May 7, 2018

To: Bureau of Land Management

Subject: Riley Ridge Project Draft Environmental Impact Statement - DOI-BLM-WY-D040-2014-0001-EIS

Submitted By: Environmental Defense Fund, Montana Environmental Information Center, Institute for Policy Integrity at New York University School of Law, Natural Resources Defense Council, Sierra Club

The Riley Ridge to Natrona Project Draft Environmental Impact Statement (DEIS) was prepared by the Bureau of Land Management (BLM). The DEIS assesses a proposed project that includes an underground nongaseous H_2S/CO_2 pipeline, an underground CO_2 pipeline, a sweetening plant on BLM-administered land, a transmission line, and ancillary facilities. BLM calculates the project's 2.8 million metric tons of CO_2-equivalent annual emissions from operations, as well as the 22.5 million metric tons of CO_2-equivalent lifetime emissions from the combustion of additional fossil fuels extracted from enhanced oil recovery,[1] but the agency fails to use the social cost of greenhouse gas metric to reveal the actual climate damages associated with those emissions. BLM incorrectly claims, citing an EIS produced by the Federal Energy Regulatory Commission, that it is not possible to attribute discrete environmental impacts to greenhouse gas emissions.[2] However, the social cost of greenhouse gases metric was precisely designed to assign value to the damages of each marginal ton of greenhouse gas emissions.

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

1. NEPA requires a "reasonably thorough discussion" and "necessary contextual information" on climate impacts. The social cost of greenhouse gases provides such information, while the mere recitation of so many tons of carbon that will be emitted by the project fails to provide the public and decisionmakers with the required information. Moreover, when an agency monetizes a project's potential benefits—as BLM does here—the potential climate costs must be treated with proportional rigor.
2. The social cost of greenhouse gases metric is appropriate for a project-level EIS with emissions of this magnitude. The metric can be applied to any action that significantly increases greenhouse gas emissions, not just to rulemakings. The uncertainty around factors like catastrophic outcomes that cannot currently be fully monetized is not a reason not to use the

[1] DEIS at 4-30, 4-33.

[2] DEIS at 4-34 (citing FERC, Southeast Market Pipelines Project, Final Supplemental Environmental Impact Statement (2018). However, FERC contradicts this statement in the Sabal Trail Remand Order (2018) at P48: "On further review, we accept that the Social Cost of Carbon methodology does constitute a tool that can be used to estimate incremental physical climate change impacts." Available at: https://www.ferc.gov/CalendarFiles/20180314230126-CP14-554-002.pdf).

metric, but rather a reason to treat available values as lower-bound estimates of the true climate costs of emissions.

3. BLM should use the Interagency Working Group's 2016 estimates of the social cost of greenhouse gases, which remain the best available values for federal agencies to use in analyses.

Below, we explain each of these points in turn.

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

BLM fails to discuss the actual climate impacts of the project, even though it quantifies the tons of direct and indirect greenhouse gas emissions. BLM neither quantitatively nor qualitatively discusses the damages to which these additional tons of greenhouse gases would contribute. Meanwhile, BLM has monetized effects like tens of millions of dollars' worth in annual economic output and labor earnings.[3] Failing to similarly monetize the climate costs of the project is inconsistently arbitrary and deprives the public and decisionmakers of the information and context they need to weigh all the project's potential effects.

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

NEPA requires "hard look" consideration of beneficial and adverse effects of each alternative option for major federal government actions. The U.S. Supreme Court has called the disclosure of impacts the "key requirement of NEPA," and held that agencies must "consider and disclose the actual environmental effects" of a proposed project in a way that "brings those effects to bear on [the agency's] decisions."[4] Courts have repeatedly concluded that an EIS must disclose relevant climate effects.[5] Though NEPA does not require a formal cost-benefit analysis,[6] agencies' approaches to assessing costs and benefits must be balanced and reasonable. Courts have warned agencies that "[e]ven though NEPA does not require a cost-benefit analysis," an agency cannot selectively monetize benefits in support of its decision while refusing to monetize the costs of its action.[7]

In *High Country Conservation Advocates v. Forest Service*, the U.S. District Court of Colorado found that it was "arbitrary and capricious to quantify the *benefits* of the lease modifications and then explain that a similar analysis of the *costs* was impossible when such an analysis was in fact possible."[8] The court explained that, to support a decision on coal mining activity, the agencies had "weighed several specific economic benefits—coal recovered, payroll, associated purchases of supplies and services, and royalties," but arbitrarily failed to monetized climate costs using the readily available social cost of

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[3] DEIS at 4-165

[4] *Baltimore Gas & Elec. Co. v. Natural Res. Def. Council*, 462 U.S. 87, 96 (1983).

[5] 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).

[6] 40 C.F.R. § 1502.23 ("[T]he weighing of the merits and drawbacks of the various alternatives need not be displayed in a monetary cost-benefit analysis.").

