October 26, 2018

Docket: NHTSA-2017-0069 (Environmental Impact Statement)

Subject: Comments on Quantifying and Monetizing Greenhouse Gas Emissions in the Draft Environmental Impact Statement for the Safer Affordable Fuel-Efficient Vehicles Rule for Model Year 2021-2026 Passenger Cars and Light Trucks

Submitted by: Environmental Defense Fund, Institute for Policy Integrity at New York University School of Law, Natural Resources Defense Council, Sierra Club, and Union of Concerned Scientists[1]

The following comments focus on the Draft Environmental Impact Statement (DEIS)'s inaccurate quantification of greenhouse gas emissions and failure to monetize the climate damages from those emissions using the social cost of greenhouse gases.

The National Environmental Policy Act (NEPA) requires agencies like NHTSA to fully and accurately estimate the environmental, public health, and social welfare differences between the no-action alternative and the proposed action, and to contextualize that information for decision-makers and the public. By inaccurately quantifying greenhouse gas emissions and failing to contextualize climate information using the social cost of greenhouse gas metrics, NHTSA has violated its responsibilities under NEPA.

Additionally, to the extent that NHTSA attempts to incorporate by reference the use of the social cost of greenhouse gases by the proposed rule's separate regulatory impact analysis, the agency's so-called "interim" metrics have manipulated and decimated the estimates of the full costs of climate damages in ways at odds with the best available science, the best practices for economic analysis, and the legal standards for rational decisionmaking. The "interim" values ignore the real costs of climate change by arbitrarily attempting to limit the valuation to purportedly domestic-only effects; by arbitrarily discounting future climate effects at a 7% discount rate that is inappropriate for long-term climate effects; and by arbitrarily failing to address uncertainty over catastrophic damages, tipping points, option value, and risk aversion.

Because NHTSA's regulations for "external review of draft environmental impact statements" do not mention any page limitation on public comments,[2] and because the DEIS's own description of the "public comment period" also does not mention a page limitation, we presume that the notice of proposed rule's reference[3] to a 15-page limit on comments submitted under 49 C.F.R. § 553.21 (a regulation focused on the adoption of rules)[4] does not apply to comments on the DEIS. In the event NHTSA does interpret the 15-page limit to apply, please consider all the content following this first page to be an attachment, as permitted by the submission instructions.[5]

---

[1] Our organizations may separately and independently submit other comments on other issues raised by the DEIS.

[2] 49 C.F.R. § 520.25.

[3] 83 Fed. Reg. 42,986 43,470 (Aug. 24, 2018).

[4] Subpart B of 49 C.F.R. pt. 553 is entitled "Procedures for Adoption of Rules."

[5] 83 Fed. Reg. at 43,470.

I. NHTSA Inaccurately and Incompletely Quantifies Emissions

It is impossible to provide decision-makers and the public with the necessary context to understand the difference in climate impacts between the no-action alternative and the proposed action if the greenhouse gas emissions have not been fully and accurately quantified. They have not.

Note that while these comments focus on greenhouse gas emissions, many of the critiques apply equally to the DEIS's estimates and presentation of criteria and toxic pollutants as well.

Problems with the Rebound, Scrappage, and Sales Modules—Plus Other Problematic Modeling Choices—Infect the DEIS's Estimates of Emissions

The DEIS's estimates of both upstream and downstream emissions derive from the Volpe model's predictions about miles driven and fuel consumed.[6] The DEIS admits that its estimates of emissions are sensitive to, among other modeling choices, the rebound and scrappage modules that NHTSA and EPA developed for the preliminary regulatory impact analysis (PRIA) and proposed rule.[7]

Various separate comments submitted by our groups on the PRIA and proposed rule detail the numerous serious problems with the economic theory, methodology, and data that NHTSA used to build its rebound, scrappage, and sales modules. To give just one example, in the vehicle sales module, the analysis assumes that consumers care about vehicle cost but place zero value on fuel savings. This unrealistic assumption lets the agencies miscalculate sales of new vehicles versus retention of older, dirtier vehicles under the standards. As a result, the agencies grossly underestimate the net emission reductions achieved by the 2012 baseline standards. Such serious problems indicate that NHTSA is likely severely underestimating the increase in emissions resulting from the proposed action as compared to the no-action alternative. NHTSA must reexamine the DEIS's estimates of all emissions—greenhouse gases, criteria pollutants, and toxic pollutants—to correct any and all problems with the Volpe model that have resulted in undercounting the increase in pollution under the proposed action as compared to the no-action alternative.

The DEIS Ignores Entire Categories of Significant Upstream Emissions

The DEIS claims that it "estimated both domestic and international upstream emissions" of greenhouse gases, criteria pollutants, and toxic air pollutants,[8] and that "emissions estimates include global CO_2, CH_4, and N_2O emissions resulting from direct fuel combustion and the production and distribution of fuel and electricity (upstream emissions)."[9] That would absolutely be the proper scope for NHTSA to take on estimating upstream emissions, not only because NEPA requires a global perspective on impacts, but also because pollution emitted outside U.S. borders can still directly impact U.S. interests. Unfortunately, both these statements about considering global upstream emissions are incorrect, and the DEIS in fact ignores entire and important categories of upstream emissions.

On page 5-22, in a section on "Methods for Modeling Greenhouse Gas Emissions," the DEIS specifies that its upstream estimates from fuel production and distribution were based on the Volpe model. Footnote 20 then clarifies that "Some modifications were made to the estimation of upstream emissions, consistent with NTHSA and EPA assumptions in the NPRM. Section 10.2.3 of the PRIA provides more information regarding these modifications."

---

[6] NHTSA. Draft Environmental Impact Statement for the Safer Affordable Fuel-Efficient Vehicles Rule for Model Year 2022-2026 Passenger Cars and Light Trucks. NHTSA-2017-0069 [Hereinafter DEIS] at 2-17.

[7] *See, e.g.*, DEIS at S-7, 2-21 fn.23.

[8] DEIS at 2-20.

[9] DEIS at 5-21.

Section 10.2.3 of the PRIA clarifies that it is only quantifying "the resulting increases in domestic emissions" from upstream fuel production and distribution.[10] In particular, the PRIA's methodology for quantifying upstream effects counts emissions only if the fuel extraction, refining, distribution, and storage activities happened within U.S. borders. The PRIA assumes that 50% of the increased fuel consumption that results from lowering CAFE standards will be satisfied by imported finished gasoline products:[11] it therefore ignores all emissions from extracting, refining, and transporting the crude oil to supply that 50% of finished gasoline products. The other 50% of increased fuel consumption is estimated to come from increased domestic refining, but the PRIA further assumes that 90% of the crude oil feeding into that increased domestic refining will come from imported crude petroleum:[12] the PRIA therefore further ignores all emissions from extracting that imported crude, and likely some portion of emissions from transporting that crude before it was imported. Altogether, the PRIA ignores 95% of upstream emissions from fuel extraction,[13] 50% of upstream emissions from refining, at least 50% of upstream emissions from distribution of crude, and some unclear portion of upstream emissions from distribution of finished gasoline.[14]

These same assumptions—50% imported finished gasoline, 90% imported crude—also appear in the proposed rule,[15] as well as in the spreadsheet on parameters for the reference case in NHTSA's sensitivity analysis files. The reference case parameters file also confirms that these "fuel import assumptions" are held constant from 2015 through 2050.

There are several significant problems with ignoring upstream emissions just because they originate outside U.S. borders.

First, as further detailed *infra* in the section on the global social cost of greenhouse gases, NEPA requires a worldwide perspective. NEPA contains a provision on "International and National Coordination of Efforts" that broadly requires that "all agencies of the Federal Government *shall* . . . recognize the worldwide and long-range character of environmental problems."[16] Other agencies recognize that, under NEPA, the best practice is to count how their actions will contribute to emissions that originate out of the United States. For example, in the 2017 Environmental Assessment prepared for a modification of the King II Mine in Colorado, the Bureau of Land Management and Office of Surface Mining acknowledged that the bulk of the coal produced "will be combusted . . . potentially anywhere in northern Mexico and in the southwestern U.S."[17] Even though the greenhouse gas emissions from the downstream combustion of that coal could originate in Mexico or elsewhere, the agencies had no troubling quantifying and disclosing all the expected greenhouse gas emissions.[18]

Second, emissions that originate abroad can still have direct impacts on the United States. This is especially true of greenhouse gases, which are global pollutants that readily mix in the atmosphere and

---

[10] EPA & NHTSA. Preliminary Regulatory Impact Analysis. The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021 – 2026 Passenger Cars and Light Trucks (Jul. 2018, updated Aug. 23, 2018, Oct. 16, 2018) [Hereinafter PRIA] at 1291.

[11] PRIA at 1299 ("Using NEMS, it was estimated that 50% of increased gasoline consumption would be supplied by increased domestic refining.").

[12] PRIA at 1291 ("90% of this additional [domestic] refining would use imported crude petroleum.").

[13] 50% * 90% = 45%. 45% +50% = 95%.

[14] It is not immediately clear which distribution, transportation, and storage activities were counted. For example, crude may be extracted in Country A, transported to Country B for refining, transported again to Country C for storage, until finally imported to the United States. It is not clear which portion of emissions during the transportation between Countries A, B, and C—if any—is counted.

[15] 83 Fed. Reg. at 43,335.

[16] 42 U.S.C. § 4332(2)(f) (emphasis added).

[17] BLM & OSMRRE, *Preliminary Environmental Assessment: Federal Coal Lease (COC-62920 Modification and Federal Mine Permit (CO-0106A) Revision and Renewal* 68 (2017).

[18] *Id*.

affect global climate. All greenhouse gases, regardless of their point of origin anywhere on the planet, will cause the same climate damages for the United States. Though criteria and toxic pollutants are usually thought of as local pollution, even some criteria and toxic pollutants emitted abroad can directly impact the United States. For example, in 2017, Canada supplied 43% of all crude imported into the United States, 45% of imported finished motor gasoline, and 30% of imported gasoline blending components; Mexico further supplied another 8% of crude imported into the United States.[19] EPA has in the past recognized that U.S. emissions of criteria and toxic pollution can affect health and welfare in our neighboring countries;[20] similarly, depending on the location of Canada and Mexico's fuel production and distribution facilities and on prevailing winds, their emissions can affect health and welfare in the United States. None of these upstream emissions—and especially the global greenhouse gas pollutants—should be completely ignored.

Third, as detailed further *infra* on the global social cost of greenhouse gases, through international spill-over effects, foreign reciprocity, the extraterritorial interest of the U.S. government and its citizens, and altruism, worldwide climate effects also affect U.S. welfare and matter to U.S. decisionmakers and the public under NEPA.

Fourth, the assumptions are also questionable, especially over the long term. Much of the PRIA explicitly relies on the assumption that the United States will very soon become a net exporter of petroleum products. Indeed, the PRIA uses that assumption as a justification for not counting other potential social costs of the proposed reduction in CAFE standards, such as military and security costs.[21] It is unclear why NHTSA thinks that, solely for the purposes of quantifying upstream emissions, the United States will continue to import 50% of its gasoline and 90% of its crude *through the year 2050* to satisfy increased fuel consumption. By failing to adjust these assumptions over time, NHTSA is not only undercounting all upstream emissions, but in particular it is undercounting *future* upstream emissions. Because the climate systems will continue to become even more stressed over time, future emissions are increasingly damaging,[22] and it is precisely these emissions that NHTSA is ignoring.

NHTSA also compounds these problems by not providing a cumulative tally of methane and nitrous oxide emissions, and not (except in a sensitivity analysis) monetizing the climate damages from methane and nitrous oxide emissions. These additional problems are discussed further below.

---

[19] In 2017, US imported from all countries: 2.9 billion barrels of crude, 11 million barrels of finished motor gasoline, 220 million barrels of motor gasoline blending components. Of that, Canada supplied 1.25 billion barrels of crude (43%), 5 million barrels of finished motor gasoline (45%), and 66 million barrels of motor gasoline blending components (30%). Mexico supplied 222 million barrels of crude (8%), 1.5 million barrels of blending components (<1%). EIA, Petroleum & Other Liquids, https://www.eia.gov/dnav/pet/pet_move_impcus_d_nus_Z00_mbbl_a.htm

[20] In the analysis of the Cross-State Air Pollution Rule, EPA noted— though could not quantify—the "substantial health and environmental benefits that are likely to occur for Canadians" as U.S. states reduce their emissions of particulate matter and ozone—pollutants that can drift long distances across geographic borders. Federal Implementation Plans to Reduce Interstate Transport of Fine Particulate Matter and Ozone, 75 Fed. Reg. 45,210, 45,351 (proposed Aug. 2, 2010). Similarly, in the Mercury and Air Toxics Standards, EPA concluded that a reduction of mercury emissions from U.S. power plants would generate health benefits for foreign consumers of fish, both from U.S. exports and from fish sourced in foreign countries. EPA did not quantify these foreign health benefits, however, due to complexities in the scientific modeling. U.S. ENVTL. PROT. AGENCY, REGULATORY IMPACT ANALYSIS FOR THE FINAL MERCURY AND AIR TOXICS STANDARDS 65 (2011) ("Reductions in domestic fish tissue concentrations can also impact the health of foreign consumers . . . [and] reductions in U.S. power plant emissions will result in a lowering of the global burden of elemental mercury.").

[21] PRIA at 1068.

[22] For example, the social cost of greenhouse gases increases over time because an additional ton of emissions will inflict greater damages in the future when total atmospheric concentrations of greenhouse gases are already much higher. As emissions accumulate in the atmosphere, each additional ton becomes that much more damaging. *See e.g.*, IWG, Technical Update of the Social Cost of Carbon (2016, hereinafter 2016 TSD), https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc_tsd_final_clean_8_26_16.pdf.

