



July 25, 2018

To: Federal Energy Regulatory Commission

Docket: No. PL18-1-000

Subject: Using the Social Cost of Greenhouse Gases to Weigh the Climate Impacts of New Natural Gas Transportation Facilities in Environmental Analyses and in Reviews of Public Convenience and Necessity

The following comments on the appropriate use of the social cost of greenhouse gases in the certification of new interstate natural gas facilities are submitted jointly by the Environmental Defense Fund, Institute for Policy Integrity at New York University School of Law, Natural Resources Defense Council, Sierra Club, and Union of Concerned Scientists.

Our organizations may separately and independently submit other comments on other issues raised by the Notice of Inquiry.¹ In particular, our organizations may submit other comments on when and how the tons of greenhouse gas emissions from natural gas transportation projects should be quantified in environmental assessments and environmental impact statements under the National Environmental Policy Act (NEPA) as well as in the review of public convenience and necessity under the Natural Gas Act (NGA), including arguments on why upstream and downstream emissions should be quantified, and on the best available data and methodologies for quantifying those emissions.

These joint comments focus instead on why and how the climate damages associated with greenhouse gas emissions should be monetized once the tons of emissions have been quantified. By monetizing climate damages, FERC can fulfill its legal obligations under NEPA to take a hard look at the incremental climate impacts of a project and to provide sufficient context to inform decisionmakers and the public of the consequences of alternative courses of action. Furthermore, by monetizing climate damages, FERC fulfills the goal under the NGA of reasonably and fully evaluating all factors bearing on the public interest. Neither quantifying the volume of emissions nor calculating a percentage of sectoral, regional, or national emissions is alone sufficient to fulfill these purposes. Regardless of legal obligations, monetizing damages can conveniently facilitate FERC's determination of whether the multitude of climate effects from a project's greenhouse gas emissions are cumulatively significant.

FERC's past arguments against using the social cost of greenhouse gas metrics all have straightforward rebuttals:

- There is a strong consensus about the appropriate discount rate to use to monetize future climate damages: specifically, a 3% or lower rate, and definitely not a 7% rate.
- Monetization of climate damages conveniently facilitates the very dilemma that FERC cites as an obstacle to using the social cost of greenhouse gases—namely, weighing the significance of effects.
- Monetization of climate damages is useful and appropriate regardless of whether FERC implements a full cost-benefit analysis in either its environmental reviews or its public convenience and necessity reviews.

¹ 83 Fed. Reg. 18,020 (Apr. 25, 2018).

- Monetization of climate damages is appropriate not just in rulemakings, but to facilitate any comparison of alternatives, including the required alternatives analysis under NEPA as well as the review of public convenience and necessity under the NGA.
- A global perspective that accounts for how international spillovers and foreign reciprocity affect U.S. welfare is appropriate under both NEPA and the NGA.

To monetize climate damages, the federal Interagency Working Group (IWG)'s 2016 estimates of the social cost of greenhouse gas continue to reflect the best available science and economics, and— notwithstanding a recent executive order disbanding the group²—federal agencies should continue to use estimates of a similar or higher value.³ FERC should use not just the IWG's 2016 estimates of the social cost of carbon, but also the IWG's 2016 estimates of the social cost of methane and social cost of nitrous oxide.

These comments primarily respond to question C.7 of the Notice of Inquiry, as well as the elements of questions C.3 and C.4 that ask about evaluating the significance of impacts.

I. Monetizing Climate Damages Fulfills the Obligations and Goals of NEPA and the NGA

When a project has climate consequences that must be assessed under NEPA, monetizing the climate damages fulfills an agency's legal obligations under NEPA in ways that simple quantification of tons of greenhouse gas emissions cannot. Similarly, if FERC has already quantified greenhouse gas emissions to weigh directly in its review of public convenience and necessity, monetizing the associated climate damages will fulfill the goals of the NGA.

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 environmental impact statement must disclose relevant climate effects.⁵ NEPA requires "a reasonably thorough discussion of the significant aspects of the probable environmental consequences," to "foster both informed decisionmaking and informed public

² Exec. Order No. 13,783 § 5, 82 Fed. Reg. 16,093 (Mar. 28, 2017), disbands the IWG and instructs "agencies" to use the "best available science and economics," "consistent with the guidance contained in OMB Circular A-4," to "monetize[e] the value of changes in greenhouse gas emissions." First, the IWG's 2016 estimates are consistent with the best available science and economics, and with Circular A-4, as explained *infra*. Second, neither Circular A-4 nor, presumably, Executive Order 13,783 is strictly binding on an independent agency such as FERC.

³ A higher value is appropriate because, while the 2016 estimates from the IWG draw from the best available data, see Richard L. Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 Science 6352 (2017), the IWG estimates nevertheless omit key damage categories and are widely recognized as almost certainly severe underestimates of actual climate damages, see, e.g. Richard L. Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, 508 Nature 173 (2014) (co-authored with Nobel laureate Kenneth Arrow); R.S. Pindyck, *The Social Cost of Carbon Revisited* (Nat'l Bureau of Econ. Res. Working Paper w22807, 2016) (estimating the social cost of carbon as between \$100 and \$200 per metric ton, based on expert elicitation to capture willingness to pay to avoid catastrophes).

⁴ *Baltimore Gas & Elec. Co. v. Natural Res. Def. Council*, 462 U.S. 87, 96 (1983) (emphasis added); see also 40 C.F.R. § 1508.8(b) (requiring assessment of the "ecological," "economic," "social," and "health" "effects") (emphasis added).

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).

participation.”⁶ In particular, “[t]he impact of greenhouse gas emissions on climate change is precisely the kind of cumulative impact analysis that NEPA requires,” and it is arbitrary to fail to “provide the necessary contextual information about the cumulative and incremental environmental impacts.”⁷ Furthermore, the analyses included in environmental assessments and impact statements “cannot be misleading.”⁸ An agency must provide sufficient informational context to ensure that decisionmakers and the public will not misunderstand or overlook the magnitude of a proposed action’s climate risks compared to the no action alternative. As this section explains, by only quantifying the volume of greenhouse gas emissions, agencies fail to assess and disclose the actual climate consequences of an action and misleadingly present information in ways that will cause decisionmakers and the public to overlook important climate consequences. Using the social cost of greenhouse gas metrics to monetize climate damages fulfills NEPA’s legal obligations in ways that quantification alone cannot.

Similarly, monetizing climate damages advances the NGA’s goals of reasoned decisionmaking. To assess whether a project is “required by present or future public convenience and necessity,”⁹ FERC must “evaluate *all factors* bearing on the public interest.”¹⁰ Relevant factors include any “adverse effects” to “general societal interests,” and specifically include “environmental impacts” beyond just those experienced by landowners and the surrounding community, extending to cover the range of “other environmental issues considered under the National Environmental Policy Act.”¹¹ When FERC “articulate[s] the critical facts upon which it relies” to review public convenience and necessity, “[a] passing reference to relevant factors . . . is not sufficient to satisfy the Commission’s obligation to carry out ‘reasoned’ and ‘principled’ decisionmaking. [Courts] have repeatedly required the Commission to ‘fully articulate the basis for its decision.’”¹² Consequently, when FERC weighs a project’s climate consequences directly into its review of public convenience and necessity, monetization using the social cost of greenhouse gas metrics achieves the goal of fully articulating a relevant factor, while quantification alone would obscure important details.

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

The tons of greenhouse gases emitted by a project are not the “actual environmental effects” (under NEPA), nor are they the relevant “factors bearing on the public interest” (under the NGA). Rather, the actual effects and relevant factors are the incremental climate impacts caused by those emissions, including:¹³

⁶ *Ctr. for Biological Diversity*, 538 F.3d at 1194 (citations omitted).

⁷ *Id.* at 1217.

⁸ *High Country Conservation Advocates v. U.S. Forest Service*, 52 F. Supp. 3d 1174, 1182 (D. Colo. 2014); *accord. Johnston v. Davis*, 698 F.2d 1088, 1094-95 (10th Cir. 1983) (disapproving of “misleading” statements resulting in “an unreasonable comparison of alternatives”); *Hughes River Watershed Conservancy v. Glickman*, 81 F.3d 437, 446 (4th Cir. 1996) (“For an EIS to serve these functions” of taking a hard look and allowing the public to play a role in decisionmaking, “it is essential that the EIS not be based on misleading economic assumptions”); *see also Sierra Club v. Sigler*, 695 F.2d 957, 979 (5th Cir. 1983) (holding that an agency’s “skewed cost-benefit analysis” was “deficient under NEPA”); *see generally Bus. Roundtable v. SEC*, 647 F.3d 1144, 1148-49 (D.C. Cir. 2011) (criticizing an agency for “inconsistently and opportunistically fram[ing] the costs and benefits of the rule” and for “fail[ing] adequately to quantify the certain costs or toe explain why those costs could not be quantified”).

⁹ 15 U.S.C. § 717f(e).

¹⁰ *Missouri Public Serv. Comm’n v. FERC*, 234 F. 3d 36, 38 (D.C. Cir. 2000) (quoting *Atlantic Ref. Co. v. Public Serv. Comm’n*, 360 U.S. 378, 391 (1959)) (emphasis added).

¹¹ 88 FERC ¶ 61,227, Statement of Policy at pp.23-24 (Sept. 15, 1999). *See, e.g., Minisink Residents for Env’tl. Pres. v. FERC*, 762 F.3d 97, 101 (D.C. Cir. 2014) (“listing “conservation” and “environmental . . . issues” as the NGA’s “subsidiary purposes”).

¹² *Missouri Public Serv. Comm’n*, 234 F.3d at 40, 41 (citations omitted).