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

[8] 52 F. Supp. 3d at 1191.

carbon protocol.[9] Similarly, in *Montana Environmental Information Center v. Office of Surface Mining* (*MEIC v. OSM*), the U.S. District Court of Montana followed the lead set by *High Country* and likewise held an environmental assessment to be arbitrary and capricious because it quantified the benefits of action (such as employment payroll, tax revenue, and royalties) while failing to use the social cost of carbon to quantify the costs.[10]

Both *High Country* and *MEIC v. OSM* were in line with *Center for Biological Diversity v. National Highway Traffic Safety Administration*.[11] In that case, the U.S. Court of Appeals for the Ninth Circuit ruled that, because the agency had monetized other uncertain costs and benefits of its vehicle fuel efficiency standard—like traffic congestion and noise costs—its "decision not to monetize the benefit of carbon emissions reduction was arbitrary and capricious."[12] Specifically, it was arbitrary to "assign[ ] no value to *the most significant benefit* of more stringent [vehicle fuel efficiency] standards: reduction in carbon emissions."[13] When an agency bases a rulemaking on cost-benefit analysis, it is arbitrary to "put a thumb on the scale by undervaluing the benefits and overvaluing the costs."[14]

In this DEIS, BLM monetizes similar economic benefits as in *MEIC v. OSM*—including tens of millions of dollars' worth in annual economic output[15]—and so is required to be consistent in monetizing other significant effects, including climate costs.

Moreover, in obligating agencies to take "hard look" at projects' climate impacts, NEPA requires more than simply disclosing the volume of anticipated emissions.[16] As discussed further below, under NEPA, agencies must provide details on discrete effects of a project's impacts within the relevant context. The social cost of greenhouse gases provides this critical information.

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

BLM compares project's annual operating emissions (but not its lifetime downstream emissions) against state and national total greenhouse gas emissions.[17] This tactic seeks to minimize and obscure the actual climate consequences of the project's emissions. Not only is the social cost of greenhouse gas methodology ideally suited for valuing the marginal climate damages of individual projects, but the monetization directly reflects the actual incremental impacts of emissions on climate change. Monetization is actually a more useful way under NEPA to present the information to decisionmakers and the public than a qualitative description of discrete effects or a mere tallying of the tons of emissions.

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[9] *Id.*

[10] 15-106-M-DWM, at 40-46, Aug. 14, 2017 (also holding that it was arbitrary to imply that there would be zero effects from greenhouse gas emissions).

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

[12] 538 F.3d 1172, 1203 (9th Cir. 2008).

[13] *Id.* at 1199.

[14] *Id.* at 1198.

[15] DEIS at 4-165.

[16] *Supra* notes 4-5.

[17] DEIS at 4-34.

The social cost of greenhouse gases directly reflects the discrete effects of climate change.[18] The three integrated assessment models used to calculate the social cost of greenhouse gases together incorporate such damage categories as: agricultural and forestry impacts, coastal impacts due to sea level rise, impacts to the energy and water sectors, impacts from extreme weather events, vulnerable market sectors impacted by changes in energy use, human health impacts including malaria and pollution, outdoor recreation impacts and other non-market amenities, impacts to human settlements and ecosystems, and some catastrophic impacts.[19] Though some important damage categories are currently omitted due to insufficient data and modeling,[20] the integrated assessment models do a reasonable job of capturing many of the discrete climate effects that decisionmakers and the public care about.

Monetizing climate damages provides the informational context required by NEPA, while a purely quantitative estimate of tons or a qualitative description of discrete climate effects like sea-level rise provide little context. Courts review NEPA documents "under an arbitrary and capricious standard," which requires "a reasonably thorough discussion of the significant aspects of the probable environmental consequences," to "foster both informed decisionmaking and informed public participation."[21] In particular, "the impact of greenhouse gas emissions on climate change is precisely the kind of cumulative impact analysis that NEPA requires," and it is arbitrary to fail to "provide the necessary contextual information about the cumulative and incremental environmental impacts."[22]

To "provide the necessary contextual information," economic theory shows that one useful tool is monetization of environmental impacts. As Professor Cass Sunstein has explained, drawing from the work of recent Nobel laureate economist Richard Thaler, a well-documented mental heuristic called "probability neglect" causes people to irrationally reduce small probability risks entirely down to zero.[23] Yet the monetized expected cost of the climate risks associated with even relatively small increases in overall emissions, which could be hundreds of millions of dollars, is less likely overlooked. As the Environmental Protection Agency's website explains, "abstract measurements" of so many tons of greenhouse gases can be rather inscrutable for the public, unless "translat[ed] . . . into concrete terms you can understand."[24] Monetization contextualizes the significance of the additional tons of emissions. BLM is required by NEPA to provide enough context to ensure that the public and decisionmakers would not overlook the associated climate risks. Monetization is one way that BLM could provide the necessary context to foster both informed decisionmaking and informed public participation.[25]

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

[19] See descriptions of the IAMs at pages 6-8 of the Interagency Working Group on the Social Cost of Carbon's 2010 Technical Support Document.

[20] Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon* (2014), *available at* http://costofcarbon.org/files/Omitted_Damages_Whats_Missing_From_the_Social_Cost_of_Carbon.pdf.

[21] *Ctr. for Biological Diversity*, 538 F.3d at 1194 (citations omitted). *See also Montana Envtl. Info. Ctr. v. Office of Surface Mining*, cv 15-106-M-DWM, at 12-13 (D.Mt., Aug. 14, 2017).

[22] *Ctr. for Biological Diversity,* 538 F.3d at 1217; *see also Montana Envtl. Info. Ctr.,* cv 15-106-M-DWM at 45.