Other Quantification Issues

<u>Overestimating EV Emissions:</u> The DEIS may be overestimating upstream emissions from electric vehicle use, and so underestimating the net greenhouse gas increases of the proposed action to roll back CAFE standards. After acknowledging that upstream emissions would vary "across the country," the DEIS instead "assumes that the future EV fleet would charge from a grid whose mix is uniform across the country."[23] This assumption ignores the fact that EV usage may be clustered in states with cleaner electricity fuel mixes. Notably, about half of EV sales in 2016 and 2017 occurred in California,[24] and California has a significantly cleaner current and planned electricity system than the national average.[25]

<u>Unclear Treatment of Refueling Emissions:</u> The proposed rule notes that greenhouse gas savings under CAFE standards from not have to drive as often to refuel are "implicitly accounted for elsewhere" in the model,[26] though the rule does not clearly explain where or how those emissions are quantified. The proposed rule admits that, while the related fuel savings from not having to drive as often to refuel (which it also assumes are "implicitly captured" elsewhere) may seem to be a small benefit per individual consumer, the effect "is much more significant at the macro level."[27] It is not clear if or how the DEIS quantifies the similarly "significant" greenhouse gas emissions from refueling trips.

<u>No Cumulative Tallies for Methane or Nitrous Oxide:</u> The DEIS seems to only quantify methane and nitrous oxide emissions in an appendix, and there the DEIS provides only selected quantifications for 5 individual years (in year 2020, 2040, 2060, 2080, and 2100); the DEIS fails to provide a clear cumulative tally of the change in methane and nitrous oxide emissions between the no-action alternative and the proposed action.[28] For example, Section 6.2.2.1 of the DEIS ("Methane Emissions from Oil and Natural Gas") does not contain any quantitative estimates of emissions from any of the alternatives under consideration.[29] This lack of adequate attention and context given to methane and nitrous oxide emissions is compounded by how the methodology overlooks significant upstream emissions resulting from the proposed action just because the emissions happen to originate outside U.S. borders, as described above. Methane especially is a significant component of upstream emissions, and its greater near-term potency in its radiative-forcing effects warrant much greater attention than the DEIS has given these non-carbon greenhouse emissions.

<u>Unexplained Inconsistency between the DEIS and PRIA:</u> Finally, the cumulative tallies of direct and indirect carbon dioxide emissions that do appear in the DEIS (a difference of 4500 $MMTCO_2$ from passenger cars between the no-action alternative and alternative 1; and a difference of 2900 $MMTCO_2$ from light trucks between the no-action alternative and alternative 1)[30] are markedly different than the quantifications that appear in the PRIA and proposed rule (a difference of 329 $MMTCO_2$ from passenger cars between the no-action alternative and alternative 1; and a difference of 480 $MMTCO_2$ from light trucks between the no-action alternative and alternative 1).[31] Not just the magnitude of the numbers but also the relative share of responsibility between cars and trucks seems to be different between the

---

[23] DEIS at 2-23; *see also* PRIA at 1304.

[24] EVAdoption, 2017 EV Sales and Market Share by US State, http://evadoption.com/ev-market-share/ev-market-share-state/; *see also* Dept. of Energy, Registered Electric Vehicles by State, https://www.afdc.energy.gov/data/10961.

[25] EIA, Energy-Related Carbon Dioxide Emissions by State, 2000-2015, https://www.eia.gov/environment/emissions/state/analysis/.

[26] 83 Fed. Reg. at 43,088.

[27] *Id.*

[28] DEIS Appendix at pages D-14 to D-15, D-19 to D-20.

[29] DEIS at 6-10 to 6-12.

[30] DEIS Appendix at page D-13.

[31] PRIA at 92, table 1-77.

DEIS estimates and the PRIA estimates. Given that the DEIS and PRIA both rely on the same models,[32] it is possible that the different cumulative estimates are explained by different timescales[33] and by the DEIS's reliance on GCAM to estimate emissions from cars and trucks over the years 2061-2100 by applying a projected rate of change.[34] Yet neither the DEIS nor the PRIA fully explains the different estimates in the two interrelated documents. The lack of a full explanation is especially problematic because, as discussed below, NHTSA states that it need not apply the social cost of greenhouse gas metrics in the DEIS because readers can refer to the calculations in the PRIA. In fact, the PRIA's monetization of climate damages based on the PRIA's estimated change in greenhouse gas emissions cannot provide the public or decisionmakers with the context needed to understand the climate damages from the DEIS's estimated cumulative change in emissions, because the quantitative estimates appearing in the two documents are so very different.

II. NHTSA Must Monetize the Social Cost of Greenhouse Gases in its EIS

The DEIS acknowledges that monetizing climate damages using the social cost of greenhouse gases provides "the decision-maker and the public . . . with the full context of the potential impacts of GHG emissions and climate change."[35] Nevertheless, NHTSA opts not to use the social cost of greenhouse gas metrics in the DEIS to provide that necessary "full context," and instead relies on incorporating the PRIA by reference. NHTSA gives two reasons for this decision, both of which are misleading.

NHTSA's first reason is that this decision "is consistent with past practice."[36] That statement is misleading. In previous CAFE rulemakings, NHTSA has monetized climate effects both directly in the EIS as well as in the regulatory impact analysis. Most importantly, when NHTSA finalized its standards for Model Years 2017-2021 and announced its augural standards for Model Years 2022-2025, its accompanying Final EIS comprehensively reviewed the environmental effects for the full range of model years (2017 through 2025) and directly monetized climate effects.[37] Because the earlier EIS documents for standards for Model Years 2021-2025 monetized climate effects, and because climate effects remain the most central environmental impact of the CAFE standards, failing to monetize the climate effects in the new EIS creates confusion among the public and agency reviewers.

NHTSA's second reason for incorporation by reference is that the PRIA is "the most appropriate place for discussing the SC-CO_2 and including it in the decision-making process," because the PRIA "monetizes [all] the potential costs and benefits"[38] and so provides "the full context of the potential impacts of GHG emissions and climate change." There are at least four problems with this argument.

One, as already mentioned, the DEIS and the PRIA contain markedly different quantitative estimates of the cumulative increases in carbon dioxide resulting from choosing the proposed action over the no-action alternative: the DEIS estimates an increase of 4500 MMTCO_2 from passenger cars and 2900 MMTCO_2 from light trucks,[39] while the PRIA estimates a difference of 329 MMTCO_2 from passenger cars and 480 MMTCO_2 from light trucks.[40] The fact that PRIA monetized climate damages from an increase of

---

[32] DEIS at 2-17 (discussing reliance on Volpe, GREET, MOVES, NEMS, and so forth).

[33] *Compare* PRIA at 123 (calculating emissions over the lifetime of the vehicles) *with* DEIS at D-13 (calculating emissions over the years 2021-2100).

[34] DEIS at 5-21.

[35] DEIS at 1-20.

[36] DEIS at 1-20.

[37] NHTSA, Final Environmental Impact Statement: Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2017-2025 (2011) at 5-24; *see also id.* at Appendix G (separately appending the regulatory impact analysis).

[38] DEIS at 1-20.

[39] DEIS Appendix at page D-13.

[40] PRIA at 92, table 1-77.

809 $MMTCO_2$ (using a severely undervalued and manipulated social cost of carbon metric, *see infra*) does not help the public and decisionmakers understand the full context of the climate damages from the 7400 $MMTCO_2$ increase estimated under the DEIS.

Two, as discussed more fully below, the PRIA buries any consideration of monetized climate damages from increases in methane and nitrous oxide emissions in a sensitivity analysis (which uses the wrong methodology for estimating the social cost of greenhouse gases), which hardly provides the full context on methane and nitrous oxide emissions for readers of the DEIS.

Three, as explained in more detail in the next subsection, it is exceedingly difficult for most readers to comprehend the significance of the associated climate impacts from mere quantitative estimates of greenhouse gas emissions. The DEIS is full of attempts to use quantitative information to trivialize what are actually billions or trillions of dollars' worth of climate damages. To fulfill NEPA's requirements to provide readers with enough context to understand the difference between alternatives under consideration, climate damages must be monetized using the social cost of greenhouse gas metrics within the NEPA documents themselves to prevent misleading the public and decisionmakers.

Four, the PRIA's description of the methodology for estimating the social cost of greenhouse gases is incomplete or inapplicable in several ways. For example, when discussing a sensitivity analysis using a 2.5% discount rate, the PRIA starts reporting different estimates of monetized climate damages "under the rate-based and mass-based scenarios, respectively."[41] There are no rate-based versus mass-based alternatives under the proposed CAFE standards. Evidently, this language and the monetized estimate of climate damages ($3.8 to $3.9 billion) were copied and pasted directly from a different rulemaking (namely, from the stay, repeal, or replacement of the Clean Power Plan). It is unclear how much of the PRIA's description of its methodology or its monetized values using the social cost of greenhouse gases are also copied from a different rulemaking and so inapplicable to this rulemaking—and consequently uninformative and in fact misleading as incorporated into this DEIS.

In addition, the PRIA promises several critical documents to enable the public to understand the derivation of the social cost of greenhouse gas estimates—documents which are, in fact, not currently in the rulemaking dockets. Specifically, the PRIA promises, on page 1101, that "the full set of SC-CO2 results through 2050 is available in the docket." Page 1100 further promises that "to better understand how the results" for estimates of the social cost of carbon "vary across scenarios, results of each model run are available in the docket." Additionally, on page 1534, footnote 910 says that "a detailed description of the methods used to construct these alternative values" for the social cost of methane and nitrous oxide "is available in the docket for this rule." None of that promised information is available in either docket for this rulemaking, at least according to our best searches of the docket. The promised but missing information is essential to allow the public to fully understand, among other things, how the discount rates and socioeconomic scenarios affect the estimates. The frequency distribution chart on page 1101, for example, provides insufficiently fine-grained information on how negative estimates of the social cost of carbon may be skewing the overall result. As the PRIA itself states, the full "results of each model run" are needed to "better understand how the results vary across scenarios." The frequency distribution chart also gives no information on the runs conducted at a 2.5% discount rate, and dockets contain none of the promised information on the methodology for calculating the social cost of methane and nitrous oxide.

For all these reasons, incorporating the PRIA by reference fails to provide the complete context necessary for readers to understand the scale of the climate damages that will be caused by the proposed action, and indeed will create confusion among readers. Agencies are only supposed to

---

[41] PRIA at 1102.

incorporate material by reference if they can do so "without impeding agency and public review of the action."[42] Given the significant confusion that this incorporation by reference has caused, NHTSA must monetize climate damages directly within the final EIS and not through incorporate by reference.

The rest of this section further explains why monetizing climate damages is required by NEPA.

Monetizing Climate Damages Fulfills the Obligations and Goals of NEPA

When a project has climate consequences that must be assessed under NEPA, monetizing the climate damages fulfills an agency's legal obligations under NEPA in ways that simple quantification of tons of greenhouse gas emissions cannot. NEPA requires "hard look" consideration of beneficial and adverse effects of each alternative option for major federal government actions. The U.S. Supreme Court has called the disclosure of impacts the "key requirement of NEPA," and held that agencies must "consider and disclose the *actual environmental effects*" of a proposed project in a way that "brings those effects to bear on [the agency's] decisions."[43] Courts have repeatedly concluded that an environmental impact statement must disclose relevant climate effects.[44] NEPA requires "a reasonably thorough discussion of the significant aspects of the probable environmental consequences," to "foster both informed decisionmaking and informed public participation."[45] In particular, "[t]he impact of greenhouse gas emissions on climate change is precisely the kind of cumulative impact analysis that NEPA requires," and it is arbitrary to fail to "provide the necessary contextual information about the cumulative and incremental environmental impacts."[46] Furthermore, the analyses included in environmental assessments and impact statements "cannot be misleading."[47] An agency must provide sufficient informational context to ensure that decisionmakers and the public will not misunderstand or overlook the magnitude of a proposed action's climate risks compared to the no action alternative. As this section explains, by only quantifying the volume of greenhouse gas emissions, agencies fail to assess and disclose the actual climate consequences of an action and misleadingly present information in ways that will cause decisionmakers and the public to overlook important climate consequences. Using the social cost of greenhouse gas metrics to monetize climate damages fulfills NEPA's legal obligations in ways that quantification alone cannot.

---

[42] 40 C.F.R. § 1502.21.

[43] *Baltimore Gas & Elec. Co. v. Natural Res. Def. Council*, 462 U.S. 87, 96 (1983) (emphasis added); *see also* 40 C.F.R. § 1508.8(b) (requiring assessment of the "ecological," "economic," "social," and "health" "*effects*") (emphasis added).

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

[45] *Ctr. for Biological Diversity*, 538 F.3d at 1194 (citations omitted).

[46] *Id.* at 1217.

[47] *High Country Conservation Advocates v. U.S. Forest Service*, 52 F. Supp. 3d 1174, 1182 (D. Colo. 2014); *accord. Johnston v. Davis*, 698 F.2d 1088, 1094-95 (10th Cir. 1983) (disapproving of "misleading" statements resulting in "an unreasonable comparison of alternatives"); *Hughes River Watershed Conservancy v. Glickman*, 81 F.3d 437, 446 (4th Cir. 1996) ("For an EIS to serve these functions" of taking a hard look and allowing the public to play a role in decisionmaking, "it is essential that the EIS not be based on misleading economic assumptions"); *see also Sierra Club v. Sigler*, 695 F.2d 957, 979 (5th Cir. 1983) (holding that an agency's "skewed cost-benefit analysis" was "deficient under NEPA"); *see generally Bus. Roundtable v. SEC*, 647 F.3d 1144, 1148-49 (D.C. Cir. 2011) (criticizing an agency for "inconsistently and opportunistically fram[ing] the costs and benefits of the rule" and for "fail[ing] adequately to quantify the certain costs or toe explain why those costs could not be quantified").