¹³ These impacts are all included to some degree in the three integrated assessment models (IAMs) used by the IWG (namely, the DICE, FUND, and PAGE models), though some impacts are modeled incompletely, and many other important damage

- property lost or damaged by sea-level rise, coastal storms, flooding, and other extreme weather events, as well as the cost of protecting vulnerable property and the cost of resettlement following property losses;
- changes in energy demand, from temperature-related changes to the demand for cooling and heating;
- lost productivity and other impacts to agriculture, forestry, and fisheries, due to alterations in temperature, precipitation, CO₂ fertilization, and other climate effects;
- human health impacts, including cardiovascular and respiratory mortality from heat-related illnesses, changing disease vectors like malaria and dengue fever, increased diarrhea, and changes in associated pollution;
- changes in fresh water availability;
- ecosystem service impacts;
- impacts to outdoor recreation and other non-market amenities; and
- catastrophic impacts, including potentially rapid sea-level rise, damages at very high temperatures, or unknown events.

Even in combination with a general, qualitative discussion of climate change, by calculating only the tons of greenhouse gases emitted or a percent comparison to sectoral or national emissions, an agency fails to meaningfully assess the actual incremental impacts to property, human health, productivity, and so forth.¹⁴ An agency therefore falls short of its legal obligations and statutory objectives by focusing just on volume estimates. Similarly, courts have held that just quantifying the acres of timber to be harvested or the miles of road to be constructed does not constitute a “description of *actual* environmental effects,” even when paired with a qualitative “list of environmental concerns such as air quality, water quality, and endangered species,” when the agency fails to assess “the degree that each factor will be impacted.”¹⁵

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

¹⁴ See *High Country*, 52 F. Supp. 3d at 1190 (“Beyond quantifying the amount of emissions relative to state and national emissions and giving general discussion to the impacts of global climate change, [the agencies] did not discuss the impacts caused by these emissions.”); *Mont. Env’tl. Info. Ctr. v. U.S. Office of Surface Mining*, 274 F. Supp. 3d 1074, 1096–99 (D. Mont. 2017) (rejecting the argument that the agency “reasonably considered the impact of greenhouse gas emissions by quantifying the emissions which would be released if the [coal] mine expansion is approved, and comparing that amount to the net emissions of the United States”).

¹⁵ *Klamath-Siskiyou Wildlands Ctr. v. Bureau of Land Mgmt.*, 387 F.3d 989, 995 (9th Cir. 2004) (“A calculation of the total number of acres to be harvested in the watershed is . . . not a sufficient description of the actual environmental effects that can be expected from logging those acres.”); see also *Oregon Natural Res. Council v. Bureau of Land Mgmt.*, 470 F.3d 818 (9th Cir. 2006).

By monetizing climate damages using the social cost of greenhouse gas metrics, FERC can satisfy the legal obligations and statutory goals to assess the incremental and actual effects bearing on the public interest. The social cost of greenhouse gas methodology calculates how the emission of an additional unit of greenhouse gases affects atmospheric greenhouse concentrations, how that change in atmospheric concentrations changes temperature, and how that change in temperature incrementally contributes to the above list of economic damages, including property damages, energy demand effects, lost agricultural productivity, human mortality and morbidity, lost ecosystem services and non-market amenities, and so forth.¹⁶ The social cost of greenhouse gas tool therefore captures the factors that actually affect public welfare and assesses the degree of impact to each factor, in ways that just estimating the volume of emissions cannot.

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

The climate damage generated by each additional ton of greenhouse gas emissions depends on the background concentration of greenhouse gases in the global atmosphere. Once emitted, greenhouse gases can linger in the atmosphere for centuries, building up the concentration of radiative-forcing pollution and affecting the climate in cumulative, non-linear ways.¹⁷ As physical and economic systems become increasingly stressed by climate change, each marginal additional ton of emissions has a greater, non-linear impact. The climate damages generated by a given amount of greenhouse pollution is therefore a function not just of the pollution's total volume but also the year of emission, and with every passing year an additional ton of emissions inflicts greater damage.¹⁸

As a result, focusing just on the volume or rate of emissions is insufficient to reveal the incremental effect on the climate. The change in the rate of emissions (flow) must be assessed given the background concentration of emissions (stock). A percent comparison to national emissions is perhaps even more misleading. A project that adds 23 million additional tons per year of carbon dioxide would have contributed to 0.43% of total U.S. carbon dioxide emissions in the year 2012.¹⁹ In the year 2014, that same project with the same carbon pollution would have contributed to just 0.41% of total U.S. carbon dioxide emissions—a seemingly smaller relative effect, since the total amount of U.S. emissions increased from 2012 to 2014.²⁰ However, because of rising background concentrations of global greenhouse gas stock, and because of growing stresses in physical and economic systems, the marginal climate damages per ton of carbon dioxide (as measured by the social cost of carbon) increased from \$33 in 2012 to \$35 in 2014 (in 2007\$).²¹ Consequently, those 23 million additional tons would have caused marginal climate damages costing \$759 million in the year 2012, but by 2014 that same 23 million tons would have caused \$805 million in climate damages. To summarize: the percent comparison to national emissions misleadingly implied that a project adding 23 million more tons of carbon dioxide would have a relatively less significant effect in 2014 than in 2012, whereas monetizing climate damages

¹⁶ 2010 TSD, *supra* note 13, at 5.

¹⁷ Carbon dioxide also has cumulative effects on ocean acidification, in addition to cumulative radiative-forcing effects.

¹⁸ See 2010 TSD, *supra* note 13, at 33 (explaining that the social cost of greenhouse gas estimates grow over time).

¹⁹ Total U.S. carbon dioxide emissions in 2012 were 5,366.7 million metric tons (for all greenhouse gases, emissions were 6,529 MMT CO₂ eq). See EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016* at ES-6, tbl. ES-2 (2018).

²⁰ Total U.S. carbon dioxide emissions in 2014 were 5,568.8 million metric tons (and for all greenhouse gases, 6,763 MMT CO₂ eq.) *Id.*

²¹ 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* at 25 tbl. A1 (2016) (calculating the central estimate at a 3% discount rate), https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc_tsd_final_clean_8_26_16.pdf [hereinafter 2016 TSD].

would accurately reveal that the emissions in 2014 were much more damaging than the emissions in 2012—almost \$50 million more.

Capturing how marginal climate damages change as the background concentration changes is especially important because NEPA and the NGA require assessing both present and future impacts. For example, the NGA requires considering “present” and “future” convenience and necessity,²² and FERC must consider both potentially positive and negative environmental outcomes.²³ Different project alternatives can have different greenhouse gas consequences over time. Most simply, different alternatives could have different start dates or other consequential changes in timing. Furthermore, a project’s relative greenhouse gas effect compared to other alternatives or to the no-action *status quo* can change over time as the fuel mix in the overall market changes.²⁴ For the reasons explained above, calculating volumes or percentages is insufficient to accurately compare the climate damages of project alternatives with varying greenhouse gas emissions over time.

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

Monetization Provides the Required Informational Context that Volume Estimates Lack

NEPA requires sufficient informational context; the NGA requires a reasoned explanation of factors and more than “passing references.” Yet without proper context, numbers like 23 million metric tons of carbon dioxide, or 0.42% of national emissions, will be misinterpreted by people as meaningless, as zero. FERC has admitted as much in its Notice of Inquiry, explaining that “calculating a proposed project’s emissions as a percentage of sector, nationwide, or global emissions” will “[g]enerally” be “too low to be considered meaningful because project emissions would be miniscule compared to nationwide or global emissions.”²⁵ Indeed, in a country of over 300 million people and over 6.5 billion tons of annual greenhouse gas emissions, it is far too easy to make highly significant effects appear relatively “miniscule.” For example, presenting all weather-related deaths as less than 0.1% of total U.S. deaths makes the risk of death by weather event sound trivial, but in fact that figure represents over 2,000 premature deaths per year²⁶—hardly an insignificant figure.²⁷

Economic theory explains why monetization is a much better tool than volume estimates or percent comparisons to provide the necessary contextual information on climate damages. For example, many decisionmakers and interested citizens would wrongly reduce down to zero the climate risks associated with 0.42% of total U.S. emissions, simply due to the leading zero before the decimal in that percentage. As Professor Cass Sunstein has explained—drawing from the work of recent Nobel laureate economist

²² 15 U.S.C. § 717f(e).

²³ See, e.g., *Myersville Citizens for a Rural Community v. FERC*, 783 F.3d 1301, 1309 (D.C. Cir. 2015).

²⁴ See U.S. Energy Info. Admin., *Annual Energy Outlook 2018 with Projections to 2050* at 84 (2018) (projecting coal’s share of electricity generation to decline over time, while renewables’ share increases).

²⁵ 83 Fed. Reg. at 18,029.

²⁶ Compare Nat’l Ctr. for Health Stat., Ctrs. for Disease Control & Prevention, *Death Attributed to Heat, Cold, and Other Weather Events in the United States, 2006-2010* at 1 (2014) (reporting about 2000 weather-related deaths per year) with Nat’l Ctr. for Health Stat., *Deaths and Mortality*, <https://www.cdc.gov/nchs/fastats/deaths.htm> (reporting about 2.7 million U.S. deaths per year total).

²⁷ The public willingness to pay to avoid mortality is typically estimated at around \$9.6 million (in 2016\$). E.g., 83 Fed. Reg. 12,086, 12,098 (Mar. 19, 2018) (U.S. Coast Guard rule using the Department of Transportation’s value of statistical life in a recent analysis of safety regulations). Losing 2,000 lives prematurely to weather-related events is equivalent to a loss of public welfare worth over \$19 billion per year.

Richard Thaler—a well-documented mental heuristic called “probability neglect” causes people to irrationally reduce small probability risks entirely down to zero.²⁸ People have significant “difficulty understanding a host of numerical concepts, especially risks and probabilities.”²⁹ Reducing 23 million tons of additional carbon dioxide emissions to 0.42% of national emissions misleadingly makes the climate impacts appear vanishingly small. By comparison, by applying the social cost of carbon dioxide (about \$50 per ton in 2017\$), decisionmakers and the public can readily comprehend that 23 million tons of carbon dioxide emitted in the year 2020 will generate over \$1 billion in climate damages.