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

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

[25] While the regulations promulgated by the Council on Environmental Quality to implement NEPA do not require a "monetary cost-benefit analysis," 40 C.F.R. § 1502.23, monetization nevertheless remains an available tool for contextualizing information. As the Council on Environmental Quality has explained, monetization may be "appropriate and relevant" and, in particular, "the Federal social cost of carbon . . . provides a harmonized, interagency metric that can give decision makers and the public useful information for their NEPA review." CEQ, *Final Guidance on Consideration of Greenhouse Gas Emissions and*

Similarly, non-monetized effects are often irrationally treated as worthless.[26] On several occasions, courts have struck down administrative decisions for failing to give weight to non-monetized effects.[27] 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."[28]

NEPA requires that agencies disclose environmental effects with sufficient detail and context. As this section has explained, simply tallying the volume of emissions fails to give the public and decisionmakers the required information about the magnitude of discrete climate effects from those emissions. The social cost of greenhouse gas metric provides that necessary context.

2. The Social Cost of Greenhouse Gas Metric Is Appropriate for a Project-Level EIS with Emissions of this Magnitude

BLM offers various implicit arguments against using the social cost of greenhouse gases in this particular DEIS. BLM claims that there is no way to tell if this action's effects are significant enough to warrant use of the metric. BLM goes one step further and claims that it is not possible to attribute climate effects discrete emissions anyway. In fact, BLM cites FERC's flawed argument, saying that "at this time there is no known Project-level significance threshold of GHG emissions for climate change, nor is it possible to attribute discrete environmental effects to GHG emissions (FERC 2018, page 6)."[29] Each of these attacks fundamentally misunderstands the social cost of greenhouse gas metric.

First, the social cost of greenhouse gas methodology is well suited to measure the marginal climate damages of individual projects. These protocols were developed to assess the cost of actions with "marginal" impacts on cumulative global emissions, and the metrics estimate the dollar figure of damages for one extra unit of greenhouse gas emissions. This marginal cost is calculated using integrated assessment models. These models translate emissions into changes in atmospheric greenhouse concentrations, atmospheric concentrations into changes in temperature, and changes in temperature into economic damages. A range of plausible socio-economic and emissions trajectories are used to account for the scope of potential scenarios and circumstances that may actually result in the coming years and decades. The marginal cost is attained by first running the models using a baseline emissions trajectory, and then running the same models again with one additional unit of emissions. The difference in damages between the two runs is the marginal cost of one additional unit. The approach assumes that the marginal damages from increased emissions will remain constant for small emissions increases relative to gross global emissions. In other words, the monetization tools are in fact perfectly suited to measuring the marginal effects of individual projects or other discrete agency actions.

Second, BLM claims there is no impact threshold to characterize the significance of a single action on global climate change.[30] While there may not be a bright-line test for significance, the emissions BLM estimates for this project—over 22.5 million tons in downstream emissions plus 2.8 million tons in

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the Effects of Climate Change in National Environmental Policy Act Reviews 32-33 & fn.86 (2016), *available* at https://obamawhitehouse.archives.gov/sites/whitehouse.gov/files/documents/nepa_final_ghg_guidance.pdf.

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

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

[28] 538 F.3d at 1199.

[29] DEIS at 4-34. *See* Montana Environmental Information Center, Institute for Policy Integrity at New York University School of Law, Sierra Club, Union of Concerned Scientists. Failure to Use the Social Cost of Greenhouse Gases in the Rivervale South to Market Project Environmental Assessment—Docket No. CP17-490-000. Available at: http://policyintegrity.org/documents/Joint_SCC_Comments_to_FERC_on_Rivervale_041618.pdf

[30] Id.

annual emissions from operations[31]—are clearly significant and warrant monetization. This is especially true since, once emissions have been quantified (as they have been here), the additional step of monetization through application of the Interagency Working Group's 2016 estimates entails nothing more than a simple arithmetic calculation.[32]

In *High Country*, the District Court for the District of Colorado found that it was arbitrary for the Forest Service not to monetize the "1.23 million tons of carbon dioxide equivalent emissions [from methane] the West Elk mine emits annually."[33] That suggests that emissions in quantities far below what BLM estimates here are significant and warrant monetization. In *Center for Biological Diversity*, the Ninth Circuit found that it was arbitrary for the Department of Transportation not to monetize the 35 million metric ton difference in lifetime emissions from increasing the fuel efficiency of motor vehicles:[34] given the estimated lifetime of vehicles sold in the years 2008-2011 (sometimes estimated at about 15 years on average), this could represent as little two million metric tons per year, below the annual emissions at stake here. In a recent environmental impact statement from the Bureau of Ocean Energy Management published in August 2017, the agency explained that the social cost of carbon was "a useful measure" to apply to a NEPA analysis of an action anticipated to have a difference in greenhouse gas emissions compared to the no-action baseline of about 25 million metric tons over a 5-year period,[35] or about 5 million metric tons per year. Once again, BLM's estimate for the Riley Ridge to Natrona project's operational and downstream emissions is of a similar magnitude.

Under any reasonable social cost of greenhouse gases, the direct and indirect emissions from the Riley Ridge project will cause hundreds of millions of dollars in climate damages. Tellingly, BLM had no problem monetizing, for example, the $8.6 million in labor earnings or the $24.2 million in total economic output.[36] Certainly, a potential climate cost of hundreds of millions of dollars is also significant, particularly in the context of a document the very purpose of which is to evaluate a project's *environmental* impacts.