NHTSA Must Assess Actual Incremental Climate Impacts, Not Just the Volume of Emissions

The tons of greenhouse gases emitted by a project are not the "actual environmental effects" under NEPA. Rather, the actual effects and relevant factors are the incremental climate impacts caused by those emissions, including:[48]

- property lost or damaged by sea-level rise, coastal storms, flooding, and other extreme weather events, as well as the cost of protecting vulnerable property and the cost of resettlement following property losses;
- changes in energy demand, from temperature-related changes to the demand for cooling and heating;
- lost productivity and other impacts to agriculture, forestry, and fisheries, due to alterations in temperature, precipitation, CO_2 fertilization, and other climate effects;
- human health impacts, including cardiovascular and respiratory mortality from heat-related illnesses, changing disease vectors like malaria and dengue fever, increased diarrhea, and changes in associated pollution;
- changes in fresh water availability;
- ecosystem service impacts;
- impacts to outdoor recreation and other non-market amenities; and
- catastrophic impacts, including potentially rapid sea-level rise, damages at very high temperatures, or unknown events.

Even in combination with a general, qualitative discussion of climate change, by calculating only the tons of greenhouse gases emitted or a percent comparison to sectoral or national emissions, an agency fails to meaningfully assess the actual incremental impacts to property, human health, productivity, and so forth.[49] An agency therefore falls short of its legal obligations and statutory objectives by focusing just on volume estimates. Similarly, courts have held that just quantifying the acres of timber to be harvested or the miles of road to be constructed does not constitute a "description of *actual* environmental effects," even when paired with a qualitative "list of environmental concerns such as air

---

[48] These impacts are all included to some degree in the three integrated assessment models (IAMs) used by the IWG (namely, the DICE, FUND, and PAGE models), though some impacts are modeled incompletely, and many other important damage categories are currently omitted from these IAMs. *Compare* Interagency Working Group on the Social Cost of Carbon, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis* at 6-8, 29-33 (2010), https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf [hereinafter 2010 TSD]; *with* Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon* (Cost of Carbon Project Report, 2014), http://costofcarbon.org/files/Omitted_Damages_Whats_Missing_From_the_Social_Cost_of_Carbon.pdf [Hereinafter Howard 2014]. For other lists of actual climate effects, including air quality mortality, extreme temperature mortality, lost labor productivity, harmful algal blooms, spread of West Nile virus, damage to roads and other infrastructure, effects on urban drainage, damage to coastal property, electricity demand and supply effects, water supply and quality effects, inland flooding, lost winter recreation, effects on agriculture and fish, lost ecosystem services from coral reefs, and wildfires, *see* EPA, *Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment* (2017); U.S. Global Change Research Program, *Climate Science Special Report: Fourth National Climate Assessment* (2017); EPA, *Climate Change in the United States: Benefits of Global Action* (2015); Union of Concerned Scientists, *Underwater: Rising Seas, Chronic Floods, and the Implications for U.S. Coastal Real Estate* (2018).

[49] *See High Country*, 52 F. Supp. 3d at 1190 ("Beyond quantifying the amount of emissions relative to state and national emissions and giving general discussion to the impacts of global climate change, [the agencies] did not discuss the impacts caused by these emissions."); *Mont. Envtl. Info. Ctr. v. U.S. Office of Surface Mining*, 274 F. Supp. 3d 1074, 1096–99 (D. Mont. 2017) (rejecting the argument that the agency "reasonably considered the impact of greenhouse gas emissions by quantifying the emissions which would be released if the [coal] mine expansion is approved, and comparing that amount to the net emissions of the United States").

quality, water quality, and endangered species," when the agency fails to assess "the degree that each factor will be impacted."[50]

By monetizing climate damages using the social cost of greenhouse gas metrics, NHTSA can satisfy the legal obligations and statutory goals to assess the incremental and actual effects bearing on the public interest. The social cost of greenhouse gas methodology calculates how the emission of an additional unit of greenhouse gases affects atmospheric greenhouse concentrations, how that change in atmospheric concentrations changes temperature, and how that change in temperature incrementally contributes to the above list of economic damages, including property damages, energy demand effects, lost agricultural productivity, human mortality and morbidity, lost ecosystem services and non-market amenities, and so forth.[51] The social cost of greenhouse gas tool therefore captures the factors that actually affect public welfare and assesses the degree of impact to each factor, in ways that just estimating the volume of emissions cannot.

Climate Damages Depend on Stock and Flow, But Volume Estimates Only Measure Flow

The climate damage generated by each additional ton of greenhouse gas emissions depends on the background concentration of greenhouse gases in the global atmosphere. Once emitted, greenhouse gases can linger in the atmosphere for centuries, building up the concentration of radiative-forcing pollution and affecting the climate in cumulative, non-linear ways.[52] As physical and economic systems become increasingly stressed by climate change, each marginal additional ton of emissions has a greater, non-linear impact. The climate damages generated by a given amount of greenhouse pollution is therefore a function not just of the pollution's total volume but also the year of emission, and with every passing year an additional ton of emissions inflicts greater damage.[53]

As a result, focusing just on the volume or rate of emissions is insufficient to reveal the incremental effect on the climate. The change in the rate of emissions (flow) must be assessed given the background concentration of emissions (stock). A percent comparison to national emissions is perhaps even more misleading. A project that adds, for example, 23 million additional tons per year of carbon dioxide would have contributed to 0.43% of total U.S. carbon dioxide emissions in the year 2012.[54] In the year 2014, that same project with the same carbon pollution would have contributed to just 0.41% of total U.S. carbon dioxide emissions—a seemingly smaller relative effect, since the total amount of U.S. emissions increased from 2012 to 2014.[55] However, because of rising background concentrations of global greenhouse gas stock, and because of growing stresses in physical and economic systems, the marginal climate damages per ton of carbon dioxide (as measured by the social cost of carbon) increased from $33 in 2012 to $35 in 2014 (in 2007$).[56] Consequently, those 23 million additional tons would have caused marginal climate damages costing $759 million in the year 2012, but by 2014 that same 23 million tons would have caused $805 million in climate damages. To summarize: the percent comparison to national emissions misleadingly implied that a project adding 23 million more tons of carbon dioxide

---

[50] *Klamath-Siskiyou Wildlands Ctr. v. Bureau of Land Mgmt.*, 387 F.3d 989, 995 (9th Cir. 2004) ("A calculation of the total number of acres to be harvested in the watershed is . . . not a sufficient description of the actual environmental effects that can be expected from logging those acres."); *see also Oregon Natural Res. Council v. Bureau of Land Mgmt.*, 470 F.3d 818 (9th Cir. 2006).

[51] 2010 TSD, *supra* note 48, at 5.

[52] Carbon dioxide also has cumulative effects on ocean acidification, in addition to cumulative radiative-forcing effects.

[53] *See* 2010 TSD, *supra* note 48, at 33 (explaining that the social cost of greenhouse gas estimates grow over time).

[54] Total U.S. carbon dioxide emissions in 2012 were 5,366.7 million metric tons (for all greenhouse gases, emissions were 6,529 MMT CO2 eq). *See* EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016* at ES-6, tbl. ES-2 (2018).

[55] Total U.S. carbon dioxide emissions in 2014 were 5,568.8 million metric tons (and for all greenhouse gases, 6,763 MMT CO2 eq.) *Id.*

[56] 2016 TSD, supra note 22.

would have a relatively less significant effect in 2014 than in 2012, whereas monetizing climate damages would accurately reveal that the emissions in 2014 were much more damaging than the emissions in 2012—almost $50 million more.

Capturing how marginal climate damages change as the background concentration changes is especially important because NEPA requires assessing both present and future impacts.[57] Different project alternatives can have different greenhouse gas consequences over time. Most simply, different alternatives could have different start dates or other consequential changes in timing. For example, Alternative 5 has a higher minimum standard for domestic passenger cars for MY 2021 than Alternatives 6 and 7 do, but a lower standard for subsequent model years,[58] and the associated emissions will have different climate effects in early years than in later years. For the reasons explained above, calculating volumes or percentages is insufficient to accurately compare the climate damages of project alternatives with varying greenhouse gas emissions over time.

By factoring in projections of the increasing global stock of greenhouse gases as well as increasing stresses to physical and economic systems, the social cost of greenhouse gas metrics enable accurate and transparent comparisons of projects with varying greenhouse gas emissions over time.

Monetization Provides the Required Informational Context that Volume Estimates Lack

NEPA requires sufficient informational context. Yet without proper context, numbers like a 60 MMTCO$_2$e increase in year 2040,[59] or an increase of global emissions of 0.15%,[60] or a temperature increase of 0.003 degrees,[61] will be wrongly misinterpreted by people as meaningless, as zero. Indeed, in a country of over 300 million people and over 6.5 billion tons of annual greenhouse gas emissions, it is far too easy to make highly significant effects appear relatively "miniscule." For example, presenting all weather-related deaths as less than 0.1% of total U.S. deaths makes the risk of death by weather event sound trivial, but in fact that figure represents over 2,000 premature deaths per year[62]—hardly an insignificant figure.[63]

Economic theory explains why monetization is a much better tool than volume estimates or percent comparisons to provide the necessary contextual information on climate damages. For example, many decisionmakers and interested citizens would wrongly reduce down to zero the climate risks associated with a 0.15% increase in global emissions, simply due to the leading zero before the decimal in that percentage. As Professor Cass Sunstein has explained—drawing from the work of recent Nobel laureate economist Richard Thaler—a well-documented mental heuristic called "probability neglect" causes people to irrationally reduce small probability risks entirely down to zero.[64] People have significant

---

[57] NEPA requires agencies to weigh the "relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity," as well as "any irreversible and irretrievable commitments of resources." 42 U.S.C. § 4332(2)(C).

[58] PRIA at 167.

[59] DEIS appendix page D-19 (comparing total GHGs in Alt. 0 versus Alt. 1).

[60] DEIS at S-14.

[61] DEIS at S-15.

[62] *Compare* Nat'l Ctr. for Health Stat., Ctrs. for Disease Control & Prevention, *Death Attributed to Heat, Cold, and Other Weather Events in the United States, 2006-2010* at 1 (2014) (reporting about 2000 weather-related deaths per year) *with* Nat'l Ctr. for Health Stat., *Deaths and Mortality*, https://www.cdc.gov/nchs/fastats/deaths.htm (reporting about 2.7 million U.S. deaths per year total).

[63] The public willingness to pay to avoid mortality is typically estimated at around $9.6 million (in 2016$). E.g., 83 Fed. Reg. 12,086, 12,098 (Mar. 19, 2018) (U.S. Coast Guard rule using the Department of Transportation's value of statistical life in a recent analysis of safety regulations). Losing 2,000 lives prematurely to weather-related events is equivalent to a loss of public welfare worth over $19 billion per year.

[64] Cass R. Sunstein, *Probability Neglect: Emotions, Worst Cases, and Law*, 112 Yale L. J. 61, 63, 72 (2002).

"difficulty understanding a host of numerical concepts, especially risks and probabilities."[65] Reducing a cumulative increase of 7400 $MMTCO_2$ down to 0.15% of global emissions misleadingly makes the climate impacts appear vanishingly small. By comparison, by applying the social cost of carbon dioxide (about $72 per ton for year 2040 emissions in 2017$[66]), decisionmakers and the public can readily comprehend that a 60 million ton increase of carbon dioxide emitted just in the year 2040 will generate over $4 billion in climate damages.[67]

Similarly, many people will be unable to distinguish the significance of project alternatives or scenario analyses with different emissions: for example, 580 million metric tons versus 582 million metric tons.[68] As the Environmental Protection Agency's website explains, "abstract measurements" of so many tons of greenhouse gases can be rather inscrutable for the public, unless "translat[ed] . . . into concrete terms you can understand."[69] Abstract volume estimates fail to give people the required informational context due to another well-documented mental heuristic called "scope neglect." Scope neglect, as explained by Nobel laureate Daniel Kahneman, among others, causes people to ignore the size of a problem when estimating the value of addressing the problem. For example, in one often-cited study, subjects were unable to meaningfully distinguish between the value of saving 2,000 migratory birds from drowning in uncovered oil ponds, as compared to saving 20,000 birds.[70]

Scope neglect means many decisionmakers and members of the public would be unable to meaningfully distinguish between the climate risks of 582 million metric tons of carbon emissions versus the climate risks of 580 million metric tons. While decisionmakers and the public certainly can discern that one number is higher, without any context it may be difficult to weigh the relative magnitude of the climate risks. In contrast, the different climate risks would have been readily discernible through application of the social cost of greenhouse gas metrics. In this example, while the difference between 582 million metric tons under the proposed action versus 580 million metric tons under the no action alternative may seem trivial, in fact those 2 million extra tons emitted in a single year will inflict over $100 million in climate damages. (Again, because NHTSA's quantification of upstream and downstream emissions is likely a severe underestimate, the real climate consequences between the alternatives would likely be much greater. NHTSA's numbers are just used here for illustrative purposes.)

In general, non-monetized effects are often irrationally treated as worthless.[71] On several occasions, courts have struck down administrative decisions for failing to give weight to non-monetized effects.[72] Most relevantly, in *Center for Biological Diversity v. NHTSA*, the U.S. Court of Appeals for the Ninth Circuit found it arbitrary and capricious to give zero value "to the most significant benefit of more stringent [fuel economy] standards: reduction in carbon emissions."[73] Monetizing climate damages

---

[65] Valerie Reyna & Charles Brainerd, *Numeracy, Ratio Bias, and Denominator Neglect in Judgments of Risk and Probability*, 18 Learning & Individual Differences 89 (2007).

[66] 2016 TSD, *supra* note 22.

[67] This calculation in no way accepts NHTSA's quantification of only 60MMTCO2e for the year 2040 as accurate or complete. In a proper cost-benefit analysis, future costs and benefits would be discounted to present value.