Similarly, many people will be unable to distinguish the significance of project alternatives or scenario analyses with different emissions: for example, 23 million metric tons versus 8.36 million metric tons.³⁰ 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.”³¹ Abstract volume estimates fail to give people the required informational context due to another well-documented mental heuristic called “scope neglect.” Scope neglect, as explained by Nobel laureate Daniel Kahneman, among others, causes people to ignore the size of a problem when estimating the value of addressing the problem. For example, in one often-cited study, subjects were unable to meaningfully distinguish between the value of saving 2,000 migratory birds from drowning in uncovered oil ponds, as compared to saving 20,000 birds.³²

Scope neglect means many decisionmakers and members of the public would be unable to meaningfully distinguish between the climate risks of 23 million metric tons of carbon emissions versus the climate risks of 8.36 million metric tons. While decisionmakers and the public certainly can discern that one number is higher, without any context it may be difficult to weigh the relative magnitude of the climate risks. In contrast, the different climate risks would have been readily discernible through application of the social cost of greenhouse gas metrics. In this example, the difference between the two scenarios is \$732 million per year in climate damages.

In general, non-monetized effects are often irrationally treated as worthless.³³ On several occasions, courts have struck down administrative decisions for failing to give weight to non-monetized effects.³⁴ 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.”³⁵ Monetizing climate damages provides the informational context required by NEPA and the NGA, whereas a simple tally of emissions

²⁸ Cass R. Sunstein, *Probability Neglect: Emotions, Worst Cases, and Law*, 112 Yale L. J. 61, 63, 72 (2002).

²⁹ Valerie Reyna & Charles Brainerd, *Numeracy, Ratio Bias, and Denominator Neglect in Judgments of Risk and Probability*, 18 Learning & Individual Differences 89 (2007).

³⁰ These numbers are taken from the Supplemental Environmental Impact Statement for the Southeast Market Pipelines Project, specifically the greenhouse gas estimates for the full burn analysis versus the net PTE analysis. Different project alternatives considered by FERC, especially if alternatives included different capacity pipelines, could just as easily have different emission estimates.

³¹ EPA, *Greenhouse Gas Equivalencies Calculator*. Available at <https://web.archive.org/web/20180212182940/https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator> (last updated Sept. 2017) (“Did you ever wonder what reducing carbon dioxide (CO₂) emissions by 1 million metric tons means in everyday terms? The greenhouse gas equivalencies calculator can help you understand just that, translating abstract measurements into concrete terms you can understand.”).

³² Daniel Kahneman et al., *Economic Preferences or Attitude Expressions? An Analysis of Dollar Responses to Public Issues*, 19 J. Risk & Uncertainty 203, 212-213 (1999).

³³ Richard Revesz, *Quantifying Regulatory Benefits*, 102 Cal. L. Rev. 1424, 1434-35, 1442 (2014).

³⁴ See *id.* at 1428, 1434.

³⁵ 538 F.3d at 1199.

volume and rote, qualitative, generic description of climate change are misleading and fail to give the public and decisionmakers the required information about the magnitude of discrete climate effects.³⁶

Climate Effects Must Be Monetized If Other Costs and Benefits Are Monetized

Though NEPA does not always require a full and formal cost-benefit analysis,³⁷ agencies' approaches to assessing costs and benefits must be balanced and reasonable. Courts have warned agencies, for example, 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.³⁸

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."³⁹ 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 monetize climate costs using the readily available social cost of carbon protocol.⁴⁰ 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.⁴¹

High Country and *MEIC v. OSM* were simply the latest applications of a broader line of case law in which courts find it arbitrary and capricious to apply inconsistent protocols for analyzing some effects compared to others, especially when the inconsistency obscures some of the most significant effects.⁴² For example, in *Center for Biological Diversity v. National Highway Traffic Safety Administration*, the U.S.

³⁶ See 42 U.S.C. § 4332(2)(B) (requiring agencies to "identify and develop methods and procedures . . . which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decisionmaking along with economic and technical considerations").

³⁷ 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."); *but see e.g., Sierra Club v. Sigler*, 695 F.2d 957, 978-79 (5th Cir. 1983) (holding that NEPA "mandates at least a broad, informal cost-benefit analysis," and so agencies must "fully and accurately" and "objectively" assess environmental, economic, and technical costs); *Chelsea Neighborhood Ass'ns v. U.S. Postal Serv.*, 516 F.2d 378, 387 (2d Cir. 1975) ("NEPA, in effect, requires a broadly defined cost-benefit analysis of major federal activities."); *Calvert Cliffs' Coordinating Comm. v. U.S. Atomic Energy Comm'n*, 449 F.2d 1109, 1113 (D.C. Cir. 1971) ("NEPA mandates a rather finely tuned and 'systematic' balancing analysis" of "environmental costs" against "economic and technical benefits"); *Nat'l Wildlife Fed. v. Marsh*, 568 F. Supp. 985, 1000 (D.D.C. 1983) ("The cost-benefit analysis of NEPA is concerned primarily with environmental costs. . . . A court may examine the cost-benefit analysis only as it bears upon the function of insuring that the agency has examined the environmental consequences of a proposed project.").

³⁸ *High Country Conservation Advocates*, 52 F. Supp. 3d at 1191; *accord. MEIC v. Office of Surface Mining*, 274 F. Supp. 3d at 1094-99 (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).

³⁹ 52 F. Supp. 3d at 1191.

⁴⁰ *Id.*

⁴¹ 274 F. Supp. 3d at 1094-99 (also holding that it was arbitrary to imply that there would be zero effects from greenhouse gas emissions).

⁴² 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).

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.”⁴³ Specifically, it was arbitrary to “assign[] no value to *the most significant benefit* of more stringent [vehicle fuel efficiency] standards: reduction in carbon emissions.”⁴⁴ When an agency bases a decision on cost-benefit analysis, it is arbitrary to “put a thumb on the scale by undervaluing the benefits and overvaluing the costs.”⁴⁵ Similarly, the U.S. Court of Appeals for the District of Columbia Circuit has chastised agencies for “inconsistently and opportunistically fram[ing] the costs and benefits of the rule [and] fail[ing] adequately to quantify certain costs or to explain why those costs could not be quantified”⁴⁶; and the U.S. Court of Appeals for the Tenth Circuit has remanded an environmental impact statement because “unrealistic” assumptions “misleading[ly]” skewed comparison of the project’s positive and negative effects.⁴⁷

FERC’s environmental impact statements regularly monetize “economic benefits” similar to those highlighted in *High Country* and *MEIC*, including direct and indirect labor income, expenditures, tax revenues, and other “long-term benefits to the local and regional economy.”⁴⁸ Unlike other agencies, FERC may not always calculate total output or consumer valuation of the increased gas throughput, in terms of the market value of the amount of gas transported. But when it does calculate and tout other economic benefits, FERC cannot inconsistently monetize some economic benefits but fail to use a readily available protocol to monetize important environmental costs.

EarthReports and Minisink Are Distinguishable

In *EarthReports v. FERC*, the U.S. Court of Appeals for the D.C. Circuit had excused FERC’s failure to use the social cost of carbon in a 2014 environmental assessment of a liquefied natural gas facility because of (1) the alleged lack of consensus about the appropriate discount rates, (2) the alleged disconnect between the tool and actual environmental impacts, and (3) the alleged lack of criteria for significance.⁴⁹ Advancements in the economic literature, in FERC’s own understanding of the social cost of greenhouse gases, and in the case law since the 2014 environmental assessment at stake in *EarthReports* all make that case now distinguishable.

First, to the extent there ever was a lack of consensus about the appropriate discount rate, recent reports from the National Academies of Sciences, among other sources, make clear that a 3% discount rate or lower—or optimally a declining discount rate—are appropriate, while a 7% discount rate is wholly inappropriate. As discussed further below in these comments in a section on the discount rate, the first basis for the decision in *EarthReports* no longer holds true.

Second, FERC now admits that “[o]n 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.”⁵⁰ A longer discussion of FERC’s concession on physical impacts appears below in these comments in a section on significance, but, in short, the second basis for the decision in *EarthReports*—the alleged disconnect between the tool and actual environmental impacts—no longer holds true.

⁴³ 538 F.3d 1172, 1203 (9th Cir. 2008).

⁴⁴ *Id.* at 1199.

⁴⁵ *Id.* at 1198.

⁴⁶ *Bus. Roundtable v. SCC*, 647 F.3d 1144, 1148-49 (D.C. Cir. 2011)

⁴⁷ *Johnston v. Davis*, 698 F.2d 1088, 1094–95 (10th Cir. 1983)

⁴⁸ E.g., FERC, *Final Environmental Impact Statement for Southeast Market Pipelines Project* at 3-185 to 3-214 (2015).

⁴⁹ 828 F.3d 949, 956 (D.C. Cir. 2016).

⁵⁰ 162 FERC ¶ 61,233 (Mar. 14, 2018) [hereinafter Sabal Remand Order] at para. 48.

The third basis for the decision in *EarthReports*, the alleged lack of criteria for significance, is also wrong, for reasons explained further below. But it is especially notable that additional case law since *EarthReports* has made clear that it is arbitrary to tout the monetized upside of a project in an environmental assessment or impact statement while refusing to apply available tools to monetize the project's costs. Crucially, the court in *EarthReports* never considered or ruled on the need for parity in the treatment of costs and benefits. By translating costs and benefits into the common metric of money, monetization facilitates comparing the significance of various effects. FERC and other agencies routinely translate economic benefits like employment effects into monetized terms to gauge their significance; the significance of monetizable costs, like climate damages, should be gauged on the same basis.