As for uncertainty, agencies in general—and BLM in this particular instance—should remember that uncertainty is *not* a reason to abandon the social cost of greenhouse gas methodologies;[37] quite the contrary, uncertainty supports higher estimates of the social cost of greenhouse gases, because most uncertainties regarding climate change entail tipping points, catastrophic risks, and unknown unknowns about the damages of climate change. Because the key uncertainties of climate change include the risk of irreversible catastrophes, applying an options value framework to the regulatory context strengthens the case for ambitious regulatory action to reduce greenhouse gas emissions. There are numerous well-established, rigorous analytical tools available to help agencies characterize and quantitatively assess uncertainty, such as Monte Carlo simulations, and the IWG's social cost of greenhouse gas protocol incorporates those tools. For more details, please see the attached technical appendix on uncertainty.

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[31] *Id.* at 4-34.

[32] Agencies simply need to multiply their estimate of tons in each year by the IWG's 2016 values for the corresponding year of emissions (adjusted for inflation to current dollars). If the emissions change occurs in the future, agencies would then discount the products back to present value.

[33] 52 F. Supp. 3d at 1191 (quoting an e-mail comment on the draft statement for the quantification of tons).

[34] 538 F.3d at 1187.

[35] BOEM, *Liberty Development and Production Plan Draft EIS* at 3-129, 4,50 (2017) (89,940,000 minus 64,570,000 is about 25 million).

[36] DEIS at 4-164.

[37] *Center for Biological Diversity v. NHTSA*, 538 F.3d 1172, 1200 (9th Cir. 2008) ("[W]hile the record shows that there is a range of values, the value of carbon emissions reductions is certainly not zero.").

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

BLM incorrectly claims that "[c]urrent science… cannot link any specific instance of GHG emissions…to any specific climate-related environmental effects."[38] However, as we explain below, the social cost of greenhouse gases metric was designed for exactly that. Furthermore, the federal Interagency Working Group's 2016 social cost of greenhouse gases estimates remain the best available assessments for federal agencies to use in evaluating climate impacts.

In 2016, the 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).[39] Agencies must continue to use estimates of a similar or higher value[40] in their regulatory analyses and environmental impact statements. A recent Executive Order disbanding the IWG does not change the fact that the IWG estimates still reflect the best available data and methodologies. In particular, when estimating the social cost of greenhouse gases, agencies must use multiple peer-reviewed models, a global estimate of climate damages, and a 3% or lower discount rate for the central estimate. These methodological approaches are consistent with NEPA's directive that agencies adopt a global perspective and consider the effects of their actions on future generations.

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

Executive Order 13,783 officially disbanded the IWG and withdrew its technical support documents that underpinned their range of estimates.[41] 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."[42] Consequently, while OSM and other federal agencies no longer benefit from ongoing technical support from the IWG on use of the social cost of greenhouse gases, by no means does the new Executive Order imply that agencies should not monetize important effects in their regulatory analyses or environmental impact statements. In fact, Circular A-4 instructs agencies to monetize costs and benefits whenever feasible.[43] 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.[44] The Executive Order does not preclude agencies from using the same range of estimates as developed by the IWG, so long as the agency explains that the data and methodology that produced those estimates are consistent with Circular A-4 and, more broadly, with standards for rational decisionmaking.

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[38] DEIS at 4-319

[39] U.S. Interagency Working Group on the Social Cost of Greenhouse Gases, "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), *available at* https://obamawhitehouse.archives.gov/omb/oira/social-cost-of-carbon.

[40] *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).

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

[42] *Id.* § 5(c).

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

[44] 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).

Similarly, the Executive Order's withdrawal of the CEQ guidance on greenhouse gases does not —and legally cannot—remove agencies' statutory requirement to fully disclose the environmental impacts of greenhouse gas emissions. As CEQ explained in its withdrawal, the "guidance was not a regulation," and "[t]he withdrawal of the guidance does not change any law, regulation, or other legally binding requirement."[45] In other words, when the guidance originally recommended the appropriate use of the social cost of greenhouse gases in environmental impact statements,[46] it was simply explaining that the social cost of greenhouse gases is consistent with longstanding NEPA regulations and case law, all of which are still in effect today.

Notably, some agencies under the Trump administration have continued to use the IWG estimates even following the Executive Order. For example, in August 2017, the Bureau of Ocean Energy Management called the social cost of carbon "a useful measure" and applied it to analyze the consequences of offshore oil and gas drilling,[47] and in July 2017, the Department of Energy used the Interagency Working Group's 2016 estimates for carbon and methane emissions to analyze energy efficiency regulation, describing the social cost of methane as having "undergone multiple stages of peer review."[48]

For more detail on why the IWG's 2016 estimates remain the best values currently available to federal agencies and why the IWG's choice of a central estimate of global damages calculated at a 3% discount rate is appropriate under *Circular A-4*, please see the attached comments on the social cost of greenhouse gases submitted last year to the Bureau of Land Management.

A Global Estimate of Climate Damages Is Required by NEPA

BLM claims that "it is not possible to quantify the effects on local, regional, or global climates due to GHG emissions from a specific project."[49] Notably, NEPA requires BLM to take a global view in its climate analysis and use a global estimate for monetizing climate damages. Any uncertainty surrounding the local or regional climate impacts of the project does not justify failing to fully account for the project's global climate effects.

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."[50] Using a global social cost of greenhouse gases to analyze and set policy fulfills these instructions. Furthermore, the Act requires agencies to, "where consistent with the foreign policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of

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[45] 82 Fed. Reg. 16,576, 16,576 (Apr. 5, 2017).

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

[47] Draft Envtl. Impact Statement: Liberty Development Project at 3-129, 4-246 (Aug. 2017).