[68] DEIS appendix page D-19 (comparing GHGs in year 2020 for Alt. 0 versus Alt. 1). Use of these numbers in no way accepts NHTSA's calculations as accurate or complete.

[69] EPA, *Greenhouse Gas Equivalencies Calculator*. *Available at* https://web.archive.org/web/20180212182940/ https:/www.epa.gov/energy/greenhouse-gas-equivalencies-calculator (last updated Sept. 2017) ("Did you ever wonder what reducing carbon dioxide (CO_2) emissions by 1 million metric tons means in everyday terms? The greenhouse gas equivalencies calculator can help you understand just that, translating abstract measurements into concrete terms you can understand.").

[70] Daniel Kahneman et al., *Economic Preferences or Attitude Expressions? An Analysis of Dollar Responses to Public Issues*, 19 J. Risk & Uncertainty 203, 212-213 (1999).

[71] Richard Revesz, *Quantifying Regulatory Benefits*, 102 Cal. L. Rev. 1424, 1434-35, 1442 (2014).

[72] *See id.* at 1428, 1434.

[73] 538 F.3d at 1199.

provides the informational context required by NEPA, whereas a simple tally of emissions volume and rote, qualitative, generic description of climate change are misleading and fail to give the public and decisionmakers the required information about the magnitude of discrete climate effects.[74]

For all the above reasons, NHTSA must monetize climate damages directly in the final EIS, rather than relying on the misleading and incomplete incorporation by reference of the PRIA.

That said, regardless of where NHTSA monetizes climate damages, it must do so using the best available estimates based on the most recent science and economic literature. The values of the social cost of greenhouse gases currently used in the PRIA fall well short of that standard. In particular, NHTSA's approaches to the issues of global versus domestic climate damages, discount rates, and treatment of uncertainty are inconsistent with best practices and the most recent science and economic literature, and result in severely undercounting the social cost of greenhouse gases. NHTSA instead should use the 2016 estimates from the Interagency Working Group for the social cost of carbon, methane, and nitrous oxide. The next several sections explain why.

III. Executive Order 13,783 Does Not Bar Agencies from Following the IWG's Best Practices

The PRIA concludes that a new "interim" social cost of carbon estimate became necessary following Executive Order 13,783.[75] 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.[76] 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."[77] Consequently, while NHTSA 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.[78]

The Executive Order does not prohibit agencies from relying on the same choice of models as the IWG, the same inputs and assumptions as the IWG, the same statistical methodologies as the IWG, or the same ultimate values as derived by the IWG. To the contrary, because the Executive Order requires consistency with Circular A-4, as agencies follow the Circular's standards for using the best available data and methodologies, they will necessarily choose similar data, methodologies, and estimates as the IWG, since the IWG's work continues to represent the best available estimates.[79] 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.

---

[74] *See* 42 U.S.C. § 4332(2)(B) (requiring agencies to "identify and develop methods and procedures . . . which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations").

[75] PRIA at 1062.

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

[77] *Id.* § 5(c).

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

[79] 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).

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[80] should be used in regulatory analyses and environmental impact statements.

IV. NHTSA Must Rely on a Global Estimate of the Social Cost of Greenhouse Gases

The proposed rule claims that "both domestic and global perspectives were considered" on "the cost of CO2 emissions and resulting climate damages," and refers the reader to "Chapter 9 of the Regulatory Impact Analysis."[81] That statement is false. While Chapter 9 does not mention the social cost of carbon, Chapter 8 and its Appendix make clear that the PRIA focuses exclusively on a domestic-only value of the social cost of carbon, claiming that such a perspective is required by Executive Order 13,783 and Circular A-4.[82] To the contrary, not only is it inconsistent with Circular A-4 and best economic practices to fail to estimate the global damages of U.S. greenhouse gas emissions in regulatory analyses, but existing methods for estimating a "domestic-only" value—including NHTSA's approach—are unreliable, incomplete, and inconsistent with Circular A-4. NHTSA's domestic-only estimate fails to use models 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.

NHTSA never explains why the proposed rule claims that the "global perspective" was considered when in fact the PRIA never uses a global estimate. Notably, an e-mail included in EPA's rulemaking docket entitled "SCC Language for Light Duty" refers to "on-going discussions regarding the global estimate," and EPA transmitted to the Office of Management and Budget a spreadsheet listing global estimates.[83] Nevertheless, neither the DEIS nor the PRIA explains why NHTSA failed to use the global numbers.

A Global Estimate of Climate Damages Is Required by NEPA

NEPA contains a provision on "International and National Coordination of Efforts" that broadly requires that "all agencies of the Federal Government *shall* . . . recognize the worldwide and long-range character of environmental problems."[84] Using a global social cost of greenhouse gases to analyze and set policy fulfills these instructions. Furthermore, the Act requires agencies to, "where consistent with the foreign

---

[80] *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). *See also* Tamma Carleton et al., *Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits* (Becker Friedmand Inst. Working Paper No. 2018-51) (finding substantial willingness to pay to avoid just climate-related mortalities).

[81] 83 Fed. Reg. at 43,106.

[82] PRIA 1062-63; 1063 ("adopting a domestic perspective in our central analysis"); 1084 (showing "economic damages from future changes in the global climate [that] will be borne throughout the U.S. economy"); 1098 (describing the "methodology used to develop interim domestic SC-CO2 estimates"); 1101 (describing sensitivity analysis but not mentioning a global SCC sensitivity analysis); 1531 (same).

[83] https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-0453 (see the PDFs entitled "Social cost of carbon email exchange between EPA and OMB, July 16, 2018" and "Social cost of carbon spreadsheet provided by EPA to OMB, July 16, 2018").

[84] 42 U.S.C. § 4332(2)(f) (emphasis added). In the Notice of Inquiry, FERC writes that cumulative impacts "must occur within the same geographic area and same time period in which the proposed project's impacts will occur." 83 Fed. Reg. at 18,023. Note that, for purposes of global climate change, the relevant geographic area is the earth, and the relevant time period is the foreseeable future.

policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind's world environment."[85] By continuing to use the global social cost of greenhouse gases to spur reciprocal foreign actions, federal agencies "lend appropriate support" to the NEPA's goal of "maximize[ing] international cooperation" to protect "mankind's world environment." Focusing solely on a domestic-only metric fails to fulfill these requirements of NEPA.

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

Since 2010, and including some recent agency actions under the Trump administration,[86] federal agencies routinely based their regulatory decision and NEPA reviews on global estimates of the social cost of greenhouse gases. Though agencies often also disclosed a "highly speculative" range that tried to capture exclusively U.S. climate costs, emphasis on a global value 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.[87]

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.[88] 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."[89] 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

---

[85] 42 U.S.C. § 4332(2)(f); *see also Environmental Defense Fund v. Massey*, 986 F.2d 528, 535 (D.C. Cir. 1993) (confirming that Subsection F is mandatory); Natural Resources Defense Council v. NRC, 647 F.2d 1345, 1357 (D.C. Cir. 1981) ("This NEPA prescription, I find, looks toward cooperation, not unilateral action, in a manner consistent with our foreign policy."); *cf.* COUNCIL ON ENVIRONMENTAL QUALITY, GUIDANCE ON NEPA ANALYSIS FOR TRANSBOUNDARY IMPACTS (1997), *available at* http://www.gc.noaa.gov/documents/transguide.pdf; Exec. Order No. 12,114, *Environmental Effects Abroad of Major Federal Actions*, 44 Fed. Reg. 1957 §§ 1-1, 2-1 (Jan. 4, 1979) (applying to "major Federal actions . . . having significant effects on the environment outside the geographical borders of the United States," and enabling agency officials "to be informed of pertinent environmental considerations and to take such considerations into account . . . in making decisions regarding such actions").

[86] 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). Note that the final EIS (August 2018) for the Liberty Development Project does change from the global estimate to the indefensible domestic-only estimate.

[87] *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).

[88] 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).

[89] 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.

> 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.[90]

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.[91]

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,"[92] suggesting that in some circumstances it is appropriate for the analysis to be global. For example, in the past NHTSA also sometimes 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.[93]

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.[94] 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.[95] Moreover, if all countries reverted to a domestic-only SCC, U.S. industry would be placed at a competitive disadvantage internationally, since a

---

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

[91] Circular A-4 at 3.

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

[93] *See* Howard & Schwartz, *supra* note 87, at 268-69.

[94] *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.").

[95] 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

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.[96]

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.[97] 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.[98] For example, until recently Canada and Mexico had explicitly borrowed the U.S. estimates of a global social cost of carbon to set their own fuel efficiency standards.[99] For the United States to now depart from this collaborative dynamic by reverting to a domestic-only estimate would undermine the country's long-term interests and could jeopardize emissions reductions underway in other countries, which are already benefiting the United States. Indeed, there is some circumstantial evidence that tit-for-tat defections may be underway. Until September 2017, Mexico explicitly borrowed the IWG's estimates of the social cost of carbon for use in its own regulatory impact analyses;[100] by October 2017, the U.S. Bureau of Land Management and EPA had begun using an interim domestic-only estimate of the social cost of carbon;[101] in a July 2018 regulatory impact analysis for a rule reducing methane emissions from the oil and gas sector, Mexico seems to abandon the IWG numbers in favor of its own valuation based solely on the cost of Mexican climate-related weather disasters.[102] If other countries follow the lead of the United States and base their climate policies without weighing the full global externalities of their emissions, the United States will suffer.

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. In particular, the Department of Energy always includes a chapter on a domestic-only value of carbon emissions in the economic analyses supporting its energy efficiency standards; EPA has also often disclosed similar estimates.[103] 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, NHTSA should have estimated, and used in its primary analysis, the global social cost of greenhouse gases.

---

[96] Other flawed methods for calculating domestic-only SCCs, like proportion of worldwide shoreline, would also result in a higher domestic SCC for the U.S. than for most other countries.

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

[98] *See* Howard & Schwartz, *supra* note 87, at Appendix B.

[99] *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).

[100] www.cofemersimir.gob.mx/expediente/20708/mir/43430/anexo/3805458 ("Para monetizar esta reducción de emisiones, se utilizó como base el concepto de costo social del carbón (CSC), publicado para su uso en los análisis de impacto normativo realizado por las agencias del gobierno de los Estados Unidos[10]. [Fn10: Véase el documento "Social Cost of Carbon for Regulatory Impact Analysis". Interagency Working Group on Social Cost of Carbon (IWGSCC), United States Government. 2011.]").

[101] https://www.regulations.gov/document?D=BLM-2017-0002-0002; https://www.epa.gov/sites/production/files/2017-11/documents/oilgas_memo_proposed-stay_2017-10.pdf

[102] http://www.cofemersimir.gob.mx/mirs/45614.

[103] Howard & Schwartz, *supra* note 87, at 220-21.

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."[104] 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.[105]

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.[106] 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.[107] 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. consumers faced higher prices for many electronic goods, from computers to cameras.[108] A recent economic study explored how heat stress-induced reductions in productivity worldwide will ripple through the interconnected global supply network.[109] 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.[110]

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.[111] Such

---

[104] Circular A-4 at 18.

[105] This section draws heavily from Howard & Schwartz (2017), *supra* note 87, and includes passages taken directly from that article (which was written by co-authors of these comments).

[106] Indeed, the integrated assessment models used to develop the global SCC estimates largely ignore inter-regional costs entirely. *See* Howard 2014, *supra* note 48. 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).

[107] *See* Freeman & Guzman, *supra* note 106, at 1563-93.

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

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

[110] *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).

[111] 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).

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.[112] Besides threats to U.S. military installations and operations at home and abroad from flooding, storms, extreme heat, and wildfires,[113] Secretary of Defense Mattis has explained that "Climate change is impacting stability in areas of the world where our troops are operating today."[114] The National Defense Authorization Act for Fiscal Year 2018 found that "climate change is a direct threat to the national security of the United States" and that "[a]s global temperature rise, droughts and famines can lead to more failed states, which are breeding grounds of extremist and terrorist organizations."[115] 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."[116] As an example of the climate-security-migration nexus, prolonged drought in Syria likely exacerbated the social and political tensions that erupted into an ongoing civil war,[117] which has triggered an international migration and humanitarian crisis.[118]

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.[119] Though surely 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.

---

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

[113] 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).

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

[115] H.R. 2810-75, § 335(a)(9), (b)(1).

[116] 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.")

[117] *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).

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

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

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."[120] 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 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.[121]

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.[122] Any attempt to estimate a domestic-only value of the social cost of greenhouse gases must include such indirect effects from reciprocal foreign actions.[123]

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.

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."[124] 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."[125] 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.

U.S. citizens have economic and other interests abroad that are not fully reflected in the U.S. share of global GDP. As explained above, GDP does not reflect significant U.S. ownership interests in foreign businesses, properties, and other assets, as well as consumption abroad including tourism, or even the 8 million Americans living abroad.

---

[120] Circular A-4 at 26.

[121] Howard & Schwartz, *supra* note 87, at 232-37 (citing acknowledgement of this phenomenon by both the Bush administration and the Obama administration).

[122] 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

[123] 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).

[124] Circular A-4 at 22.

[125] *Id.*

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."[126] 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.[127] Though the methodologies for calculating existence value remain controversial,[128] U.S. citizens certainly have a non-zero willingness to pay to protect rainforests, charismatic megafauna like pandas, 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.[129] 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.[130]

NHTSA Implicitly Counts Global Cost Savings While Ignoring Global Climate Effects: The inextricable interconnectedness of global economic interests is apparent from the fact that NHTSA never attempts to separate out cost savings to foreign interests. Yet because all industry compliance costs ultimately fall on the owners, employees, or customers of regulated and affected firms, a significant portion of the proposed action's alleged cost savings would ultimately accrue to foreign owners and foreign customers of manufacturers. NHTSA never distinguishes between those cost savings that would accrue to foreign entities as opposed to U.S. citizens or U.S. entities, and so its calculations of cost savings implicitly include all global effects.

