollier & Hammitt, 2014; Cropper et al., 2014, *supra* note 317. 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." Christian Gollier, Discounting with fat-tailed economic growth, 37*Journal of Risk and Uncertainty* 171-186 (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." Christian Gollier, The consumption-based determinants of the term structure of discount rates, 1 *Mathematics and Financial Economics* 81-101 (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 *supra* note 317).

[344] The precautionary effect measures aversion to future "wiggles" in consumption (i.e., preference for consumption smoothing); see Christian P Traeger, *On option values in environmental and resource economics*, 37 *Resource and Energy Economics* 242-252 (2014).

[345] *See* Cropper et al 2014 *supra* note 317.

[346] Cropper et al., 2014; Arrow et al., 2014; IPCC, 2014) 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. See Cropper et al., 2014 and Arrow et al., 2014 *supra* note 317. *See also* Intergovernmental Panel on Climate Change, *Climate Change 2014–Impacts, Adaptation and Vulnerability: Regional Aspects*, Cambridge University Press, 2014 [hereinafter, IPCC 2014].

[347] *See* Christian Gollier, Should we discount the far-distant future at its lowest possible rate?, 3 *Economics: The Open-Access, Open-Assessment E-Journal* 1-14 (2009). 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; see Gollier (2012) *supra* note 336 and Martin L Weitzman, A Review of The Stern Review of the Economics of Climate Change, 45 J. ECON. LIT. 703 (2007). 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 (*see* Cropper et al., 2014 *Supra* note 317). Again, theory shows that ambiguity leads to a declining discount rate schedule by Jensen's inequality (*see* Cropper et al 2014 *supra* note 317).

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[348], 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.[349] 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.[350]

Additionally, a related literature has developed over the last decade demonstrating that normative uncertainty (i.e., heterogeneity) over the pure rate of time preference (δ)—a measure of impatience—also leads to a declining social discount rate.[351] Despite individuals differing in their pure rate of time preference,[352] 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.[353] The literature generally finds a declining social discount rate due to a declining collective pure rate of time preference.[354] The heterogeneity of preferences and the uncertainty surrounding economic growth hold simultaneously,[355] 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).[356] One possible declining interest rate schedule for consideration by the IWG is the one proposed by Weitzman (2001).[357] It is derived from a broad survey of top economists in context of climate change, and explicitly incorporates arguments around interest rate uncertainty.[358] Other declining discount rate schedule include Newell

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[348] For example, Arrow et al. (2014) *supra* note 317

[349] *See* Gollier and Hammitt 2014 *supra* note 322 and Arrow et al. (2014) *supra* note 317.

[350] 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. See also Marten et al 2015 *supra* note 345 and William D. Nordhaus, *Estimates of the Social Cost of Carbon: Concepts and Results from the DICE-2013R Model and Alternative Approaches*, 1 J. ASSOC. ENVIRON. RESOUR. ECON. 1 (2014).

[351] See Arrow et al 2014 and Cropper et al 2014 *supra 317*. See also Mark C. Freeman, & Ben Groom, How certain are we about the certainty-equivalent long term social discount rate?, 79 J. ENVIRON. ECON. MANAGE. 152-168 (2016).

[352] *See* Christian Gollier, & Richard Zeckhauser, Aggregation of heterogeneous time preferences, 113 J. POL. 878-896 (2005).

[353] See Antony Millner & Geoffrey Heal, *Collective intertemporal choice: time consistency vs. time invariance,* Grantham Research Institute on Climate Change and the Environment No. 220 (2015). See also Freeman and Groom 2016 *supra* 346.

[354] See Jouini and Napp, 2014 *supra* note 331, Freeman and Groom 2016 *supra* 346, and Gollier & Zeckhauser, 2005 *supra* note 347. *See also* Elyès Jouini, Jean-Michel Marin, & Clotilde Napp, Discounting and divergence of opinion, 145 J. ECON. THEORY 830-859 (2010). 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).

[355] *See* Jouini and Napp 2014 *supra* note 331 and Jouini et al 2010 *supra* note 349.

[356] *See* Arrow et al 2014 and Cropper et al 2014 *supra* note 317.