[48] Energy Conservation Program: Energy Conservation Standards for Walk-In Cooler and Freezer Refrigeration Systems, 82 Fed. Reg. 31,808, 31,811, 31,857 (July 10, 2017).

[49] DEIS at 4-13.

[50] 42 U.S.C. § 4332(2)(f) (emphasis added).

mankind's world environment."[51] By continuing to use the global social cost of greenhouse gases to spur reciprocal foreign actions, federal agencies "lend appropriate support" to the NEPA's goal of "maximize[ing] international cooperation" to protect "mankind's world environment." Furthermore, not only is it consistent with Circular A-4 and best economic practices to estimate the global damages of U.S. greenhouse gas emissions in regulatory analyses and environmental impact statements, but no existing methodology for estimating a "domestic-only" value is reliable, complete, or consistent with Circular A-4.

From 2010 through 2016, federal agencies based their regulatory decision and NEPA reviews on global estimates of the social cost of greenhouse gases. Though agencies often also disclosed a "highly speculative" range that tried to capture exclusively U.S. climate costs, emphasis on a global value was recognized as more accurate given the science and economics of climate change, as more consistent with best economic practices, and as crucial to advancing U.S. strategic goals.[52]

Opponents of climate regulation challenged the global number in court and other forums, and often attempted to use Circular A-4 as support.[53] 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."[54] Importantly, despite this language and such challenges, the U.S. Court of Appeals for the Seventh Circuit had no trouble concluding that a global focus for the social cost of greenhouse gases was reasonable:

> AHRI and Zero Zone [the industry petitioners] next contend that DOE [the Department of Energy] arbitrarily considered the global benefits to the environment but only considered the national costs. They emphasize that the [statute] only concerns "national energy and water conservation." In the New Standards Rule, DOE did not let this submission go unanswered. It explained that climate change "involves a global externality," meaning that carbon released in the United States affects the climate of the entire world. According to DOE, national energy conservation has global effects, and, therefore, those global effects are an appropriate consideration when looking at a national policy. Further, AHRI and Zero Zone point to no global costs that should have been considered alongside these benefits. Therefore, DOE acted reasonably when it compared global benefits to national costs.[55]

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

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

[52] *See generally* Howard & Schwartz, *supra* note **Error! Bookmark not defined.**.

[53] 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).

[54] 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.

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

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.[56]

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,"[57] suggesting that in some circumstances it is appropriate for the analysis to be global. For example, EPA and DOT have adopted a global perspective on the analysis of potential monopsony benefits to U.S. consumers resulting from the reduced price of foreign oil imports following energy efficiency increases, and EPA assesses the global potential for leakage of greenhouse gas emissions owing to U.S. regulation.[58]

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.[59] 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.[60]

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.[61] 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.[62] For example, Canada and Mexico have explicitly borrowed the IWG's global SCC metric to set

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[56] Circular A-4 at 3 (emphasis added).

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

[58] *See* Howard & Schwartz, *supra* note **Error! Bookmark not defined.**, at 268-69.

[59] *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.").

[60] 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

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

[62] *See* Howard & Schwartz, *supra* note **Error! Bookmark not defined.**, at Appendix B.

their own fuel efficiency standards.[63] For the United States to now depart from this collaborative dynamic by reverting to a domestic-only estimate would undermine the country's long-term interests and could jeopardize emissions reductions underway in other countries, which are already benefiting the United States.

For these and other reasons, the IWG properly relied on global estimates to develop its SCC metric, and many federal agencies have since relied on this global metric to evaluate and justify their decisions. At the same time, some agencies have, in addition to the global estimate, also disclosed a "highly speculative" estimate of the domestic-only effects of climate change. In particular, the Department of Energy always includes a chapter on a domestic-only value of carbon emissions in the economic analyses supporting its energy efficiency standards; EPA has also often disclosed similar estimates.[64] Such an approach is consistent with Circular A-4's suggestion that agencies should usually disclose domestic effects separately from global effects. However, as we have discussed, reliance on a domestic-only methodology would be inconsistent with both the inherent nature of climate change and the standards of Circular A-4. Consequently, it is appropriate under Circular A-4 for agencies to continue to rely on global estimates of the social cost of greenhouses to justify their regulatory decisions or their choice of alternatives under NEPA.

Moreover, no current methodology can accurately estimate a "domestic-only" value of the social cost of greenhouse gases. OMB, the National Academies of Sciences, and the economic literature all agree that existing methodologies for calculating a "domestic-only" value of the social cost of greenhouse gases are deeply flawed and result in severe and misleading underestimates. In developing the social cost of carbon, the IWG did offer some such domestic estimates. Using the results of one economic model (FUND) as well as the U.S. share of global gross domestic product (GDP), the group generated an "approximate, provisional, and ***highly speculative***" range of 7–23% of the global social cost of carbon as an estimate of the purely direct climate effects to the United States.[65] 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.[66]

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.[67] 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

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[63] *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).

[64] Howard & Schwartz, *supra* note **Error! Bookmark not defined.**, at 220-21.

[65] Interagency Working Group on Social Cost of Carbon, Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12,866 at 11 (2010) (emphasis added).

[66] *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").

[67] *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.