For example, NHTSA's calculations of compliance costs for the CAFE standards make the simplifying assumption that manufacturers will be able to pass through all technology costs to U.S. consumers. In reality, NHTSA acknowledges that manufacturers will not always be able to pass costs directly to the buyer of the specific car associated with those costs. Instead, either the manufacturer's profits will decline to the detriment of its investors, or else the manufacturer will recover those extra costs by charging higher prices for its other models.[131] In particular, NHTSA assumes that the buyers of electric vehicles are not willing to pay the full additional technology costs, and the difference must be borne by investors or other customers. There is no reason to think that when a manufacturer tries to recover lost profits by increasing the price of other models, it will only affect prices of vehicles sold to U.S. citizens as opposed to also affecting the prices of vehicles either sold abroad in foreign markets or sold

---

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

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

[128] *Id.* at 129.

[129] *See* Arden Rowell, *Foreign Impacts and Climate Change*, 39 Harvard Environmental Law Rev. 371 (2015); David A. Dana, *Valuing Foreign Lives and Civilizations in Cost-Benefit Analysis: The Case of the United States and Climate Change Policy* (Northwestern Faculty Working Paper 196, 2009), http://scholarlycommons.law.northwestern.edu/cgi/viewcontent.cgi?article=1195&context=facultyworkingpapers (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).

[130] 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).

[131] 83 Fed. Reg. at 43,085.

domestically to foreign-owned businesses that operate fleets in the United States. Putting aside any problems with NHTSA's assumptions about EV buyers' willingness to pay, it is clear that when NHTSA reports that its proposed action will save U.S. purchasers of new cars $255.6 billion,[132] some significant but undefined portion of that amount will actually accrue to: foreign shareholders of manufacturers, foreign customers of vehicles sold abroad, and foreign entities purchasing vehicles in the United States, including investors of businesses that operate fleets in the United States. Nevertheless, NHTSA fully counts all these global cost savings and lumps them together with domestic cost savings.

NHTSA does not, for instance, distinguish between savings that might accrue to the investors of Japan-headquartered Toyota Motors as compared to savings that might accrue to the investors of U.S.-headquartered General Motors. And of course, both manufacturers are publicly traded companies with significant non-U.S. investors. Economy-wide, between 20-30% of U.S. stocks and 35% of U.S. corporate debt are held by foreigners.[133] Similarly, both manufacturers have customers not just in the United States, but across the world. Finally, foreign entities may purchase cars and light trucks within the U.S. marketplace. For instance, Agrium's retail agricultural supply business operates one of the largest corporate fleets of pickup trucks and cargo vans operating in the United States;[134] Agrium is a privately-owned company based in Canada.[135] In sum, a significant portion of the regulatory effects passing through regulated companies would ultimately be experienced by foreign owners or foreign customers. Yet despite counting compliance costs in full regardless of whether they are accrued inside or outside of the United States, NHTSA ignores legitimate effects of climate change occurring outside U.S. borders. This inconsistent treatment of costs and benefits is patently arbitrary and capricious.

NHTSA also takes a global perspective on the monopsony effect even while insisting it must take a domestic perspective on climate change. NHTSA argues that even though relaxing the CAFE standards will increase U.S. fuel demand, the resulting increase in the global fuel price will not result in a monopsony cost effect for U.S. consumers. NHTSA's reason is that the United States is increasingly self-sufficient with respect to its supply of gasoline and will become a net exporter within the decade.[136] As a result, NHTSA concludes that any increase in global fuel price resulting from the proposed action will result in a transfer from U.S. consumers to domestic producers, and not to foreign producers, resulting in $0 in monopsony costs from the domestic perspective.

This assumption on monopsony is wrong for several reasons, and is inconsistent with the approach NHTSA takes on climate damages. Even assuming that the United States will soon become a net exporter of petroleum, there are still foreign suppliers in the meantime, and there would continue to be foreign suppliers even after the United States achieves net-export status. Petroleum prices are set in a global market. The assumption that all U.S. consumers purchase their fuel from domestic producers also runs counter to NHTSA's wildly different assumptions regarding upstream emissions, where the analysis imagined that 95% of increased fuel consumption through the year 2050 would come either from

---

[132] 83 Fed. Reg. 43,062. Using this figure in no way endorses NHTSA's calculations of cost savings as accurate.

[133] 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.

[134] FleetTrax, The Largest Fleets in America, https://fleettrax.net/largest-fleets-america/ ("Agrium also owns and operates a staggering 7,627 pickup trucks and cargo vans—a record number for this list."; reporting on "the largest private fleets operating in the United States"); *see also* Transport Topics, 2017 Essential Financial and Operating Information for the 100 Largest Private Carriers in North America https://www.ttnews.com/top100/private/2017?order=field_pickups_cargo_vans&sort=desc. Presumably Agrium purchases at least some of its new light trucks from manufacturers in the U.S. market subject to CAFE standards.

[135] Yahoo Finance, Agrium, https://finance.yahoo.com/company/agrium?h=eyJlIjoiYWdyaXVtIiwibiI6IkFncml1bSJ9&.tsrc=fin-srch. Agrium's parent company is the Canadian-based Nutrien.

[136] PRIA at 114; 83 Fed. Reg. 43,067.

imported gasoline or imported crude.[137] If the assumptions from the upstream analysis were applied to the monopsony analysis, the price increase resulting from the CAFE rollbacks would result in a hefty transfer from U.S. consumers to foreign producers. Regardless, there are significant foreign shareholders of even "domestic" producers. The Government Pension Fund of Norway, for instance, owned over seven million shares in ConocoPhillips as of 2017,[138] and in general there is significant foreign direct investment in U.S. fossil fuel extraction.[139] Even within a transfer from a U.S. consumer to a nominally domestic producer, some of the distributional benefits accrue outside the United States.

Yet NHTSA ignores all this and instead assumes $0 in monopsony costs. Essentially, NHTSA is taking a global perspective on the monopsony effect, counting any financial transfers from a U.S. consumer to a foreign entity as a wash. Despite this global approach to monopsony costs, NHTSA inconsistently insists on taking a domestic-only perspective on climate damages. Again, this inconsistent treatment of effects is patently arbitrary and capricious.

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.[140]

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),"[141] which, in the year 2006 when the rule was issued, would have been consistent with estimates of a global social cost of carbon.[142] 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.[143]

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

---

[137] *See supra* on upstream emissions; *see also* PRIA at 1073, which assumes for the purposes of calculating energy shock costs that 75% of increased consumption will come from increased imports—again, that number is very different from 0%.

[138] See Morningstar, ConocoPhillips Major Shareholders (last visited Dec. 12, 2017), http://investors.morningstar.com/ownership/shareholders-major.html?t=COP&region=usa&culture=en-US&ownerCountry=USA.

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

[140] 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").

[141] 538 F.3d at 1199, 1201.

[142] *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).

[143] 832 F.3d at 679.

appears in a letter published in a recent issue of *The Review of Environmental Economics and Policy*, co-authored by Nobel laureate Kenneth Arrow.[144]

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

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.[145] 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.[146]

Neither the existing IAMs nor a share of global GDP are appropriate bases for calculating a domestic-only estimate. The IAMs were never designed to calculate a domestic SCC, since a global SCC is the economic efficient value. FUND, like other IAMS, includes some simplifying assumptions: of relevance, FUND and the other IAMs are not able to capture the adverse effects that the impacts of climate change in other countries will have on the United States through trade linkages, national security, migration, and other forces.[147] 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.[148] 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."[149] GDP therefore does not reflect significant U.S. ownership interests in foreign businesses, properties, and other assets, as well as consumption abroad including tourism,[150] or even the 8 million Americans living abroad.[151] 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

---

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

[145] 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).

[146] *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").

[147] *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.

[148] 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).

[149] 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).

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

[151] 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.

its scope not by location but by ownership interests.[152] However, not only has GNI fallen out of favor as a metric used in international economic policy,[153] 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.[154] 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.[155]

As a result, in 2015, OMB concluded, along with several other agencies, that "good methodologies for estimating domestic damages do not currently exist."[156] Similarly, the NAS recently concluded that current IAMs cannot accurately estimate the domestic social cost of greenhouse gases, and that estimates based on U.S. share of global GDP would be likewise insufficient.[157] NHTSA even quotes the NAS report's warnings that current IAMs do not model international spillovers or reciprocity[158]—and yet, NHTSA takes no action as a result of that caution against domestic-only estimates. William Nordhaus, the developer of the DICE model who recently won the Nobel Prize in Economics for his work on modeling climate effects,[159] recently cautioned that "regional damage estimates are both incomplete and poorly understood," and "there is little agreement on the distribution of the SCC by region."[160] 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.

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

NHTSA reports that its domestic-only estimates are "calculated directly" from the models FUND and PAGE; for the model DICE, the agencies simply assume that U.S. damages are 10% of global damages.[161] NHTSA thus uses these models in ways they were never designed for—indeed, in ways their designers specifically cautioned against. NHTSA furthermore fails to assess the most up-to-date literature on U.S.

---

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

[153] *Id*.

[154] 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).

[155] 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).").

[156] 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].

[157] 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].

[158] PRIA at 1065 ("The Academies' report also discussed the challenges in developing domestic SC-CO2 estimates, noting that current IAMs do not 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. The Academies 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. More thoroughly estimating a domestic SC-CO2 would therefore need to consider the potential implications of climate impacts on, and actions by, other countries, which also have impacts on the United States.'").

[159] https://www.nobelprize.org/prizes/economic-sciences/2018/nordhaus/facts/

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

[161] PRIA at 1098.

damages and fails to take steps to reflect spillover effects, reciprocal benefits, or U.S. interests beyond our borders. NHTSA's methodology is deeply flawed.

The integrated assessment models used by the agency to calculate the social cost of greenhouse gases 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 greenhouse gases. For example, the models make simplifying assumptions about the extent of heterogeneity in crucial parameters like relative prices and discount rates.[162] The models also simplify or ignore completely global spillovers from trade, migration, and other sources.[163] 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.[164] Global estimates will also generally be more accurate than domestic estimates because aggregation of multiple values reduces the error of the overall estimate.[165]

Examining the individual models used by the agency to calculate the domestic social cost of greenhouse gases 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.[166] 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."[167] 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.[168] Scaling damages by gross domestic product and population will fail to 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.[169] 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.[170] 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

---

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

[163] *See generally* Howard & Schwartz (2017), *supra* note 87.

[164] *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.

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

[166] PRIA at 1098.

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

[168] *Id.* at 10.

[169] 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).

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

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."[171] The model also uses GDP scaling, stating that "other regions lose more or less [output] depending upon their GDP per capita and weights factors."[172] 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.[173] 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."[174] These statements reinforce the conclusion of OMB that "good methodologies for estimating domestic damages do not currently exist."[175]

In conclusion, NHTSA's estimation of the domestic-only social cost of greenhouse gases 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.[176]

V. NHTSA 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. NHTSA now proposes to give equal consideration to estimates calculated at a 7% discount rate, alleging that this is required by Circular A-4.[177] NHTSA is wrong. Not only does use of a 7% discount rate violate NEPA's statutorily required consideration of impacts on future generations, but a 7% rate for 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. "[178] While Circular A-4 tells agencies

---

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

[172] 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.

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

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

[175] OMB 2015 Response to Comments, *supra* 156.

[176] 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").

[177] PRIA 1078.

[178] OMB 2015 Response to Comments, *supra* note 156, at 36.

generally to use a 7% discount rate in addition to lower rates for typical rules,[179] 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.

NEPA Requires Protecting the Needs of Future Generations; a 7% Discount Rate Ignores Those Future Needs

NEPA requires agencies to weigh the "relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity," as well as "any irreversible and irretrievable commitments of resources."[180] That requirement is prefaced with a congressional declaration of policy that explicitly references the needs of future generations:

> The Congress, recognizing the profound impact of man's activity on the interrelations of all components of the natural environment . . . declares that it is the continuing policy of the Federal Government . . . to use all practicable means and measures . . . to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and **future generations** of Americans.[181]

When the Congressional Conference Committee adopted that language, it reported that the first "broad national goal" under the statute is to "fulfill the responsibilities of each generation as trustee of the environment for future generations. It is recognized in this [congressional] statement [of policy] that each generation has a responsibility to improve, enhance, and maintain the quality of the environment *to the greatest extent possible for the continued benefit of future generations*."[182]

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

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."[183] As such, analysis must be "based on the best reasonably obtainable scientific, technical, and economic information available,"[184] and agencies must "***[u]se sound and defensible values*** or procedures to monetize benefits and costs, and ensure that key analytical assumptions are defensible."[185] 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."[186] Based on Circular A-4's

---

[179] 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.").

[180] 42 U.S.C. § 4332(2)(C).

[181] 42 U.S.C. § 4331.

[182] *See* 115 Cong. Rec. 40419 (1969) (emphasis added); *see also* same in S. Rep. No. 91-296 (1969).

[183] Circular A-4 at 3.

[184] *Id.* at 17.

[185] *Id.* at 27.

[186] *Id.* at 3.

criteria, there are numerous reasons why applying a 7% discount rate to climate effects that occur over a 300-year time horizon would be unjustifiable.

First, basing the discount rate on the **consumption rate of interest** is the correct framework for analysis of climate effects; a discount rate based on the private return to capital is inappropriate. Circular A-4 does suggest that 7% should be a "default position" that reflects regulations that primarily displace capital investments; however, the Circular explains that "[w]hen regulation primarily and directly affects private consumption . . . *a lower discount rate is appropriate*."[187] 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,[188] a 7% rate is inappropriate.