Another case, *Minisink Residents for Environmental Preservation and Safety v. FERC*, is also distinguishable on the facts.⁵¹ The D.C. Circuit disagreed with petitioners' argument that NEPA required FERC to "focus[] more" than it had "on the monetary costs and benefits of the respective proposals."⁵² However, in that case, FERC's "fail[ure] to undertake a more fulsome cost-benefit analysis"⁵³ did not constitute a failure to consider the actual, relevant impacts of the project. Petitioners' complaint was that, in comparing two project alternatives, FERC had not explicitly compared monetized estimates of long-term operating costs and savings against monetized estimates of capital costs; petitioners also cited insufficient supporting data for the estimates of capital costs.⁵⁴ In other words, petitioners wanted FERC to base its choice between alternatives on a summing of monetized costs and cost-savings, to use a monetized cost-benefit equation as the exclusive tool for weighing the relevant factors that the agency had identified.⁵⁵ That is a very different argument than the one made here, which is that by failing to monetize climate damages using the social cost of greenhouse gases, FERC in fact fails to give any weight to the actual, incremental effects of climate change. As explained further below, FERC can use the social cost of greenhouse gases without necessarily conducting a full cost-benefit analysis. Because climate damages are diffused geographically and temporally and vary with increasing stock concentrations, monetization is especially crucial to capture the actual environmental impacts of greenhouse gas emissions. Unlike the *Minisink* petitioners' complaints about under-analyzed operating costs, failing to consider the actual incremental climate impacts of a project in an environmental impact statement is not mere "flyspecking"⁵⁶—rather, it goes to the heart of the hard look requirement. And whereas the *Minisink* petitioners did not identify an alternate methodology for estimating the operating and capital costs, a readily available and widely accepted tool exists to monetize climate damages: the social cost of greenhouse gases.

⁵¹ 762 F.3d 97 (D.C. Cir. 2014).

⁵² *Id.* at 112.

⁵³ *Id.*

⁵⁴ Pet'rs Reply Brief at 12, 2013 WL 5935149; Pet'r Opening Brief at 42, 2013 WL 5935148; see also Respondent Brief at 35, 2013 WL 5935151 ("Residents assert that the Commission violated NEPA by failing to include in the Environmental Assessment a cost-benefit analysis that compares the cost of the Project versus the Wagoner Alternative.").

⁵⁵ Reply Brief, *supra* note 54, at 12 ("Over a 30-year project lifetime, the reduced operating expenses readily exceed the capital costs of Wagoner if they are fifty percent more and come close to offsetting the capital costs of Wagoner if it costs twice as much."); Opening Brief, *supra* note 54, at 42-43 ("EA lacks any rigorous analysis of whether the savings in fuel costs over the life of the project make the Wagoner project more cost effective overall [after comparison to the capital costs].").

⁵⁶ Note that the *Minisink* case concerned an environmental assessment, and the court acknowledged that the requirements to monetize costs and benefits may be different for environmental impact statements. 762 F.3d at 112 ("[W]e disagree that NEPA requires such an approach, particularly where only an environmental assessment, rather than an environment impact statement, is involved."). See also *supra* note 40, listing several cases explaining that NEPA requires at least an informal cost-benefit assessment.

Finally, at most *EarthReports* and *Minisink* gave FERC some deference constrained by rationality, and FERC can always change its mind based on the current record and within the standards of rationality. Based on everything that FERC now knows about the social cost of greenhouse gas metrics, FERC should use the tool in both environmental reviews under NEPA and in reviews of public convenience and necessity.

Regardless of Legal Obligations, Monetizing Climate Damages Is Helpful and Easy

FERC has often complained that “there is no standard established by international or federal policy, or by a recognized scientific body that the Commission could rely on in determining whether project-specific GHG emissions are significant.”⁵⁷ Yet by applying the social cost of greenhouse gases, the common metric of money provides the very framework for assessing significance that FERC is looking for. While the relative significance of 20,000 additional tons of carbon dioxide per year versus 2 million additional tons per year may be somewhat challenging to discern, the relative significance of \$1 million per year in climate damages versus \$100 million per year in climate damages is much easier to discern. Determining the significance of \$100 million in annual climate damages versus \$1 million still requires FERC to exercise its professional judgment, but that is no different than how FERC routinely applies its judgment to determine the significance of impacts to landowners, the local community, or the tax base. Compared to volume estimates, the monetized figures of climate damage are also easier to weigh against reasonable judgments about a project’s other qualitative, quantitative, or monetized costs and benefits. And as discussed above, using the social cost of greenhouse gases may be especially helpful when comparing alternatives with varying emission levels across time.

The value of the additional information generated by applying the social cost of greenhouse gas metrics easily outweighs the cost of the minimal effort required to apply the metrics. Once the tons of carbon dioxide, methane, and nitrous oxide emissions have already been quantified, monetization simply requires multiplying the tons emitted in a given year by that year’s values for the social cost of carbon, methane, or nitrous oxide, and further multiplying by a standard discount formula to produce the present value.⁵⁸ Reliable estimates of the social cost of greenhouse gases are readily available, from the 2016 technical support document issued by the federal Interagency Working Group on the Social Cost of Greenhouse Gases (IWG). FERC either can focus on IWG’s central estimates or else has the option of also using the additional range of three other estimates from the IWG to conduct sensitivity analyses. The continuing validity of IWG’s 2016 estimates is discussed further below.

For example, suppose that FERC has already calculated that a project will emit 23 million metric tons of carbon dioxide per year. FERC can then multiply by the social cost of carbon for each year of emissions. For year 2020 emissions, IWG’s central estimate of climate damages is \$42 per ton in 2007\$, which equals \$51 per ton in 2017\$. $23\text{MMTCO}_2 * \$51/\text{MTCO}_2 = \1.17 billion in climate damages from emissions in year 2020. Discounting back to present value in the year 2018 at a 3% discount rate gives a present value of about \$1.05 billion in climate damages expected from the carbon pollution that the project will emit in the year 2020. By summing such estimates for each year of operations of the project, a total present-value estimate of the project’s expected climate damages is readily calculated.

⁵⁷ *E.g.*, 83 Fed. Reg. at 18,029.

⁵⁸ Depending on which dollar-year values FERC uses for other calculations, it may also need to inflate the estimates, since the Interagency Working Group numbers are given in year 2007\$. The Bureau of Labor Statistics provides an easy-to-use CPI Inflation Calculator, <https://data.bls.gov/cgi-bin/cpicalc.pl>.

II. FERC's Past Objections to the Social Cost of Greenhouse Gases Do Not Withstand Scrutiny

In its Order on Remand Reinstating Certification for the Southeast Market Pipelines Project, as well as in other orders and NEPA reviews, FERC has articulated various objections to using the social cost of greenhouse gas metrics. All of those objections are easily rebutted and so should not inhibit FERC from adopting a policy of using the social cost of greenhouse gas metrics to monetize the climate damages of any quantified greenhouse gas emissions.

A Strong Consensus Exists to Use a 3% or Lower (or Declining) Discount Rate for a Central Estimate

In the Southeast Market Pipeline supplemental EIS, FERC cites a 2013 EPA factsheet for the proposition that there is such a lack of consensus around the appropriate discount rate that the resulting range of estimates of the social cost of greenhouse gases is too wide to be helpful.⁵⁹ Not only was this line of thinking rejected by the Ninth Circuit in *Center for Biological Diversity*—“while . . . there is a range of values, the value of carbon emissions reduction is certainly not zero”⁶⁰—but the range of values recommended by the Interagency Working Group⁶¹ and endorsed by the National Academies of Sciences⁶² is rather manageable. In 2016, the IWG recommended values at discount rates from 2.5% to 5%, calculated as between \$12 and \$62 for year 2020 emissions.⁶³ Numerous federal agencies have had no difficulty either applying this range in their environmental impact statements or else focusing on the central estimate at a 3% discount rate.⁶⁴ Most recently, in August 2017, the Bureau of Ocean Energy Management applied the IWG's range of estimates calculated at three discount rates (2.5%, 3%, and 5%) to its environmental impact statement for an offshore oil development plan,⁶⁵ and called this range of estimates “a useful measure to assess the benefits of CO₂ reductions and inform agency decisions.”⁶⁶

More importantly, there is widespread consensus that a central estimate calculated at a 3% or lower discount rate, or else using a declining discount rate, is most appropriate, while a 7% discount rate would be wholly inappropriate in the context of intergenerational climate damages. Because of the long lifespan of greenhouse gases and the long-term or irreversible consequences of climate change, the effects of today's emissions changes will stretch out over the next several centuries. The time horizon

⁵⁹ FERC, *Final Supplemental Environmental Impact Statement: Southeast Market Pipelines Project* at 8 (2018). *But see* Sabal Remand Order (Comm'r LaFleur, dissenting in part) (“[T]he Commission could estimate the appropriate discount rate or to use more than one discount rate in our calculations or to provide a range of numbers for consideration.”); *id.* (Comm'r Glick, dissenting) (“[P]erceived technical challenges including the presence of assumptions or unknowns, such as discount rate, . . . does not diminish the Commission's responsibility to provide a qualitative assessment, rather the Commission simply must make a disclosure ‘so that readers can take the resulting estimates with the appropriate amount of salt.’”).

⁶⁰ 538 F.3d at 1200.

⁶¹ *See* 2016 TSD, *supra* note 21.

⁶² *See* National Academies of Sciences, *Assessment of Approaches to Updating the Social Cost of Carbon* (2016) [hereinafter First NAS Report] (endorsing continued near-term use of the IWG numbers); in 2017, the NAS recommended moving to a declining discount rate, *see* National Academies of Sciences, *Valuing Climate Damages* (2017) [hereinafter Second NAS Report].

⁶³ 2016 TSD, *supra* note 21. The values given here are in 2007\$. The IWG also recommended a 95th percentile value of \$123.