[357] 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; see Weitzman (2001) *supra* note 319.

[358] Freeman and Groom (2015) 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; *see* Mark C Freeman., & Ben Groom, Positively gamma discounting: combining the opinions of experts on the social discount rate, 125 ECON. J. 1015-1024 (2015). A recent survey by Drupp et al. (2015) – which includes Freeman and Groom as co-authors – supports the Weitzman (2001)

and Pizer (2003); Groom et al. (2007); Freeman et al. (2015).[359] Many leading economists support the United States government adopting a declining discount rate schedule.[360] 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.[361] The U.K. schedule explicitly subtracts out an estimated time preference.[362] 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),[363] suggesting that even the lowest discount rate evaluated by the IWG is too high.[364] 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).[365]

A declining discount rate motived by discount rate or growth rate uncertainty avoids the time inconsistency problem that can arise if a declining pure rate of time preference (δ) is used. Circular A-4 cautions that "[u]sing the same discount rate across generations has the advantage of preventing time-inconsistency problems."[366] 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 (δ) 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 δ is constant.

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

assumption; see Moritz A Drupp, Mark Freeman, Ben Groom, & Frikk Nesje, Discounting disentangled, Memorandum, Department of Economics, University of Oslo, No. 20/2015 (2015).

359 See Richard G. Newell, and William A. Pizer, Discounting the distant future: how much do uncertain rates increase valuations?, 46 J. ENVIRON. ECON. MANAGE. 52-71 (2003). See also Ben Groom, Phoebe Koundouri, Ekaterini Panopoulou, &Theologos Pantelidis, Discounting the distant future: how much does model selection affect the certainty equivalent rate?, 22 J. APPL. ECONOMETRICS 641-656 (2007). Finally, see Freeman et al., 2015 *supra* note 353.

360 *See* Arrow et al 2014 and Cropper et al 2014 *supra* note 317.

361 *See* Gollier and Hammitt 2014 *supra* note 322 and Cropper et al 2014 *supra* note 317.

362 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.

363 *See* IWG (2010) *supra* note 316.

364 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_2, 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. *See* IWG (2010) *supra* note 316.

365 *See* Arrow et al 2013 and Arrow et al 2014 *supra* note 317. See also Freeman et al., 2015 *supra* note 353.

366 *Circular A-4* at 35.

rate of time preference, not due to a decreasing discount rate term structure.[367] 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."[368]

We should note that time-inconsistency is not a reason to ignore heterogeneity (i.e., normative uncertainty) over the pure rate of time preference (δ). 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)[369] 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,[370] 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).[371] 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).[372] This consensus holds across panels of experts on the social cost of

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[367] Gollier (2012) *supra* note 336 ("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.").

[368] National Academies of Sciences, Engineering, and Medicine, *Valuing climate damages: Updating estimation of the social cost of carbon dioxide* at 53 (2017) at 182.

[369] Antony Millner, & Geoffrey Heal, Collective intertemporal choice: time consistency vs. time invariance, Grantham Research Institute on Climate Change and the Environment No. 220 (2015).

[370] See Weitzman (2001) *supra* note 319, Howard and Sylvan 2015 *supra* note 323, and Drupp et al 2015 *supra* note 353.

[371] See Weitzman (2001) *supra* note 319 and Freeman et al., 2015 *supra* note 353.

[372] The former co-chair of the National Academy of Sciences' Committee on Assessing Approaches to Updating the Social Cost of Carbon – Richard Newell (2017) *supra* note 312 – states that "[t]hough 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."

carbon[373]; surveys of experts on climate change and discount rates;[374] the three most commonly cited IAMs employed in calculating the federal SCC; and the government's own analysis.[375] For more 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.

[373] See generally NAS 2017 *supra* note 363.

[374] See Weitzman (2001) *supra* note 319, Howard and Sylvan 2015 *supra* note 323, Drupp et al 2015 *supra* note 353, and Robert Pindyck, The social cost of carbon revisited, National Bureau of Economic Research No. w22807(2016).

[375] *See* IWG 2010 *supra* note 316 and 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).