NHTSA itself also indicated that, because the main effect of CAFE standards is to change the price of cars—a consumer good—a 3% discount rate is most appropriate. NHTSA indicates that the 7% discount rate is only used in its regulatory impact analysis because there is some uncertainty over whether the compliance costs of CAFE can completely be passed through to buyers instead of affecting manufacturers' investments.[189] Yet, much of the PRIA's conclusions hinges on the assumption that all costs will be passed through from manufacturers to consumers.[190] NHTSA never explains why some uncertainty about the completeness of cost pass-through is so much more important than the considerable uncertainty about long-term discount rates such that it is willing to entertain an inappropriately high discount rate like 7% but fails to consider a declining discount rate framework.

In 2013, OMB called for public comments on the social cost of greenhouse gases. In its 2015 Response to Comment document,[191] 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.[192]

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

---

[187] *Id.* at 33.

[188] "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.

[189] PRIA at 1078.

[190] See supra on global costs.

[191] Note that this document was not withdrawn by Executive Order 13,783.

[192] OMB 2015 Response to Comments, *supra* note 156, at 22.

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."[193] The NAS also explained that a consumption rate of interest is the appropriate basis for a discount rate for climate effects.[194] There is also strong consensus through the economic literature that a capital discount rate like 7% is inappropriate for climate change.[195] Finally, each of the three integrated assessment models upon which the agencies bases their 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.[196] 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."[197]

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.[198] 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***."[199] The NAS makes the same point about discount rates and uncertainty.[200] In fact, as discussed more below and in the technical appendix

---

[193] 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).

[194] NAS Second Report, *supra* note 157, 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).

[195] 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, https://www.regulations.gov/document?D=BLM-2017-0002-16107).

[196] Circular A-4 at 34. *See also* OMB 2015 Response to Comments, *supra* note 156, at 21 ("While most regulatory impact analysis is conducted over a time frame in the range of 20 to 50 years").

[197] Circular A-4 at 36.

[198] *Id*.

[199] *Id.*; *see also* CEA, *supra* note 193, 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)."

[200] NAS Second Report, *supra* note 157, at 27.

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 NHTSA's graph of the frequency distribution of social cost of carbon 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. As Pindyck explains "the possibility of a catastrophic outcome is an essential driver of the [social cost of greenhouse gases]."[201] 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 NHTSA's statutory duty under NEPA 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.[202] A negative social cost of greenhouse gases implies a discount rate so high that society is willing to sacrifice serious impacts to future generations for the sake of small, short-term benefits (such as slightly and temporarily improved fertilization for agriculture). Again, this assumption contravenes NHTSA's statutory responsibilities under NEPA 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."[203] 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.[204] 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.[205]

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."[206] The latest OMB updates to Circular A-94, the document on which Circular A-4 based its discount rates,[207] also show that more up-to-date long-run discount rates are historically low. In the February 2018 update to

---

[201] Pindyck, Robert. 2013. "Climate change policy: What do the models tell us?" Journal of Economic Literature, 51(3), 860-872.

[202] 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%.

[203] 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).

[204] 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.

[205] CEA, *supra* note 193, 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.").

[206] *Id.* at 1.

[207] Circular A-4 at 33.

Circular A-94's discount rates, the OMB found that the real, 30-year discount rate is 0.6 percent,[208] the lowest rate since the OMB began tracking the number.[209] Notably, the OMB also shows that the current real interest rate is negative for maturities less than 10 years.[210]

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[211]—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.[212] Based on current economic data and theory, the most appropriate discount rate for climate change is 3% or lower.

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.[213]

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."[214] 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***.[215]

---

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

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

[210] Circular A-94 Appendix C, *supra* note 208.

[211] Circular A-4 at 41.

[212] 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 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%.

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

[214] *Id.* at 3.

[215] *Id.* at 42.

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. The agencies' selection of a 7% discount rate 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.[216] As the Council of Economic Advisers explained earlier this year, Weitzman and others developed the foundation for a declining discount rate approach, wherein rates start relatively higher for near-term costs and benefits but steadily decline over time according to a predetermined schedule until, in the very long-term, very low rates dominate due to uncertainty.[217] The National Academies of Sciences' report also strongly endorses a declining discount rate approach.[218] Notably, Marten et al., which developed the methodology for the social cost of methane, 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."[219]

One possible schedule of declining discount rates was proposed by Weitzman.[220] 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.[221] Another schedule of declining discount rates has been adopted by the United Kingdom.[222]

---

[216] 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.

[217] CEA, *supra* note 193, 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.").

[218] NAS Second Report, *supra* note 157.

[219] 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.

[220] 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%

[221] 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).

[222] 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%

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. NHTSA is wrong in stating that "additional research and analysis is still needed to develop a methodology for implementing a declining discount rate."[223]

Problems with NHTSA's Use of a 2.5% Discount Rate in a Sensitivity Analysis

The PRIA suggests that a 2.5% discount rate should be used as a sensitivity analysis.[224] Unfortunately, as already discussed above, NHTSA's description of its 2.5% discount rate sensitivity run is incomplete and inapplicable to this proceeding. The description references different estimates of forgone climate benefits "under the rate-based and mass-based scenarios, respectively."[225] There are no rate-based versus mass-based scenarios for the CAFE standards. This language, and likely the associated numbers, was evidentially taken from a different regulatory analysis. It is impossible for the reader to know what portion of the PRIA's description of the 2.5% sensitivity run, if any, is actually applicable to this rulemaking. The impossibility for the reader to understand is compounded by NHTSA's failure to include in the regulatory docket the complete "full set of SC-CO_2 results" as promised.[226]

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 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."[227] 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."[228] 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.[229]

VI. NHTSA Arbitrarily Fails to Follow Prescribed Practices for Dealing with Uncertainty

NHTSA 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.[230] That mere mention of significant uncertainty that could lead to much higher social cost of greenhouse gas estimates hardly satisfies *Circular A-4*'s requirements for

---

[223] PRIA 1102.

[224] PRIA 1102.

[225] PRIA 1102.

[226] PRIA 1101 (promising materials available in the docket); see supra on their unavailability.

[227] NAS Second Report, *supra* note 157, at 78.

[228] *Id.*

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

[230] PRIA 1064.

quantitative treatment of uncertainty. The IWG highlighted a 95th percentile estimate to address uncertainty over catastrophic damages, tipping points, option value, and risk aversion. NHTSA should have done the same, but failed to do so. NHTSA admits that the distributions "have long right tails"[231] and depicts a range of estimates from the 5th to 95th percentiles,[232] but by giving a 5th percentile estimate equal standing with the 95th percentile estimate, NHTSA obscures the significance of low-probability, high-catastrophe outcomes.[233] By failing to give serious treatment to such sensitivity analyses, NHTSA 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.)

Circular A-4's Prescriptions for Uncertainty

Circular A-4 requires thorough treatment of uncertainty around both values and outcomes,[234] and for especially large or complex matters it recommends a formal probabilistic analysis.[235] 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.[236]

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."[237] But if society is risk averse—as is the case with climate change[238]—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."[239] 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."[240]

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.

---

[231] PRIA at 1101.

[232] *Id*.

[233] The 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 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).

[234] 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.

[235] *Id.* at 41.

[236] 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.").

[237] *Id.* at 42.

[238] *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).

[239] 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.

[240] Circular A-4 at 39.

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 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.[241] 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:

---

[241] 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).

- There is no reason to believe the public or the government will be systematically risk seeking with respect to climate change.[242]
- 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 balance, most uncertainties strongly point toward higher, not lower, social cost of greenhouse gas estimates.[243]
- 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.[244] There is little to no support among economic experts to give weight to any estimate lower than the 5% discount rate estimate.[245] 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.[246] 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

---

[242] 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 241, at 3 (citing 2009 survey).

[243] *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.").

[244] *See* Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, *supra* note 80; Howard 2014, *supra* note 48; 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).

[245] 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 241, 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 241, at 18.

[246] 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.").

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, NHTSA 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 the 5th and 95th percentiles, NHTSA 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.

Tellingly, NHTSA's sensitivity analysis files include a spreadsheet that details the reference scenario. That spreadsheet's "emissions cost" tab shows the social cost of carbon numbers that NHTSA used in its analysis from the 2012 rulemaking, with columns for the low estimates (calculated at a 5% discount rate), average estimate (3% discount rate), high estimate (2.5% discount rate) and "very high" (the 95th percentile of the 3% distribution). Those same column headings were copied to list the social cost of carbon estimates used in this proposed action. Under the "very high" column, which had previously served as a placeholder for the 95th percentile estimate treatment of uncertainty, the NHTSA files now simply list the value as $0.

Uncertainty over Climate Damages Points Toward a Higher Social Cost of Greenhouse Gases

NHTSA attempts to call into question the validity of the social cost of greenhouse gas estimates by highlighting the "uncertainty" around climate change. The proposed rule says that greenhouse gases only "theoretically" contribute to climate change,[247] when in fact the causal relationship is very well established.[248] The proposed rule belittles the climate damages that will be directly experienced in the United States—"albeit uncertain"[249]—despite the assessment of the U.S. Global Change Research Program that the United States is already experiencing significant climate impacts.[250] The implication is that climate impacts are somehow more uncertain and so should be treated with more skepticism than other costs and benefits, despite the fact that the U.S. Court of Appeals for the Ninth Circuit has already cautioned NHTSA about that sort of logic.[251]

The PRIA also insists that "uncertainties do not all work in the same direction in terms of their influence on the SC-CO2 estimates."[252] While that may be technically true, overall uncertainty about the full effects of climate change actually *raises* the social cost of greenhouse gases and warrants *more* stringent climate policy.[253] The integrated assessment models (IAMs) currently used to calculate the social cost of

---

[247] 83 Fed. Reg. 43,067.

[248] *See e.g.,* 74 Fed. Reg. 66,496 (Dec. 15, 2009) ("Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act").

[249] 83 Fed. Reg. at 43,067.

[250] https://science2017.globalchange.gov/chapter/executive-summary/ ("Global sea level rise has already affected the United States; the incidence of daily tidal flooding is accelerating in more than 25 Atlantic and Gulf Coast cities. . . . Annual trends toward earlier spring melt and reduced snowpack are already affecting water resources in the western United States and these trends are expected to continue.")

[251] *Center for Biological Diversity v. NHTSA*, 538 F.2d 1172, 1199 (9th Cir. 2008) (holding that NHTSA could not fail to quantify and monetize the most important regulatory effect—climate change—when it had quantified other uncertain effects like congestion).

[252] PRIA at 1064.

[253] 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).

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.[254] 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.[255] 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 greenhouse gases. 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.

VII. NHTSA Has Cherry-Picked Methodological Revisions to Advance a Predetermined Goal, without Engaging in a Holistic Update

NHTSA explains that its estimates of the social cost of carbon are simply "interim values" until an improved estimate can be developed.[256] The revisions to the Interagency Working Group's 2016 estimates that NHTSA made to produce these interim values are all methodologically unsound: ignoring the global values in favor of an inaccurate and incomplete domestic-only estimate; applying the inappropriate 7% discount rate alongside the 3% discount rate in NHTSA'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. NHTSA does not engage with any of the most recent literature on damages (see the technical appendix attached to these comments on damage literature), does not update the underlying models (NHTSA continues to use DICE-2010, even though DICE-2016R has been published[257]), 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. NHTSA notes, but then does nothing about, the National Academies of Sciences' warning that domestic-only numbers fail to account for spillovers and reciprocity.[258] Agencies should pursue a holistic update of the social cost of greenhouse

---

Uncertainty and economic analysis of climate change: A survey of approaches and findings. *Environmental Modeling & Assessment*, *11*(1), 1-17.

[254] 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).

[255] 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.

[256] PRIA 1062.

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

[258] PRIA 1065.

gas methodology, but NHTSA's revisions all appear cherry-picked to lower the valuation. As such, NHTSA'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.[259] 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.[260] 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."[261]

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 NHTSA might review their recommendations for a holistic update to the methodology.

VIII. NHTSA Fails to Appropriately Consider Unquantified Benefits

The PRIA repeatedly talks about its proposed action's "total net benefits,"[262] without acknowledging that the proposal may entail significant unquantified forgone benefits. In fact, over the course of 1621 pages, the PRIA has only a single section, passingly a mere paragraph, that includes the word "unquantified" in the heading.[263] Though the DEIS does contain some scattered additional discussion of some qualitative effects, by incorporating the PRIA into the DEIS and referring readers to the PRIA's monetization of costs and benefits to understand "the full context of the potential impacts of GHG emissions and climate change," the DEIS implies that the PRIA's presentation of the social cost of greenhouse gases fully captures all relevant climate impacts from the rule. It does not, since the PRIA gives no serious weight to the unquantified forgone benefits to climate, as well as other unquantified forgone benefits, such as the unquantified public health consequences of various criteria and toxic

---

[259] 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.

[260] *See generally* 2010 TSD, *supra* note 48.

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

[262] PRIA at 14, 107 ("the preferred alternative . . . maximizes net benefits"), 537 ("Net Benefits—Total benefits minus total costs"), 1080.

[263] PRIA 1327 ("Other Unquantified Health and Environmental Effects").

pollution. Even putting aside NHTSA's severely manipulated underestimates of the monetized forgone climate benefits, the PRIA fails to explain why the proposed action's estimated cost savings justify the sum of both the monetized and unmonetized forgone benefits.

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.[264] 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.[265] 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).[266]

Circular A-4 requires that "When there are important non-monetary values at stake, you should also identify them in your analysis."[267] 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."[268] The Circular cautions that "the most efficient alternative will not necessarily be the one with the largest quantified and monetized net-benefit estimate."[269] NHTSA must therefore fully disclose the limitations of its social cost of greenhouse gas estimates and include detailed charts of all important, unquantified climate effects. The PRIA's cursory reference to "the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts"[270] is insufficient. The PRIA must then explain why, after giving appropriate weight to all the unquantified climate effects and all the unquantified forgone benefits from other emissions, the proposed action's cost savings justify its forgone benefits.