⁶⁴ E.g., BLM, *Envtl. Assessment—Waste Prevention, Prod. Subject to Royalties, and Res. Conservation* at 52 (2016); BLM, *Final Env'tl. Assessment: Little Willow Creek Protective Oil and Gas Lease*, DOI-BLM-ID-B010-2014-0036-EA, at 82 (2015); Office of Surface Mining, *Final Env'tl. Impact Statement—Four Corners Power Plant and Navajo Mine Energy Project* at 4.2-26 to 4.2-27 (2015) (explaining the social cost of greenhouse gases “provide[s] further context and enhance[s] the discussion of climate change impacts in the NEPA analysis.”); U.S. Army Corps of Engineers, *Draft Env'tl. Impact Statement for the Missouri River Recovery Mgmt. Project* at 3-335 (2016); U.S. Forest Serv., *Rulemaking for Colorado Roadless Areas: Supplemental Final Env'tl. Impact Statement* at 120-123 (Nov. 2016) (using both the social cost of carbon and social cost of methane relating to coal leases).

⁶⁵ BOEM, *Liberty Development Project: Draft Environmental Impact Statement*, at 4-247 (2017).

⁶⁶ *Id.* at 3-129.

for an agency's analysis of climate effects, as well as the discount rate applied to future costs and benefits, determines how an agency treats future generations. Current central estimates of the social cost of greenhouse gases are based on a 3% discount rate and a 300-year time horizon. Executive Order 13,783 disbanded the Interagency Working Group in March 2017 and instructs agencies to reconsider the "appropriate discount rates" when monetizing the value of climate effects.⁶⁷ By citing the official guidance on typical regulatory impact analyses (namely, *Circular A-4*), the Order implicitly called into question the IWG's choice not to use a 7% discount rate. In its Sabal Remand Order, FERC suggests that the Executive Order may require use of a "7 percent (or higher)" discount rate.⁶⁸ However, use of a 7% discount would not only be inconsistent with best economic practices but would violate both NEPA's and NGA's requirements to consider impacts on future generations.

NEPA requires agencies to weigh the "relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity," as well as "any irreversible and irretrievable commitments of resources."⁶⁹ That requirement is prefaced with a congressional declaration of policy that explicitly references the needs of future generations:

The Congress, recognizing the profound impact of man's activity on the interrelations of all components of the natural environment . . . declares that it is the continuing policy of the Federal Government . . . to use all practicable means and measures . . . to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and **future generations** of Americans.⁷⁰

When the Congressional Conference Committee adopted that language, it reported that the first "broad national goal" under the statute is to "fulfill the responsibilities of each generation as trustee of the environment for future generations. It is recognized in this [congressional] statement [of policy] that each generation has a responsibility to improve, enhance, and maintain the quality of the environment *to the greatest extent possible for the continued benefit of future generations.*"⁷¹

Similarly, the NGA requires weighing both "the present or *future* public convenience and necessity."⁷² FERC has interpreted this broadly to require consideration of "the effects of the project on *all* the affected interests."⁷³

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

Moreover, a 7% discount rate is inconsistent with best economic practices, including under Circular A-4. In 2015, OMB explained that "Circular A-4 is a **living document**. . . [T]he use of **7 percent is not considered appropriate** for intergenerational discounting. There is wide support for this view in the

⁶⁷ Exec. Order No. 13,783 § 5(c).

⁶⁸ Sabal Remand Order at para. 49; *see also id.* at para. 46.

⁶⁹ 42 U.S.C. § 4332(2)(C).

⁷⁰ 42 U.S.C. § 4331.

⁷¹ *See* 115 Cong. Rec. 40419 (1969) (emphasis added); *see also* same in S. Rep. No. 91-296 (1969).

⁷² 15 U.S.C. § 717f(e).

⁷³ 88 FERC ¶ 61,227 at p. 23.

academic literature, and it is recognized in Circular A-4 itself.⁷⁴ While Circular A-4 tells agencies generally to use a 7% discount rate in addition to lower rates for typical rules,⁷⁵ the guidance does not intend for default assumptions to produce analyses inconsistent with best economic practices. Circular A-4 clearly supports using lower rates to the exclusion of a 7% rate for the costs and benefits occurring over the extremely long, 300-year time horizon of climate effects.

Circular A-4 requires agency analysts to do more than rigidly apply default assumptions: “You cannot conduct a good regulatory analysis according to a formula. Conducting high-quality analysis requires competent professional judgment.”⁷⁶ As such, analysis must be “based on the best reasonably obtainable scientific, technical, and economic information available,”⁷⁷ and agencies must “[u]se **sound and defensible values** or procedures to monetize benefits and costs, and ensure that key analytical assumptions are defensible.”⁷⁸ Rather than assume a 7% discount rate should be applied automatically to every analysis, Circular A-4 requires agencies to justify the choice of discount rates for each analysis: “[S]tate in your report what assumptions were used, *such as . . . the discount rates* applied to future benefits and costs,” and explain “clearly how you arrived at your estimates.”⁷⁹ Based on Circular A-4’s criteria, there are numerous reasons why applying a 7% discount rate to climate effects that occur over a 300-year time horizon would be unjustifiable.

First, basing the discount rate on the **consumption rate of interest** is the correct framework for analysis of climate effects; a discount rate based on the private return to capital is inappropriate. Circular A-4 does suggest that a 7% rate should be a “default position” for regulations that primarily displace capital investments; however, the Circular explains that “[w]hen regulation primarily and directly affects private consumption . . . a lower discount rate is appropriate.”⁸⁰ The 7% discount rate is based on a private sector rate of return on capital, but private market participants typically have short time horizons. By contrast, climate change concerns the public well-being broadly. Rather than evaluating an optimal outcome from the narrow perspective of investors alone, applying economic theory to climate policy requires analysts to make the optimal choices based on societal preferences and social discount rates. Moreover, because climate change is expected to largely affect large-scale consumption, as opposed to capital investment,⁸¹ a 7% rate is inappropriate.

⁷⁴ Interagency Working Group on the Social Cost of Carbon, *Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12,866* at 36 (July 2015) [hereinafter, OMB 2015 Response to Comments].

⁷⁵ Office of Mgmt. & Budget, *Circular A-4* at 36 (2003) (“For regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent....If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent.”).

⁷⁶ *Id.* at 3.

⁷⁷ *Id.* at 17.

⁷⁸ *Id.* at 27 (emphasis added).

⁷⁹ *Id.* at 3 (emphasis added).

⁸⁰ *Id.* at 33 (emphasis added).

⁸¹ “There are two rationales for discounting future benefits—one based on consumption and the other on investment. The consumption rate of discount reflects the rate at which society is willing to trade consumption in the future for consumption today. Basically, we discount the consumption of future generations because we assume future generations will be wealthier than we are and that the utility people receive from consumption declines as their level of consumption increases. . . . The investment approach says that, as long as the rate of return to investment is positive, we need to invest less than a dollar today to obtain a dollar of benefits in the future. Under the investment approach, the discount rate is the rate of return on investment. If there were no distortions or inefficiencies in markets, the consumption rate of discount would equal the rate of return on investment. There are, however, many reasons why the two may differ. As a result, using a consumption rather than investment approach will often lead to very different discount rates.” Maureen Cropper, *How Should Benefits and Costs Be Discounted in an Intergenerational Context?*, 183 *RESOURCES* 30, 33.

In 2013, OMB called for public comments on the social cost of greenhouse gases. In its 2015 Response to Comment document,⁸² OMB (together with the other agencies from the IWG) explained that

the consumption rate of interest is the correct concept to use . . . as the impacts of climate change are measured in consumption-equivalent units in the three IAMs used to estimate the SCC. This is consistent with OMB guidance in Circular A-4, which states that when a regulation is expected to primarily affect private consumption—for instance, via higher prices for goods and services—it is appropriate to use the consumption rate of interest to reflect how private individuals trade-off current and future consumption.⁸³

The Council of Economic Advisers similarly interprets Circular A-4 as requiring agencies to choose the appropriate discount rate based on the nature of the regulation: “[I]n Circular A-4 by the Office of Management and Budget (OMB) the appropriate discount rate to use in evaluating the net costs or benefits of a regulation depends on whether the regulation primarily and directly affects private consumption or private capital.”⁸⁴ The National Academies of Sciences also explained that a consumption rate of interest is the appropriate basis for a discount rate for climate effects.⁸⁵ For this reason, 7% is an inappropriate choice of discount rate for the impacts of climate change.⁸⁶ Finally, each of the three integrated assessment models upon which the social cost of greenhouse gas estimates are based—DICE, FUND, and PAGE—uses consumption discount rates; a capital discount rate is thus inconsistent with the underlying models. For these reasons, 7% is an inappropriate choice of discount rate for the impacts of climate change.

Second, **uncertainty over the long time horizon** of climate effects should drive analysts to select a lower discount rate. As an example of when a 7% discount rate is appropriate, Circular A-4 identifies an EPA rule with a 30-year timeframe of costs and benefits.⁸⁷ By contrast, greenhouse gas emissions generate effects stretching out across 300 years. As Circular A-4 notes, while “[p]rivate market rates provide a reliable reference for determining how society values time within a generation, but for extremely long time periods no comparable private rates exist.”⁸⁸

⁸² Note that this document was not withdrawn by Executive Order 13,783.

⁸³ OMB 2015 Response to Comments, *supra* note 74, at 22.

⁸⁴ Council of Econ. Advisers, *Discounting for Public Policy: Theory and Recent Evidence on the Merits of Updating the Discount Rate* at 1 (CEA Issue Brief, 2017), available at https://obamawhitehouse.archives.gov/sites/default/files/page/files/201701_cea_discounting_issue_brief.pdf. In theory, the two rates would be the same, but “given distortions in the economy from taxation, imperfect capital markets, externalities, and other sources, the SRTP and the marginal product of capital need not coincide, and analysts face a choice between the appropriate opportunity cost of a project and the appropriate discount rate for its benefits.” *Id.* at 9. The correct discount rate for climate change is the social return to capital (i.e., returns minus the costs of externalities), not the private return to capital (which measures solely the returns).