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.[68] 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."[69] GDP therefore does not reflect significant U.S. ownership interests in foreign businesses, properties, and other assets, as well as consumption abroad including tourism,[70] or even the 8 million Americans living abroad.[71] At the same time, GDP is also over-inclusive, counting productive operations in the United States that are owned by foreigners. Gross National Income (GNI), by contrast, defines its scope not by location but by ownership interests.[72] However, not only has GNI fallen out of favor as a metric used in international economic policy,[73] 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.[74] 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.[75]

Of course, there already are and will continue to be significant, quantifiable, localized effects of climate change. For example, a peer-reviewed EPA report, *Climate Change in the United States: Benefits of Global Action*, found that by the end of the century, the U.S. economy could face damages of $110 billion annually in lost labor productivity alone due to extreme temperatures, plus $11 billion annually in agricultural damages, $180 billion in losses to key economic sectors due to water shortages, and $5 trillion in damages U.S. coastal property.[76] But the existence of those examples of quantifiable estimates of localized damages does not mean that the current IAMs are able to extrapolate a U.S.-only number that accurately reflects total domestic damages—especially since, as already explained, the IAMs do not reflect spill overs.

As a result, in 2015, OMB concluded, along with several other agencies, that "good methodologies for estimating domestic damages do not currently exist."[77] Similarly, the NAS recently concluded that

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[68] 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).

[69] 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).

[70] "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.

[71] 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.

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

[73] *Id*.

[74] 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).

[75] 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).").

[76] EPA, *Climate Change in the United States: Benefits of Global Action* (2015).

[77] 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

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.[78] William Nordhaus, the developer of the DICE model, cautioned earlier this year that "regional damage estimates are both incomplete and poorly understood," and "there is little agreement on the distribution of the SCC by region."[79] In short, any domestic-only estimate will be inaccurate, misleading, and out of step with the best available economic literature, in violation of Circular A-4's standards for information quality.

For more details on the justification for a global value of the social cost of greenhouse gases, please see Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 Columbia J. Envtl. L. 203 (2017). Another strong defense of the global valuation as consistent with best economic practices appears in a letter published in a recent issue of *The Review of Environmental Economics and Policy*, co-authored by the late Nobel laureate economist Kenneth Arrow.[80]

Agencies Should Follow the Social Cost of Greenhouse Gas Protocol's Treatment of Uncertainty

The approach developed and utilized by the IWG remains the best methodology, based on the best currently available scientific and economic data. In particular, the IWG modeled the uncertainty over the value of the equilibrium climate sensitivity parameter using the Roe and Baker distribution calibrated to the IPCC reports. 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. Rather than guess about "a range of potential global temperature changes that may result," NHTSA must undertake a quantitative assessment of uncertainty and can rely on the same models and methodologies as the IWG to connect each ton of greenhouse gases avoided or emitted as a result of the CAFE standards with the associated global climate effects.[81]

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.[82] Because the

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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].

[78] NAS Second Report, *supra* note **Error! Bookmark not defined.**, at 53.

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

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

[81] NHTSA may have used other methodologies for quantitative assessment of uncertainty in the past.

[82] 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

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. Consequently, in any treatment of uncertainty, NHTSA should give sufficient attention to the long tail on the probability distribution that extends into high temperature ranges and catastrophic damages.

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

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

- There is no reason to believe the public or the government will be systematically risk seeking with respect to climate change.[83]
- 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.[84]
- 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.[85]

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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).

[83] 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 82, at 3 (citing 2009 survey).

[84] *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.").

[85] *See* Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, *supra* note 84; Peter Howard, *Omitted Damages: What's Missing from the Social Cost of Carbon* (Cost of Carbon Project Report, 2014); Frances C. Moore & Delavane

There is little to no support among economic experts to give weight to any estimate lower than the 5% discount rate estimate.[86] 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.[87] However, that does not mean it would be appropriate for individual agencies to rely on low-percentile estimates to justify decisions. While disclosing low-percentile estimates as a sensitivity analysis may promote transparency, relying on such an estimate for decisionmaking—in the face of contrary guidance from the best available science and economics on uncertainty and risk—would not be a "credible, objective, realistic, and scientifically balanced" approach to uncertainty.

More generally, agencies in general—and FERC in this particular instance—should remember that uncertainty is *not* a reason to abandon the social cost of greenhouse gas methodologies; quite the contrary uncertainty supports higher estimates of the social cost of greenhouse gases, because most uncertainties regarding climate change entail tipping points, catastrophic risks, and unknown unknowns about the damages of climate change. Because the key uncertainties of climate change include the risk of irreversible catastrophes, applying an options value framework to the regulatory context strengthens the case for ambitious regulatory action to reduce greenhouse gas emissions. There are numerous well-established, rigorous analytical tools available to help agencies characterize and quantitatively assess uncertainty, such as Monte Carlo simulations, and the IWG's social cost of greenhouse gas protocol incorporates those tools. For more details, please see the attached technical appendix on uncertainty.

Sincerely,

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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).

[86] 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 82, 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 82, at 18.

[87] 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.").

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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.[88] 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.[89] 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.[90] Rather than being a reason not to take action, uncertainty increases the SCC and should lead to more stringent policy to address climate change.[91]

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.[92] Stochastic uncertainty is persistent randomness in the economic-climate system, including various environmental phenomena such as volcanic eruptions and sun spots.[93] 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).[94]

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[88] 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.").

[89] Richard SJ Tol, Safe policies in an uncertain climate: an application of FUND, 9 *Global Environmental Change* 221-232 (1999); Peterson 2006 *supra* note **Error! Bookmark not defined.**.

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

[91] *See* cites *supra* note 90.

[92] 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).