---

[264] *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).

[265] *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.

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

[267] Circular A-4 at 3.

[268] *Id.* at 27.

[269] *Id.* at 2.

[270] PRIA 1064.

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

NHTSA explains that it has relied on "the same ensemble of three integrated assessment models (IAMs) that were used to develop the IWG global SC-CO2 estimates."[271] Indeed, because the Interagency Working Group used the best available data and methodology, it is appropriate for agencies to continue to rely on its methodology and its 2016 estimates. In fact, NHTSA 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.

NHTSA also 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.[272] In any future applications of the social cost of greenhouse gases, NHTSA should continue to rely on the Interagency Working Group's methodology and use multiple peer-reviewed models. That said, NHTSA has failed to use the most up-to-date versions of those models, and should use the updated models in future calculations.

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).[273] 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[274] 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."[275]

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[276]), FUND (the Climate

---

[271] PRIA 1100.

[272] PRIA at 1101.

[273] 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).

[274] *See supra* note 80.

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

[276] 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).

Framework for Uncertainty, Negotiation, and Distribution[277]), and PAGE (Policy Analysis of the Greenhouse Effect[278])—draw on the best available scientific and economic data to link physical impacts to the economic damages of each marginal ton of greenhouse gas emissions. 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.[279] 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.[280] 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.[281] 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.[282] The economics literature confirms that estimates based on these three IAMs remain the best available estimates.[283] In 2016, the U.S. Court of Appeals for the Seventh Circuit held the estimates used to date by agencies are reasonable.[284] Just last month, the District of Montana rejected an agency's Environmental Assessment for failure to

---

[277] 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.

[278] 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).

[279] 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").

[280] 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"].

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

[282] Howard & Schwartz, *supra* note 87, at Appendix A.

[283] *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).

[284] *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).

incorporate the federal social cost of carbon estimates into its cost-benefit analysis of a proposed mine expansion.[285]

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

The unavoidable fact is that DICE, FUND, and PAGE are still the dominant, most peer-reviewed models,[286] and most estimates in the literature continue to rely on those models.[287] 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,[288] 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.[289]

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.[290] However, each IAM also has its own limitations and is sensitive to its own assumptions. No model fully captures all the significant climate effects.[291] By giving weight to multiple models—as the IWG did—agencies can balance out some of these limitations and produce more robust estimates.[292]

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

---

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

[286] *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").

[287] 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).

[288] 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.

[289] 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.

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

[291] *See* Howard 2014, *supra* note 48.

[292] 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*.

carbon dioxide, and a high-percentile estimate of about $120, for year 2015 emissions (in 2016 dollars, at a 3% discount rate). The latest central estimate from DICE's developers is $87 (at a 3% discount rate);[293] from FUND's developers, $12;[294] and from PAGE's developers, $123, with a high-percentile estimate of $332.[295]

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,[296] and a soon-to-be-published update by the same author finds a mean estimate of $108 (at a 1% discount rate).[297] 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.[298] Various studies relying on expert elicitation[299] from a large body of climate economists and scientists have found mean estimates of $50 per ton of carbon dioxide,[300] $96-$144 per ton of carbon dioxide,[301] and $80-$100 per ton of carbon dioxide.[302] 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.[303] 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.[304]

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

---

[293] William Nordhaus, *Revisiting the Social Cost of Carbon*, Proc. Nat'l Acad. Sci. (2017) (estimate a range of $21 to $141).

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

[295] 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).

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

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

[298] 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).

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

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

[301] 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).

[302] 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).

[303] *E.g.,* Howard & Sylvan, *supra* note 301; Pindyck, *supra* note 302. 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 291; Revesz et al., *supra* note 2836; 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).

[304] 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.[305]

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 NHTSA 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.

NHTSA Should Use the Most Updated Models

NHTSA explains it uses DICE 2010, FUND 3.8, and PAGE 2009.[306] However, not only is DICE 2010 not considered to be a major update of the DICE model,[307] but two major updates have occurred more recently: DICE-2013R[308] and DICE-2016R.[309] In using the outdated DICE 2010, NHTSA 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.[310] 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.[311]

X. NHTSA Must Use the Social Cost of Methane and Social Cost of Nitrous Oxide

It is only in a sensitivity analysis that NHTSA gives any non-zero value to the climate damages associated with methane and nitrous oxide emissions.[312] In the PRIA's main analysis, all methane and nitrous oxide emissions, and consequently the vast majority of upstream greenhouse gas emissions, are not monetized at all. That is a blatantly arbitrary omission, because, as the U.S. Court of Appeals for the Ninth Circuit has ruled, the social cost of greenhouse gases is certainly not zero.[313] The approach also misunderstands the role of sensitivity analysis, which is to test "how the results of your analysis vary with plausible changes in assumptions."[314] The non-zero value of methane and nitrous oxide emissions is

---

[305] *See* Howard & Schwartz, *supra* note 87, at Appendix B. All these estimates are in 2016$.

[306] PRIA 1098.

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

[308] Nordhaus, W. (2014). Estimates of the social cost of carbon: concepts and results from the DICE-2013R model and alternative approaches. *Journal of the Association of Environmental and Resource Economists*, *1*(1/2), 273-312.

[309] Nordhaus, W. D. (2017). Revisiting the social cost of carbon. *Proceedings of the National Academy of Sciences*, 201609244.

[310] *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).

[311] The update would also increase the agencies' calculation of the domestic-only share from 10% to 15%, *see* Nordhaus, W. D. (2017). Revisiting the social cost of carbon. *Proceedings of the National Academy of Sciences*, 201609244. But, as explained *supra* in these comments, a domestic-only value is the wrong framework and is inaccurate.

[312] PRIA 1062 fn 604.

[313] 538 F.3d at 1200.

[314] Circular A-4 at 41.

a fact, not an assumption, and it was not plausible in the first place to assume the social cost of methane and nitrous oxide to be zero in the main analysis.

The sensitivity analysis first proposes to value the social cost of methane and nitrous oxide by converting emissions into carbon dioxide-equivalent units using the relative global warming potentials. There are several problems with such an approach. First, conversion using relative global warming potential is less accurate than direct modeling. Scientists have long argued that the full social costs of specific, non-carbon dioxide gases like methane and nitrous oxide should be assessed through separate models and methodologies, which would more accurately account for varying atmospheric life spans, among other differences.[315] The Interagency Working Group did precisely that in 2016,[316] endorsing estimates developed in the peer-reviewed work by Marten *et al*.[317] The IWG's estimates of the social cost of methane and social cost of nitrous oxide are based on the same transparent, consensus-driven, publically reviewed, conservative approach as the social cost of carbon's thoroughly vetted methodology. Under Executive Order 13,783's call to base estimates on the best available science and economics, NHTSA should use the more accurate direct estimates of the social cost of methane and nitrous oxide.

Second, even if NHTSA were to stick with the less accurate approach of converting using relative global warming potentials, NHTSA has chosen at best an outdated and at worst an incorrect estimate of GWP. The PRIA claims that its sensitivity analysis uses the GWP values of 25 for methane and 298 for nitrous oxide, citing the Intergovernmental Panel on Climate Change's 2007 work.[318] However, there is some confusion even about this: in the sensitivity analysis files, the "emission damage costs $/metric-ton" for methane is set at "$25," not at 25 times the value of the social cost of carbon. It is therefore unclear which value the sensitivity analysis actually used. Regardless, a GWP of 25 for methane is out of date. EPA currently lists methane's global warming potential as 28-36 over 100 years, and 84-87 over 20 years.[319] Meanwhile, the IPCC updated its estimates in 2013, and now recommends using a GWP for methane of 85 to 87 times greater than carbon dioxide after 20 years and 30 to 36 times greater than carbon dioxide after 100 years (after making the recommended adjustment for fossil methane).[320] NHTSA's use of 25 for methane's GWP is below even the low end of the new ranges, and is severely below the range that captures methane's relative impacts over a shorter 20-year period. While NHTSA's best option remains directly calculating the social cost of methane and nitrous oxide, minimally NHTSA should update its GWP values and should conduct sensitivity analysis over the entire global warming potential range, instead of merely utilizing the low estimate from an outdated 100-year timescale range.

Sincerely,

Susanne Brooks, Director of U.S. Climate Policy and Analysis, Environmental Defense Fund
Tomás Carbonell, Senior Attorney and Director of Regulatory Policy, Environmental Defense Fund
Rachel Cleetus, Ph.D., Lead Economist and Climate Policy Manager, Union of Concerned Scientists

---

[315] *See* Disa Thureson & Chris Hope, *Is Weitzman Right? The Social Cost of Greenhouse Gases in an IAM World* 21 (Örebro University-Swedish Business School Working Paper 3/2012).

[316] 2016 Addendum, *supra* note 273.

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

[318] PRIA 1534, fn 910.

[319] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

[320] IPCC Working Group I, Fifth Assessment Report, Climate Change 2013: The Physical Science Basis, Chapter 8: Anthropogenic and Natural Radiative Forcing (2014) at 633, 711-712, 714 (Table 8.7), available at https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf (see the adjustment identified in note B for fossil methane).

Denise Grab, Western Regional Director, Institute for Policy Integrity, NYU School of Law*
Peter H. Howard, Ph.D., Economic Director, Institute for Policy Integrity, NYU School of Law*
Benjamin Longstreth, Senior Attorney, Natural Resources Defense Council
Alejandra Núñez, Senior Attorney, Sierra Club
Iliana Paul, Policy Analyst, Institute for Policy Integrity, NYU School of Law*
Richard L. Revesz, Director, Institute for Policy Integrity, NYU School of Law*
Martha Roberts, Senior Attorney, Environmental Defense Fund
Jason A. Schwartz, Legal Director, Institute for Policy Integrity, NYU School of Law*
Jeffrey Shrader, Affiliated Scholar, Institute for Policy Integrity, NYU School of Law*
Peter Zalzal, Director of Special Projects and Senior Attorney, Environmental Defense Fund

For any questions regarding these comments, please contact jason.schwartz@nyu.edu.
* No part of this document purports to present New York University School of Law's views, if any.

Attached:

- Technical Appendix on Uncertainty
- Technical Appendix on Discounting
- Technical Appendix on Damage Literature
- Interagency Working Group on the Social Cost of Greenhouse Gases: 2010 TSD, 2015 Response to Comments, 2016 TSD, 2016 Addendum.
- National Academies of Sciences, *Valuing Climate Damages: Updating Estimates of the Social Cost of Carbon Dioxide* (2017)
- Robert S. Pindyck, Comments on Proposed Rule and Regulatory Impact Analysis on the Delay and Suspension of Certain Requirements for Waste Prevention and Resource Conservation (2017)
- Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 Columbia J. Envtl. L. 203 (2017)
- Richard L. Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 Science 6352 (2017)
- Peter Howard & Thomas Sterner, *Few and Not So Far Between: A Meta-analysis of Climate Damage Estimates*. *Environmental and Resource Economics*, 1-29 (2016).
- Peter Howard & Derek Sylvan, *The Economic Climate: Establishing Expert Consensus on the Economics of Climate Change* (Inst. Policy Integrity Working Paper 2015/1)

Due to copyright limitations, other literature cited in these comments is not attached to our submission. We note, however, that NHTSA already captured many of these citations, drawn from our comments on the NEPA scoping process, and listed them in an appendix to the DEIS. We presume that the agencies will similarly enter into the record all the relevant literature from these comments. We have provided full citations and URLs wherever possible, and the agencies have access to journal articles and so forth.

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.[321] 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.[322] 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.[323] Rather than being a reason not to take action, uncertainty increases the SCC and should lead to more stringent policy to address climate change.[324]

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.[325] Stochastic uncertainty is persistent randomness in the economic-climate system, including various environmental phenomena such as volcanic eruptions and sun spots.[326] 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).[327]

When modeling climate change uncertainty, scientists and economists have long emphasized the importance of accounting for the potential of catastrophic climate change.[328] Catastrophic outcomes combine several overlapping concepts including unlucky states of the world (i.e., bad draws), deep

---

[321] 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.").

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

[323] Robert S Pindyck, *Uncertainty in environmental economics*, 1 Review of environmental economics and policy 45-65 (2007); Golub et al, *surpa* note 255; Lemoine & Rudik, *supra* note 255.

[324] *See* cites *supra* note 323.

[325] 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).

[326] A potential third type of uncertainty arises due to ethical or value judgements: normative uncertainty. Peterson (2006) *supra* note 321; 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 325 and Golub et al. *supra* note 255.

[327] Peterson (2006), *supra* note 321; Pindyck (2007), *supra* note 255; Heal & Millner 2014, *supra* note 326.

[328] 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).

uncertainty, and climate tipping points and elements.[329] 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.[330] 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.[331] Given the general opinion that bad surprises are likely to outweigh good surprises in the case of climate change,[332] modelers capture deep uncertainty by selecting probability distributions with a fat upper tail which reflects the greater likelihood of extreme events.[333] 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).[334]

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.[335] 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.[336] 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.[337] Social tipping points—including climate-induced migration and conflict—also exist. These various tipping points interact, such that triggering one tipping point may affect the probabilities of triggering other tipping points.[338] There is some overlap between tipping point events and fat tails in

---

[329] Kopp et al. (2016), *supra* note 328.

[330] *Id.*

[331] 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).

[332] 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).

[333] Weitzman (2011), *supra* note 331, 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."

[334] 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 331; Weitzman (2011), *supra* note 331.

[335] 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 328.

[336] *Id.*

[337] *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); 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 328, for a full list of known tipping elements and points.