⁸⁵ NAS Second Report, *supra* note 62, at 28; see also Kenneth Arrow et al., *Is There a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation?*, 272 *Science* 221 (1996) (explaining that a consumption-based discount rate is appropriate for climate change).

⁸⁶ See also this article by the former chair of the NAS panel on the social cost of greenhouse gases: Richard Newell, *Unpacking the Administration’s Revised Social Cost of Carbon*, Oct. 10, 2017, <http://www.rff.org/blog/2017/unpacking-administration-s-revised-social-cost-carbon> (“It is clearly inappropriate, therefore, to use such modeling results with OMB’s 7 percent discount rate.”); see also Comments from Robert Pindyck, to BLM, on the Social Cost of Methane in the Proposed Suspension of the Waste Prevention Rule, BLM-2017-0002-16107 (submitted Nov. 5, 2017) (explaining that 3%, not 7%, is the appropriate discount rate).

⁸⁷ Circular A-4 at 34. See also OMB 2015 Response to Comments, *supra* note 74, at 21 (“While most regulatory impact analysis is conducted over a time frame in the range of 20 to 50 years . . .”).

⁸⁸ Circular A-4 at 36.

Circular A-4 discusses how uncertainty over long time horizons drives the discount rate lower: “the longer the horizon for the analysis,” the greater the “uncertainty about the appropriate value of the discount rate,” which supports a lower rate.⁸⁹ Circular A-4 cites the work of renowned economist Martin Weitzman and concludes that the “certainty-equivalent discount factor corresponds to **the minimum discount rate having any substantial positive probability.**”⁹⁰ The NAS makes the same point about discount rates and uncertainty.⁹¹ In fact, as discussed more below and in the technical appendix on discounting, uncertainty over the discount rate is best addressed by adopting a declining discount rate framework.

Third, a 7% discount rate **ignores catastrophic risks and the welfare of future generations.** As demonstrated in the frequency distribution graphs included in some agencies’ recent and misguided attempts to calculate the social cost of greenhouse gases at a 7% discount rate,⁹² the 7% rate truncates the long right-hand tail of social costs relative to the 3% rate’s distribution. The long right-hand tail represents the possibility of catastrophic damages. The 7% discount rate effectively assumes that present-day Americans are barely willing to pay anything at all to prevent medium- to long-term catastrophes. This assumption violates statutory duties under NEPA and the NGA to protect the future needs of Americans. At the same time, the 7% distribution also misleadingly exaggerates the possibility of negative estimates of the social cost of greenhouse gases.⁹³ A negative social cost of greenhouse gases implies a discount rate so high that society is willing to sacrifice serious impacts to future generations for the sake of small, short-term benefits (such as slightly and temporarily improved fertilization for agriculture). Again, this assumption contravenes statutory responsibilities to protect the welfare of future Americans.

Fourth, a 7% discount rate would be inappropriate for climate change because it is based on **outdated data and diverges from the current economic consensus.** Circular A-4 requires that assumptions—including discount rate choices—are “based on the best reasonably obtainable scientific, technical, and economic information available.”⁹⁴ Yet Circular A-4’s own default assumption of a 7% discount rate was published 14 years ago and was based on data from decades ago.⁹⁵ Circular A-4’s guidance on discount rates is in need of an update, as the Council of Economic Advisers detailed in 2017 after reviewing the best available economic data and theory:

The discount rate guidance for Federal policies and projects was last revised in 2003. Since then a general reduction in interest rates along with a reduction in the forecast of

⁸⁹ *Id.*

⁹⁰ *Id.* (emphasis added); see also CEA, *supra* note 84, at 9: “Weitzman (1998, 2001) showed theoretically and Newell and Pizer (2003) and Groom et al. (2007) confirm empirically that discount rate uncertainty can have a large effect on net present values. A main result from these studies is that if there is a persistent element to the uncertainty in the discount rate (e.g., the rate follows a random walk), then it will result in an effective (or certainty-equivalent) discount rate that declines over time. Consequently, lower discount rates tend to dominate over the very long term, regardless of whether the estimated investment effects are predominantly measured in private capital or consumption terms (see Weitzman 1998, 2001; Newell and Pizer 2003; Groom et al. 2005, 2007; Gollier 2008; Summers and Zeckhauser 2008; and Gollier and Weitzman 2010).”

⁹¹ NAS Second Report, *supra* note 62, at 27.

⁹² E.g., EPA, *Estimated Cost Savings and Forgone Benefits Associated with the Proposed Rule, “Oil and Natural Gas: Emission Standards for New, Reconstructed, and Modified Sources: Stay of Certain Requirements”* at 19 (Oct. 17, 2017).

⁹³ In the Monte Carlo simulation data from EPA, the 7% discount rate doubles the frequency of negative estimates compared to the 3% discount rate simulations, from a frequently of 4% to 8%.

⁹⁴ CEQ regulations implementing NEPA similarly require that information in NEPA documents be “of high quality” and states that “[a]ccurate scientific analysis . . . [is] essential to implementing NEPA.” 40 C.F.R. § 1500.1(b).

⁹⁵ The 7% rate was based on a 1992 report; the 3% rate was based on data from the thirty years preceding the publication of Circular A-4 in 2003. Circular A-4 at 33.

long-run interest rates, warrants serious consideration for a reduction in the discount rates used for benefit-cost analysis.⁹⁶

In addition to recommending a value below 7% as the discount factor based on private capital returns, the Council of Economic Advisers further explains that, because long-term interest rates have fallen, a discount rate based on the consumption rate of interest “should be at most 2 percent.”⁹⁷ The latest OMB updates to Circular A-94, the document on which Circular A-4 based its discount rates,⁹⁸ also show that more up-to-date long-run discount rates are historically low. In the February 2018 update to Circular A-94’s discount rates, OMB found that the real, 30-year discount rate is 0.6 percent,⁹⁹ the lowest rate since the OMB began tracking the number.¹⁰⁰ Notably, OMB also shows that the current real interest rate is negative for maturities less than 7 years.¹⁰¹

These low interest rates further confirm that applying a 7% rate to a context like climate change would be wildly out of step with the latest data and theory. Similarly, recent expert elicitations—a technique supported by Circular A-4 for filling in gaps in knowledge¹⁰²—indicate that a growing consensus among experts in climate economics for a discount rate between 2% and 3%; 5% represents the upper range of values recommended by experts, and few to no experts support discount rates greater than 5% being applied to the costs and benefits of climate change.¹⁰³ Based on current economic data and theory, the most appropriate discount rate for climate change is 3% or lower.

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

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

Special ethical considerations arise when comparing benefits and costs across generations. . . It may not be appropriate for society to demonstrate a similar preference when deciding between the well-being of current and future generations. . . If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent.¹⁰⁴

⁹⁶ CEA, *supra* note 84, at 1; *id.* at 3 (“In general the evidence supports lowering these discount rates, with a plausible best guess based on the available information being that the lower discount rate should be at most 2 percent while the upper discount rate should also likely be reduced.”); *id.* at 6 (“The Congressional Budget Office, the Blue Chip consensus forecasts, and the Administration forecasts all place the ten year treasury yield at less than 4 percent in the future, while at the same time forecasting CPI inflation of 2.3 or 2.4 percent per year. The implied real ten year Treasury yield is thus below 2 percent in all these forecasts.”).

⁹⁷ *Id.* at 1.

⁹⁸ Circular A-4 at 33.

⁹⁹ OMB Circular A-94 Appendix C (2018).

¹⁰⁰ <https://obamawhitehouse.archives.gov/sites/default/files/omb/assets/a94/dischist-2017.pdf>.

¹⁰¹ Circular A-94 Appendix C.

¹⁰² Circular A-4 at 41.

¹⁰³ Peter Howard & Derek Sylvan, *The Economic Climate: Establishing Expert Consensus on the Economics of Climate Change* (Inst. Policy Integrity Working Paper 2015/1); M.A. Drupp, et al., *Discounting Disentangled: An Expert Survey on the Determinants of the Long-Term Social Discount Rate* (London School of Economics and Political Science Working Paper, May 2015) (finding consensus on social discount rates between 1-3%).

¹⁰⁴ Circular A-4 at 35-36.

Elsewhere in Circular A-4, OMB clarifies that sensitivity analysis should not result in a rigid application of all available assumptions regardless of plausibility. Circular A-4 instructs agencies to depart from default assumptions when special issues “call for different emphases” depending on “the sensitivity of the benefit and cost estimates to the key assumptions.”¹⁰⁵ More specifically:

If benefit or cost estimates depend heavily on certain assumptions, you should make those assumptions explicit and carry out *sensitivity analyses using plausible alternative assumptions*. If the value of net benefits changes from positive to negative (or vice versa) or if the relative ranking of regulatory options changes with alternative plausible assumptions, you should conduct further analysis to determine **which of the alternative assumptions is more appropriate**.¹⁰⁶

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

Finally, to the extent there is uncertainty around the discount rate over long periods of time, the growing economic consensus supports shifting to a declining discount rate framework. Circular A-4 contemplates the use of declining discount rates in its reference to the work of Weitzman.¹⁰⁷ As the Council of Economic Advisers explained earlier this year, Weitzman and others developed the foundation for a declining discount rate approach, wherein rates start relatively higher for near-term costs and benefits but steadily decline over time according to a predetermined schedule until, in the very long-term, very low rates dominate due to uncertainty.¹⁰⁸ The National Academies of Sciences’ report also strongly endorses a declining discount rate approach due to uncertainty.¹⁰⁹ In other words, the rational response to a concern about uncertainty over the discount rate is not to abandon the social cost of greenhouse gas methodology, but to apply declining discount rates and to treat the estimates calculated at a constant 3% rate as conservative lower-bound estimates.

One possible schedule of declining discount rates was proposed by Weitzman.¹¹⁰ It is derived from a broad survey of top economists and other climate experts and explicitly incorporates arguments around interest rate uncertainty. Work by Arrow *et al*, Cropper *et al*, and Gollier and Weitzman, among others,

¹⁰⁵ *Id.* at 3.