[93] A potential third type of uncertainty arises due to ethical or value judgements: normative uncertainty. Peterson (2006) *supra* note 88; Geoffrey Heal & Antony Millner, *Reflections: Uncertainty and decision making in climate change economics*, 8 Review of Environmental Economics and Policy 120-137 (2014). For example, there is some normative debate over the appropriate consumption discount rate to apply in climate economics, though widespread consensus exists that using the social opportunity cost of capital is inappropriate (see earlier discussion). Preference uncertainty should be modeled as a declining discount rate over time (see earlier discussion), not using uncertain parameters. Kann & Weyant, *supra* note 261 and Golub et al. *supra* note 90.

[94] Peterson (2006), *supra* note *257*; Pindyck (2007), *supra* note 90; Heal & Millner 2014, *supra* note 93.

When modeling climate change uncertainty, scientists and economists have long emphasized the importance of accounting for the potential of catastrophic climate change.[95] Catastrophic outcomes combine several overlapping concepts including unlucky states of the world (i.e., bad draws), deep uncertainty, and climate tipping points and elements.[96] 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.[97] 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.[98] Given the general opinion that bad surprises are likely to outweigh good surprises in the case of climate change,[99] modelers capture deep uncertainty by selecting probability distributions with a fat upper tail which reflects the greater likelihood of extreme events.[100] 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).[101]

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.[102] 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.[103] Tipping point examples include the reorganization of the Atlantic meridional overturning circulation (AMOC) and a shift to a more persistent El Niño regime in the

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[95] 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).

[96] Kopp et al. (2016), *supra* note 95.

[97] *Id.*

[98] 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).

[99] 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).

[100] Weitzman (2011), *supra* note 98, 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."

[101] 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 98; Weitzman (2011), *supra* note 98.

[102] 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 95.

[103] *Id.*

Pacific Ocean.[104] 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.[105] There is some overlap between tipping point events and fat tails in that the probability distributions for how likely, how quick, and how damaging tipping points will be are unknown.[106] 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[107] 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.[108] Tol, Anthoff, and Hope employ this technique in FUND and PAGE—as did the IWG (2010, 2013, and 2016)[109]—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

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[104] *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 95, for a full list of known tipping elements and points.

[105] Kriegler et al. (2009), *supra* note 104; 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 95.

[106] 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 95.

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

[108] 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 90. 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.

[109] 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).

uncertainty, leading to a stricter policy when uncertainty is taken into account than when it is ignored.[110] 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)[111] reported the various moments and percentiles—including the 95th percentile—of the resulting SCC estimates. Third, the IWG put in place an updating process, e.g., the 2013 and 2016 revisions, which updates the models as new information becomes available.[112] 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.[113] 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.[114] Recent work in stochastic dynamic programming tends to better integrate fat tails –

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[110] Tol (1999), *supra* note 89, 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."

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

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

[113] Howard (2014), *supra* note 106. 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.

[114] Weitzman (2011), *supra* note 98; Kopp et al. (2016) *supra* note 95.

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.[115]

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.[116] In PAGE09, Hope also explicitly models climate tipping points as a singular, discrete event (of a 5% to 25% loss in GDP) that has a probability (which grows as temperature increases) of occurring in each time period.[117] 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.[118] Despite the obvious methodological basis for addressing tipping points, the latest versions of DICE[119] 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.[120]

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

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[115] Derek Lemoine & Christian P. Traeger, *Ambiguous tipping points*, 132 Journal of Economic Behavior & Organization 5-18 (2016); Lemoine & Rudik (2017), *supra* note 90. IAM modelers currently assume that society is equally averse to known unknown and known unknowns. Lemoine & Traeger, *id*.

[116] William Nordhaus & Joseph Boyer, Warning the World: Economic Models of Global Warming (2000); Nordhaus (2008) *supra* note 264; Howard (2014), *supra* note 106; Kopp et al. (2016) *supra* note 95.

[117] 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 106.

[118] Kopp et al. (2016) *supra* note 95.

[119] 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).

[120] 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).

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.[121] 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.[122] 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,[123] current IAM assumptions,[124] 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).[125] 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.[126] Option value reflects the value of future flexibility due to uncertainty and irreversibility; in this case, the irreversibility of CO2 emissions

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

[122] 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.

[123] IWG, 2010 *supra* note 278, at fn 22; Cai et al., 2016, *supra* note 105, at 521.

[124] The developers of each of the three IAMs used by the IWG (2010; 2013; 2016) assume a risk aversion society. Nordhaus and Sztorc 2013 *supra* note 276; Anthoff & Tol (2013) *supra* note 282; DAVID ANTHOFF & RICHARD S. J. TOL, THE CLIMATE FRAMEWORK FOR UNCERTAINTY, NEGOTIATION, AND DISTRIBUTION (FUND), TECHNICAL DESCRIPTION, VERSION 3.5 (2010); Chris Hope, *Critical issues for the calculation of the social cost of CO2: why the estimates from PAGE09 are higher than those from PAGE2002*, 117 CLIM. CHANGE 531–543 (2013) at 539.

[125] According to Heal and Millner (2014) *supra* note 262, there is an ongoing debate of whether ambiguity aversion is rational or a behavioral mistake. Given the strong possibility that this debate is unlikely to be resolved, the authors recommend exploring both assumptions.