[338] Kriegler et al. (2009), *supra* note 337; 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 328.

that the probability distributions for how likely, how quick, and how damaging tipping points will be are unknown.[339] 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[340] 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.[341] Tol, Anthoff, and Hope employ this technique in FUND and PAGE—as did the IWG (2010, 2013, and 2016)[342]—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.[343] 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)[344] reported the various moments and percentiles—including the 95th percentile—of the resulting

---

[339] 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 328.

[340] *See* Nordhaus & Sztorc 2013, *supra* note 307.

[341] 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 255. 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.

[342] 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).

[343] Tol (1999), *supra* note 322, 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."

[344] IWG (2016) *supra* note 342.

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.[345] 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.[346] 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.[347] 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.[348]

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.[349] 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

---

[345] IWG (2010) *supra* note 342.

[346] Howard (2014), *supra* note 339. 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.

[347] Weitzman (2011), *supra* note 331; Kopp et al. (2016) *supra* note 328.

[348] Derek Lemoine & Christian P. Traeger, *Ambiguous tipping points*, 132 Journal of Economic Behavior & Organization 5-18 (2016); Lemoine & Rudik (2017), *supra* note 255. IAM modelers currently assume that society is equally averse to known unknown and known unknowns. Lemoine & Traeger, *id*.

[349] William Nordhaus & Joseph Boyer, Warning the World: Economic Models of Global Warming (2000); Nordhaus (2008) *supra* note 264; Howard (2014), *supra* note 339; Kopp et al. (2016) *supra* note 328.

each time period.[350] 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.[351] Despite the obvious methodological basis for addressing tipping points, the latest versions of DICE[352] 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.[353]

The IWG approach also fails to include a risk premium—that is, the amount of money society would require in order to accept the uncertainty (i.e., variance) over the magnitude of warming and the resulting damages from climate change relative to mean damages (IWG, 2010; IWG, 2015)). The mean of a distribution, which is a measure of a distribution's central tendency, represents only one descriptor or "moment" of a distribution's shape. Each IAM parameter and the resulting SCC distributions have differing levels of variance (i.e., spread around the mean), skewness (i.e., a measure of asymmetry), and kurtosis (which, like skewness, is another descriptor of a distribution's tail) as well as means.[354] 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.[355] 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,[356] current IAM assumptions,[357] the

---

[350] 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 339.

[351] Kopp et al. (2016) *supra* note 328.

[352] 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).

[353] 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).

[354] 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 342.

[355] 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.

[356] IWG, 2010 *supra* note 342, at fn 22; Cai et al., 2016, *supra* note 338, at 521.

[357] 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 307; Anthoff & Tol (2013) *supra* note 294; 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*

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).[358] 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.[359] 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.[360] 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 behavior."[361] 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.[362] 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

---

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.

[358] According to Heal and Millner (2014) *supra* note 326, 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.

[359] 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 359, 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.*

[360] Even if society drastically reduced CO2 emissions, CO2 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).

[361] Pindyck (2007) *supra* note 255.

[362] Kann & Weyant *supra* note 325; Pindyck (2007) *supra* note 255; Golub et al. (2014) *supra* note *255*.

damages on the optimal emissions path rather than on the BAU emissions path.[363] 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),[364] 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.[365] Recent computational advancements in SDP are helping overcome the need for strong simplifying assumptions in this literature for purpose of tractability. Traditionally, these simplifications led to unrealistically fast rates of learning – leading to incorrect outcomes – and difficulty in comparing results across papers (due to differing uncertain parameters, models of learning, and model types). Even so, newer methods still only allow for a handful of uncertain parameters compared to the hundreds of uncertain parameters in FUND and PAGE. Despite these limitations, the literature supports the above finding that the SCC, if anything, increases under uncertainty.[366]

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.[367] For SDP models, uncertainty

---

[363] 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).

[364] 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.

[365] Kann & Weyant *supra* note 325; Pindyck (2007) *supra* note 255; Golub et al. (2014) *supra* note 255.

[366] Kann & Weyant *supra* note 325; Pindyck (2007) *supra* note 255; Golub et al. (2014) *supra* note 255; Lemoine & Rudik 2017 supra note 255. 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*).

[367] 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 255), 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

tends to strengthen the optimal emissions path relative to the determinist case even without tipping points,[368] and these results are strengthened under realistic preference assumptions.[369] Given that there is no counter-balancing tipping abatement cost,[370] 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%[371] to 800%[372] 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.[373] Recent research has shown that accurate estimation of decisions under uncertainty crucially depends on distinguishing between risk and time preferences.[374] 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.[375] 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.[376] Including more realistic preference assumptions in IAMs would further increase the SCC under uncertainty.

(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 *255*).

[368] 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 *255*; Lemoine & Rudik 2017 supra note 255). 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.

[369] Pindyck (2007) *supra* note 255; Golub et al. (2014) *supra* note *255*; Lemoine & Rudik 2017 supra note 255.

[370] Pindyck (2007) *supra* note 255.

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

[372] Cai et al. 2016 *supra* note 338.

[373] Cai et al. 2016 *supra* note 338; Lemoine & Rudik 2017 supra note 255. The standard utility function adopted in IAMs with constant relative risk version implies that the elasticity of substitution equals the inversion of relative risk aversion. As a consequence, the society's preferences for the intra-generational distribution of consumption, the intergenerational distribution of consumption, and risk aversion hold a fixed relationship. For purposes of stochastic dynamic programming, this is problematic because this assumption conflates intertemporal consumption smoothing and risk aversion. 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 338 replace the DICE risk aversion of 1.45 and elasticity parameter of 1/1.45 with values of 3.066 and 1.5, respectively.

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

[375] Lemoine & Traeger (2016) *supra* note 348.

[376] 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

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.[377] 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.

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).

[377] Golub et al. (2014) *supra* note 255 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

1. 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.[378] 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%.[379] 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.[380] 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%,[381] 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[382] 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.

2. 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.[383] Not only are declining discount rate theoretically

---

[378] 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.

[379] 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.

[380] 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.

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

[382] 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).

[383] 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 "Establishing a procedure for estimating a [declining discount rate]

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.[384] 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.[385] 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[386] 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.[387] Several key papers[388] 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)[389], 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.[390] Second, uncertainty about the growth rate of consumption or output also implies that a declining discount rate should be used, so long as shocks to consumption are positively correlated over time.[391] In addition to these two arguments, other motivations for declining discount

---

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

[384] 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.)

[385] 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).

[386] *See generally* Arrow et al. (2013), *supra* note 317.

[387] 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).

[388] *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).

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

[390] 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.

[391] *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).

rates have long been recognized. For instance, if the growth rate of consumption declines over time, the Ramsey rule[392] for discounting will lead to a declining discount rate.[393]

In the descriptive setting adopted by the IWG (2010),[394] 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.[395] 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.[396] 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.[397]

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.[398] Past U.S. government analyses[399] modeled three consumption discount rates reflecting this uncertainty. If the U.S. government correctly returns its focus on multiple consumption discount rates, then the expected net present value argument given above implies that a declining discount rate is the appropriate way to perform discounting. As an alternative, given that the Ramsey discount rate approach is the appropriate methodology in intergenerational settings, the U.S. government could use a fixed, low discount rate as an approximation of the Ramsey equation following the recommendation of Marten et al. (2015);[400] see our discussion on Martin et al. (2015). This is roughly IWG (2010)[401]'s goal for using the constant 2.5% discount rate.

---

[392] 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).

[393] 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.

[394] 394 *See* IWG (2010), *supra* note 316.

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

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

[397] *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).

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

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

[400] *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).

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

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[402] implies a declining discount rate when (1) the growth rate of per capita consumption is stochastic,[403] and (2) consumption shocks are positively correlated over time (or their mean or variances are uncertain).[404] While a constant adjustment downwards (known as the precautionary effect[405]) can be theoretically correct when growth rates are independent and identically distributed,[406] 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).[407] 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).[408]

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[409], 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.[410] It should be noted that

---

[402] 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.

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

[404] *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).

[405] 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).

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

[407] 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].

[408] *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).

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

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

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.[411]

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.[412] Despite individuals differing in their pure rate of time preference,[413] 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.[414] The literature generally finds a declining social discount rate due to a declining collective pure rate of time preference.[415] The heterogeneity of preferences and the uncertainty surrounding economic growth hold simultaneously,[416] 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).[417] One possible declining interest rate schedule for consideration by the IWG is the one proposed by Weitzman (2001).[418] It is derived from a broad survey of top economists in context of climate change, and explicitly incorporates arguments around interest rate uncertainty.[419] Other declining discount rate schedule include Newell and Pizer (2003); Groom et al. (2007); Freeman et al. (2015).[420] Many leading economists support the

---

[411] 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).

[412] 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).

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

[414] 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.

[415] 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).

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

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

[418] 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.

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

[420] 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.

United States government adopting a declining discount rate schedule.[421] 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.[422] The U.K. schedule explicitly subtracts out an estimated time preference.[423] 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),[424] suggesting that even the lowest discount rate evaluated by the IWG is too high.[425] 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).[426]

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."[427] 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 rate of time preference, not due to a decreasing discount rate term structure.[428] 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

---

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

[422] *See* Gollier and Hammitt 2014 *supra* note 322 and Cropper et al 2014 *supra* note 317.

[423] 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.

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

[425] 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.

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

[427] *Circular A-4* at 35.

[428] 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.").

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."[429]

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)[430] 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,[431] 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).[432] 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).[433] This consensus holds across panels of experts on the social cost of carbon[434]; surveys of experts on climate change and discount rates;[435] the three most commonly cited IAMs employed in calculating the federal SCC; and the government's own analysis.[436] 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.

---

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

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

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

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

[433] 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."

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

[435] 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).

[436] *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).

TECHNICAL APPENDIX: DAMAGE LITERATURE

The Fourth National Climate Assessment was recently published by the U.S. Global Change Research Program.[437] In addition to reviewing that report and the literature on U.S. damages cited therein, the agencies must review the following literature, which contains some of the most up-to-date estimates of U.S. damages from climate change.

Overall Damage Estimates and Review Articles

Solomon Hsiang et al., *Economic Damage from Climate Change in the United States*, 356 SCIENCE. 1362–1369 (2017).

Delavane Diaz & Frances Moore, *Quantifying the economic risks of climate change*, 7 NAT. CLIM. CHANG. 774–782 (2017).

Roberto Roson & Martina Sartori, *Estimation of Climate Change Damage Functions for 140 Regions in the GTAP 9 Database*, 1 J. GLOB. ECON. ANAL. 78–115 (2016).

Derek Lemoine & Sarah Kapnick, *A top-down approach to projecting market impacts of climate change*, NAT. CLIM. CHANG. 7 (2015).

Marshall Burke, Solomon M. Hsiang & Edward Miguel, *Global non-linear effect of temperature on economic production*, 527 NATURE 235–239 (2015).

Agriculture Damages

Wolfram Schlenker, *Crop Responses to Climate and Weather: Cross-Section and Panel Models*, *in* CLIMATE CHANGE AND FOOD SECURITY 99–108 (David Lobell & Marshall Burke eds., 2010).

David B. Lobell, Wolfram Schlenker & Justin Costa-Roberts, *Climate Trends and Global Crop Production Since 1980*, 333 SCIENCE (80). (2011).

Olivier Deschênes & Michael Greenstone, *The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather: Reply*, 102 AM. ECON. REV. 3761–3773 (2012).

Marshall Burke & Kyle Emerick, *Adaptation to Climate Change: Evidence from US Agriculture*, 8 AM. ECON. J. ECON. POLICY 106–140 (2016).

Christopher Severen, Christopher Costello & Olivier Deschênes, *A Forward Looking Ricardian Approach: Do Land Markets Capitalize Climate Change Forecasts?*, 22413 NBER WORK. PAP. 46 (2016).

Wolfram Schlenker, Michael J. Roberts & David B. Lobell, *US maize adaptability*, 3 NAT. CLIM. CHANG. 690–691 (2013).

Wolfram Schlenker & Michael J Roberts, *Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change.*, 106 PROC. NATL. ACAD. SCI. 15594–8 (2009).

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. 1–9 (2017).

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

Forestry Damages

Christopher Guo & Christopher Costello, *The value of adaption: Climate change and timberland management*, 65 J. ENVIRON. ECON. MANAGE. 452–468 (2013).

Effects on Health and Mortality

Alan Barreca et al., *Adapting to climate change: The remarkable decline in the U.S. temperature-mortality relationship over the 20th century*, 124 NBER WORK. PAP. 46 (2016).

Garth Heutel, Nolan H Miller & David Molitor, *Adaptation and the mortality effects of temperature across U.S. climate regions*, No. 23271 NBER WORK. PAP. 58 (2017).

---

[437] https://science2017.globalchange.gov/

Jan C. Semenza et al., *Climate change and microbiological water quality at California beaches*, 9 ECOHEALTH 293–297 (2012).
Tamma Carleton et al., *Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits* (Becker Friedmand Inst. Working Paper No. 2018-51).

Effects on Labor Productivity and Learning

Joshua Graff Zivin & Matthew MJ Neidell, *Temperature and the allocation of time: Implications for climate change*, 32 J. LABOR ECON. 1–26 (2010).
M. Donadelli et al., *Temperature Shocks and Welfare Costs*, J. ECON. DYN. CONTROL (2017).
Adam Isen & W Reed Walker, *Heat and Long-Run Human Capital Formation*, 26 (2017).
Geoffrey Heal, Jisung Park & Nan Zhong, *Labor Productivity and Temperature*, 1–33 (2017).
Joshua Graff Zivin, Solomon Hsiang & Matthew Neidell, *Temperature and human capital in the short- and long-run*, J. ASSOC. ENVIRON. RESOUR. ECON. 694177 (Forthcoming)

Sea Level Rise

Mathew E. Hauer, Jason M. Evans & Deepak R. Mishra, *Millions projected to be at risk from sea-level rise in the continental United States*, advance on NAT. CLIM. CHANG. (2016).