¹⁰⁶ *Id.* at 42 (emphasis added).

¹⁰⁷ Circular A-4, at page 36, cites to Weitzman’s chapter in Portney & Weyant, eds. (1999); that chapter, at page 29, recommends a declining discount rate approach: “a sliding-scale social discounting strategy” with the rate at 3-4% through year 25; then around 2% until year 75; then around 1% until year 300; and then 0% after year 300.

¹⁰⁸ CEA, *supra* note 84, at 9 (“[A]nother way to incorporate uncertainty when discounting the benefits and costs of policies and projects that accrue in the far future—applying discount rates that decline over time. This approach uses a higher discount rate initially, but then applies a graduated schedule of lower discount rates further out in time. The first argument is based on the application of the Ramsey framework in a stochastic setting (Gollier 2013), and the second is based on Weitzman’s ‘expected net present value’ approach (Weitzman 1998, Gollier and Weitzman 2010). In light of these arguments, the governments of the United Kingdom and France apply declining discount rates to their official public project evaluations.”).

¹⁰⁹ NAS Second Report, *supra* note 62.

¹¹⁰ Martin L. Weitzman, *Gamma Discounting*, 91 AM. ECON. REV. 260, 270 (2001). Weitzman’s schedule is as follows:

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

similarly argue for a declining interest rate schedule and lay out the fundamental logic.¹¹¹ Another schedule of declining discount rates has been adopted by the United Kingdom.¹¹²

The technical appendix on discounting attached to these comments more thoroughly reviews the various schedules of declining discount rates available for agencies to select and explains why agencies not only can but should adopt a declining discount framework to address uncertainty. An additional technical appendix on uncertainty explains in detail why uncertainty around the social cost of greenhouse gas points toward higher values. Shifting to a declining discount rate framework would increase the social cost of greenhouse gases.¹¹³ Consequently, a central estimate calculated at 3% should be considered a lower-bound of the social cost of greenhouse gases. But even providing a lower-bound estimate of the social cost of greenhouse gases helps inform decisionmakers and the public, and FERC is required by NEPA to provide some monetization of climate damages, consistent with economic best practices.

Similarly, a 300-year time horizon is required by best economic practices. In 2017, the National Academies of Sciences issued a report stressing the importance of a longer time horizon for calculating the social cost of greenhouse gases. The report states that, “[i]n the context of the socioeconomic, damage, and discounting assumptions, the time horizon needs to be long enough to capture the vast majority of the present value of damages.”¹¹⁴ The report goes on to note that the length of the time horizon is dependent “on the rate at which undiscounted damages grow over time and on the rate at which they are discounted. Longer time horizons allow for representation and evaluation of longer-run geophysical system dynamics, such as sea level change and the carbon cycle.”¹¹⁵ In other words, after selecting the appropriate discount rate based on theory and data (in this case, 3% or below), analysts should determine the time horizon necessary to capture all costs and benefits that will have important net present values at the discount rate. Therefore, a 3% or lower discount rate for climate change implies the need for a 300-year horizon to capture all significant values. NAS reviewed the best available, peer-reviewed scientific literature and concluded that the effects of greenhouse gas emissions over a 300-year period are sufficiently well established and reliable as to merit consideration in estimates of the social cost of greenhouse gases.¹¹⁶

The Social Cost of Greenhouse Gas Metrics Provides a Tool to Assess the Significance of Individual Physical Impacts

In *EarthReports*, FERC had argued that the social cost of greenhouse gas “tool does not measure the actual incremental impacts of a project on the environment.”¹¹⁷ FERC now admits that statement was

¹¹¹ Kenneth J. Arrow et al., *Determining Benefits and Costs for Future Generations*, 341 SCIENCE 349 (2013); Kenneth J. Arrow et al., *Should Governments Use a Declining Discount Rate in Project Analysis?*, REV ENVIRON ECON POLICY 8 (2014); Maureen L. Cropper et al., *Declining Discount Rates*, AMERICAN ECONOMIC REVIEW: PAPERS AND PROCEEDINGS (2014); Christian Gollier & Martin L. Weitzman, *How Should the Distant Future Be Discounted When Discount Rates Are Uncertain?* 107 ECONOMICS LETTERS 3 (2010).

¹¹² Joseph Lowe, H.M. Treasury, U.K., *Intergenerational Wealth Transfers and Social Discounting: Supplementary Green Book Guidance 5* (2008), available at [http://www.hm-treasury.gov.uk/d/4\(5\).pdf](http://www.hm-treasury.gov.uk/d/4(5).pdf). The U.K. declining discount rate schedule that subtracts out a time preference value is as follows:

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

¹¹³ This assumes the use of reasonable values in the Ramsey equation. But in general, as compared to a constant discount rate, a declining rate approach should decrease the effective discount rate.

¹¹⁴ NAS Second Report, *supra* note 62, at 78.

¹¹⁵ *Id.*

¹¹⁶ NAS First Report, *supra* note 62, at 32.

¹¹⁷ See Sabal Remand Order para. 47.

wrong, and the metric does capture the incremental physical impacts of climate change.¹¹⁸ Nevertheless, FERC continues to repeat that “there is no standard methodology to determine how a project’s relatively small incremental contribution to GHGs would translate into physical effects on the global environment.”¹¹⁹ Such statements are also wrong. 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.

Going forward, FERC should scrub from its environmental reviews and orders any misleading statements about the supposed lack of a methodology to link a single project’s emissions with global climate change. Instead, FERC should more consistently acknowledge that the social cost of greenhouse gas methodology (and the underlying integrated assessment models) can link the marginal emissions of a single project to the incremental physical impacts of climate change.

Despite FERC’s occasional (if inconsistent) acknowledgment that the social cost of greenhouse gas methodology can capture incremental physical impacts, FERC has continued to insist that “although the integrated assessment models could be run through a first phase to estimate . . . physical climate change impacts . . . , we would still have to arbitrarily determine what potential increase in atmospheric GHG concentration, rise in sea level, rise in sea water temperatures, and other calculated physical impacts would be significant for that particular pipeline project.”¹²⁰ More generally, FERC claims there is a lack of any “standard” or “criteria” to determine the significance of a project’s greenhouse gas emissions, and insists that “any attempt by the Commission to create a significance threshold would be arbitrary.”¹²¹ FERC also suggests that monetizing the climate damages will not help, “because we have no basis to designate a particular dollar figure . . . as ‘significant.’”¹²² Finally, FERC insists that applying the social cost of greenhouse metric is useless, because “any two projects with the same capacity” would “contribute identically to global climate change” anyway, and thus monetization reveals no difference in

¹¹⁸ *Id.* at para. 48.

¹¹⁹ E.g., FERC, *Environmental Assessment: Rivervale South to Market Project* at 59 (2018). *See also* 83 Fed. Reg. at 18,029 (noting “the difficulty in identifying the extent to which a specific action or project may contribute to overall climate change, given that climate change results from the cumulative buildup of carbon dioxide and other GHGs, rather than from the incremental emissions of any one project.”).

¹²⁰ Sabal Remand Order at para. 48.

¹²¹ 83 Fed. Reg. at 18,029 (“[T]here is no standard established by international or federal policy, or by a recognized scientific body that the Commission could rely on in determining whether project-specific GHG emissions are significant.”)

¹²² Sabal Remand Order at para. 51; *see also id.* at para. 50.

significance between the effects of the alternatives.¹²³ Throughout this line of argument about significance, FERC repeatedly misunderstands the value of using the social cost of greenhouse gas tool.

First, a key advantage of using the social cost of greenhouse gas tool is that each physical impact—such as sea-level rise and increasing temperatures—need not be assessed in isolation. Instead, the social cost of greenhouse gas tool conveniently groups together the multitude of climate impacts and, consistent with NEPA regulations,¹²⁴ enables agencies to assess whether all those impacts are cumulatively significant and to then compare those impacts with other impacts or alternatives using a common metric.

Second, contrary to how FERC characterizes our position in the Notice of Inquiry, neither in these comments nor in past comments submitted jointly on the social cost of greenhouse gases do our organizations “argue that all projects relying on fossil fuels should be considered to cause a significant impact on climate change.”¹²⁵ Rather, we argue that FERC should use its reasonable judgment to assess whether monetized climate damages are significant, especially in light of other costs and benefits. While the relative significance of 20,000 additional tons per year of carbon dioxide versus 2 million additional tons per year may be challenging to discern, the relative significance of \$1 million per year in climate damages versus \$100 million per year in climate damages is much easier to discern, especially when compared to FERC’s reasonable judgments about the project’s other qualitative, quantitative, and monetized costs and benefits. While judging the significance of \$100 million in climate damages will require FERC’s professional judgment, by monetizing the effects, FERC will be in familiar territory, as the Commission routinely evaluates the relative importance of millions, hundreds of millions, and billions of dollars’ worth of costs and benefits in many contexts. Using the social cost of greenhouse gas metrics helps FERC apply its expertise and judgment as an economic regulator to the climate context.

Third, FERC takes an overly narrow view when it suggests that the social cost of greenhouse gas metrics yield little insight into comparing the significance of two projects with identical capacity. Even assuming that is true,¹²⁶ FERC is not required to look only at projects with identical capacity.¹²⁷ To the contrary, FERC is required to look at least at a no-action alternative under NEPA.¹²⁸ Furthermore, FERC is able to assess a broad range of alternatives, including pipelines with different capacities, and the social cost of greenhouse gas metric is an exceedingly useful tool to compare the impacts of such projects. Additionally, even projects of the same capacity could have different estimates of public benefits, and the social cost of greenhouse gas metric would allow FERC to more transparently weigh those estimated benefits against climate costs.

Finally, while there may not be a bright-line test for significance, several cases suggest that, minimally, projects with estimated emissions of over 1 million tons of carbon dioxide-equivalent emissions per year warrant monetization—and projects with fewer emissions may have significant climate damages as well.