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

In the discrete emission case, there are two overlapping types of option value: real option value and quasi-option value. Real option value is the full value of future flexibility of maintaining the option to mitigate, and mathematically equals the maximal value that can be derived from the option to [emit] now or later (incorporating learning) less the maximal value that can be derived from the possibility to [emit] now or never. Traeger (2014) *supra* note 295, equation 5. Quasi-option value is the value of future learning conditional on delaying the emission decision, which mathematically equals the value of mitigation to the decision maker who anticipates learning less the value of mitigation to the decision maker who anticipates only the ability to delay his/her decision, and not learning. *Id.* The two values are related, such that real option value can be decomposed into:

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

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

due to their long life in the atmosphere.[127] 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."[128] 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.[129] By nature of being optimization models (instead of policy models), these complex models focus on calculating the optimal tax and not the social cost of carbon, which differ in that the former is the present value of marginal damages on the optimal emissions path rather than on the BAU emissions path.[130] 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),[131] 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.

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

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

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

[130] 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).

[131] 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.

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.[132] 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.[133]

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.[134] For SDP models, uncertainty tends to strengthen the optimal emissions path relative to the determinist case even without tipping points,[135] and these results are strengthened under realistic preference assumptions.[136] Given that there is no counter-balancing tipping abatement cost,[137] 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

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

[133] Kann & Weyant *supra* note 261; Pindyck (2007) *supra* note 296; Golub et al. (2014) *supra* note *259*; Lemoine & Rudik 2017 supra note *259*. Comparing the optimal tax to the mean SCC is made further difficult by the frequent use of DICE as the base from which most stochastic dynamic optimization models are built. As a consequence, deterministic model runs are frequently the base of comparison for these models (Lemoine & Rudik, *id*).

[134] The real options literature tends to find an increase in the optimal emissions path under uncertainty relative to the deterministic case (Pindyck 2007 *supra* note 296), though the opposite is true when modelers account for the possibility of large damages (i.e., tipping point or black swan events) even with a risk-neutral society (Pindyck 2007 *supra* note 296; Golub et al 2014 *supra* note *259*). Solving finite horizon models employing non-recursive methods, modelers find that the results differ depending on the model of learning – the research demonstrates stricter emission paths under uncertainty without learning (with emission reductions up to 30% in some cases) and the impact under passive learning has a relatively small impact due the presence of sunken mitigation investment costs - except when tipping thresholds are included (Golub et al 2014 *supra* note *259*).

[135] Using SDP, modelers find that uncertainty over the equilibrium climate sensitivity parameter generally increases the optimal tax by a small amount, though the magnitude of this impact is unclear (Golub et al. (2014) *supra* note *259*; Lemoine & Rudik 2017 supra note *259*). Similarly, non-catastrophic damages can have opposing effects dependent on the parameters changed, though emissions appear to decline overall when you consider their uncertainty jointly.

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

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

in the optimal tax by 100%[138] to 800%[139] 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.[140] Recent research has shown that accurate estimation of decisions under uncertainty crucially depends on distinguishing between risk and time preferences.[141] 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.[142] 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.[143] Including more realistic preference assumptions in IAMs would further increase the SCC under uncertainty.

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

Conclusion: Uncertainty Raises the Social Cost of Greenhouse Gases

Overall, the message is clear: climate uncertainty is *never* a rationale for ignoring the SCC or shortening the time horizon of IAMs. Instead, our best estimates suggest that increased variability implies a higher SCC and a need for more stringent emission regulations.[144] Current omission of key features of the

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

[139] Cai et al. 2016 *supra* note 105.

[140] Cai et al. 2016 *supra* note 105; Lemoine & Rudik 2017 supra note *259*. The standard utility function adopted in IAMs with constant relative risk version implies that the elasticity of substitution equals the inversion of relative risk aversion. As a 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 105 replace the DICE risk aversion of 1.45 and elasticity parameter of 1/1.45 with values of 3.066 and 1.5, respectively.

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

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

[143] Typically, IAMs assume constant relative prices of consumption goods. Reyer Gerlagh & B. C. C. Van der Zwaan, *Long-term substitutability between environmental and man-made goods*, 44 Journal of Environmental Economics and Management 329-345 (2002); Thomas Sterner & U. Martin Persson, *An even sterner review: Introducing relative prices into the discounting debate*, 2 Review of Environmental Economics and Policy 61-76 (2008). By replacing the standard isoelastic utility function in IAMs with a nested CES utility function following Sterner and Persson (2008), Cai et al. (2015) find that even a relatively small tipping point (i.e., a 5% loss) can substantially increase the SCC in the stochastic dynamic setting. Yongyang Cai, Kenneth L. Judd, Timothy M. Lenton, Thomas S. Lontzek, & Daiju Narita, *Environmental tipping points significantly affect the cost− benefit assessment of climate policies*, 112 PROC. NATL. ACAD. SCI. 4606-4611 (2015).

[144] Golub et al. (2014) *supra* note *259* states "The most important general policy implication from the literature is that despite a wide variety of analytical approaches addressing different types of climate change uncertainty, none of those studies supports the argument that no action against climate change should be taken until uncertainty is resolved. On the contrary, uncertainty despite its resolution in the future is often found to favor a stricter policy." *See also* Comments from Robert Pindyck, to BLM, on the Social Cost of Methane in the Proposed Suspension of the Waste Prevention Rule (submitted Nov. 5, 2017) ("Specifically, my expert opinion about the uncertainty associated with Integrated Assessment Models (IAMs) was used to justify setting the SC-CH4 to zero until this uncertainty is resolved. That conclusion does not logically follow and I have

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.

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."