¹²³ *Id.* at para. 51.

¹²⁴ 40 C.F.R. § 1508.27(b)(7) (explaining that actions can be significant if related to individually insignificant but cumulatively significant impacts).

¹²⁵ 83 Fed. Reg. at 18,029.

¹²⁶ In fact, different projects with the same capacity could have, for example, somewhat different upstream emissions or direct emissions, depending on such operational decisions as managing methane releases during extraction, limiting carbon dioxide emissions during construction, or controlling methane leaks along the pipeline; leaks may also vary with pipeline length.

¹²⁷ Note that FERC misstates the standard under NEPA when the Notice of Inquiry say that “an agency need only evaluate alternatives that can satisfy the purpose and need of the proposed project.” 83 Fed. Reg. at 18,022.

¹²⁸ 40 C.F.R. § 1502.14 (requiring agencies to “[r]igorously explore and objectively evaluate all reasonable alternatives,” including “reasonable alternative not within the jurisdiction of the lead agency” and, minimally, “the alternative of no action”).

In *High Country*, the U.S. 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.”¹²⁹ That suggests that emissions in that range are significant and warrant monetization. In *Montana Environmental Information Center*, the U.S. District Court for the District of Montana found it was arbitrary for the Office of Surface Mining not to monetize the 23.16 million metric tons per year from that mine expansion.¹³⁰ In *Center for Biological Diversity*, the U.S. Court of Appeals for 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:¹³¹ given the estimated lifetime of vehicles sold in the years 2008-2011 (sometimes estimated at about 15 years on average), this could represent two million metric tons per year. 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,¹³² or about 5 million metric tons per year.

Monetizing Climate Damages Is Appropriate and Useful Regardless of Whether Every Effect Can Be Monetized in a Full Cost-Benefit Analysis

FERC has argued that while the social cost of greenhouse gas metrics are useful in the context of a cost-benefit analysis,¹³³ FERC ostensibly “does not conduct a monetary cost-benefit analysis in its NEPA review,”¹³⁴ and its assessment of public convenience and necessity in pipeline certifications is “qualitative” only—“we do not monetize.”¹³⁵ According to FERC, adding the social cost of greenhouse gases to either the NEPA review or the certification review would require quantifying and monetizing “all” of the project’s other positive and negative effects.¹³⁶ Similarly, the Notice of Inquiry assumes that using the social cost of greenhouse gases will necessitate that FERC “acquire complete information to appropriately quantify all of the monetized costs/negative impacts and monetized benefits of a proposed project.”¹³⁷ This is wrong for two reasons. First, FERC does quantify and monetize other non-climate effects in both its NEPA analyses and its reviews of public convenience and necessity. Second, monetizing one key impact still provides useful information for decisionmakers and the public even when monetizing other impacts is not feasible. The social cost of greenhouse gases enables a more accurate and transparent comparison of alternatives along the dimension of climate impacts even if other costs and benefits cannot be quantified, and “breakeven analysis” could provide a framework for making decisions when some effects but not others are monetized.

First, FERC does at times rely on both quantified and monetized values to inform its NEPA analyses and its reviews of public convenience and necessity. As discussed above, FERC’s environmental impact

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

¹³⁰ *Mont. Env'tl. Info. Ctr. v. U.S. Office of Surface Mining*, 274 F. Supp. 3d 1074, 1094 (D. Mont. 2017).

¹³¹ 538 F.3d at 1187.

¹³² 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).

¹³³ *Final Supplemental EIS for Southeast Market Pipelines Project* at 8 (“The SCC tool may be useful for rulemakings or comparing regulatory alternatives using cost-benefit analyses where the same discount rate is consistently applied.”)

¹³⁴ Sabal Remand Order, para. 40.

¹³⁵ *Id.* at para. 43.

¹³⁶ *Id.* at para. 41; *id.* at para. 44 (“We do not monetize the social benefits of the proposed project itself, which would be necessary to appropriately balance against the Social Cost of Carbon tool’s monetized damages.”).

¹³⁷ 83 Fed. Reg. at 18,032.

statements regularly monetize “economic benefits” including direct and indirect labor income, expenditures, tax revenues, and other “long-term benefits to the local and regional economy.”¹³⁸ Nothing about those economic benefits suggests a stronger case for monetizing them than for monetizing climate costs. Employment effects, for example, could easily be presented quantitatively as changes in job-years rather than monetized as labor income, or could be discussed qualitatively in terms of the general effect on regional and sectoral labor markets. Agencies instead monetize the labor income to help explain employment effects with the kind of informational context that the public and decisionmakers need to understand the nature and degree of the effect. But the same is true of the social cost of greenhouse gas metrics, as discussed at length above in these comments.

Examples from past NGA reviews also show that, contrary to FERC’s claims of qualitative-only assessments, FERC does rely on quantitative and monetized data to weigh public convenience and necessity, and has done so without necessarily undertaking a full cost-benefit analysis. For example, in 2012 FERC issued a certificate of public convenience and necessity to Millennium Pipeline Company to construct and operate the Minisink Compressor Project.¹³⁹ FERC concluded that “the benefits of the project” justified “the minimal adverse effect on existing shippers, other pipelines and their captive customers.”¹⁴⁰ To make that determination, FERC had asked Millennium to “explain how [the company] will protect the shippers on the existing system from any rate impact or costs.”¹⁴¹ In response, Millennium submitted a spreadsheet listing quantitative data on loads and monetized fuel cost forecasts.¹⁴² This quantitative and monetized data with respect to possible adverse effects surely informed FERC’s majority decision to issue the certificate of public convenience and necessity. Furthermore, FERC’s order compared two alternative options by quantitatively considering acres of forested land impacted (47.61 acres versus 0.4 acres), sensitive wetlands impacts (11 versus 0), and special status species impacts (5 versus 1).¹⁴³ Similarly, Chairman Wellinghoff’s dissent from that order preferred an alternative to the proposed compressor project in part because of monetized estimates of the \$1.6 million difference in annual fuel costs.¹⁴⁴ Even without a full cost-benefit analysis, FERC considered quantitative and monetized data to determine the public convenience and necessity.

Second, climate damages can and should be monetized even if other costs and benefits are harder to quantify or monetize and so must be discussed qualitatively. Many effects can readily be quantified and monetized, and agencies should generally do so when feasible; other effects, like water quality, are notoriously difficult to quantify and monetize, due to the geographically idiosyncratic nature of individual water bodies. Greenhouse gases, by comparison, have the same impact on climate change no matter where they are emitted, and those impacts are readily monetized using the social cost of greenhouse methodology. Regardless of whether all other effects can be monetized, using the social cost of greenhouse gases provides useful and necessary information to the public and decisionmakers. In particular, whether or not other effects are monetized, using the social cost of greenhouse gases will facilitate comparison between alternative options along the dimension of climate change. As discussed

¹³⁸ E.g., FERC, *Final Environmental Impact Statement for Southeast Market Pipelines Project* at 3-185 to 3-214 (2015).

¹³⁹ 140 FERC ¶ 61,045 (July 17, 2012) (docket CP11-515-000). See also *supra*, explaining and distinguishing the D.C. Circuit’s ruling in *Minisink*: there, the court never said that monetized costs and benefits were inappropriate or irrelevant to FERC’s NEPA analyses, but only that a fully monetized cost-benefit analysis was not required, such that FERC did not need to base its decision solely on the summation of monetized costs and benefits.

¹⁴⁰ 140 FERC ¶ 61,045 at para. 15.

¹⁴¹ Millennium Response to FERC Staff Data Requests, submitted Sept. 30, 2011 to docket CP11-515-000 (see request No. 2(c)).

¹⁴² *Id.* (attachment DR-AR-2.xls).

¹⁴³ 140 FERC ¶ 61,045 at para. 27; see also *Minisink Residents for Env’tl. Pres. v. FERC*, 762 F.3d 97, 107 n.5 (D.C. Cir. 2014) (recounting the quantitative comparison of two alternatives).

¹⁴⁴ 140 FERC ¶ 61,045: Wellinghoff dissent at page 2.

above, different alternatives could have varying greenhouse gas consequences over time, and monetization provides the best means of comparing project alternatives along the dimension of climate change.

Moreover, analytical frameworks exist to weigh qualitative effects alongside monetized effects. For example, while NEPA regulations do state that if there are “important qualitative considerations,” then the ultimate “weighing of the merits and drawbacks of the various alternatives” should not be displayed exclusively as a “monetary cost-benefit analysis,” nevertheless NEPA regulations also acknowledge that when monetization of costs and benefits is “relevant to the choice among environmentally different alternatives,” “that analysis” can be presented alongside “any analyses of unquantified environmental impacts, values, and amenities.”¹⁴⁵ In other words, the monetization of some impacts does not require the monetization of all impacts.

The Office of Management and Budget’s *Circular A-4*¹⁴⁶ guidance to agencies on conducting economic analysis also provides a framework for weighing monetized and qualitative costs and benefits, called break-even analysis:

It will not always be possible to express in monetary units all of the important benefits and costs. When it is not, the most efficient alternative will not necessarily be the one with the largest quantified and monetized net-benefit estimate. In such cases, you should exercise professional judgment in determining how important the non-quantified benefits or costs may be in the context of the overall analysis. If the non-quantified benefits and costs are likely to be important, you should carry out a “threshold” analysis to evaluate their significance. Threshold or “break-even” analysis answers the question, “How small could the value of the non-quantified benefits be (or how large would the value of the non-quantified costs need to be) before the rule would yield zero net benefits?” In addition to threshold analysis you should indicate, where possible, which non-quantified effects are most important and why.¹⁴⁷

Even without using something as formal as a break-even analysis, it is clear that monetizing climate damages provides useful information whether or not every effect can be monetized in a full cost-benefit analysis.

Monetization Is Appropriate and Useful in Any Decision with Significant Climate Impacts, Not Just Regulations and Not Just Direct Production Authorizations

FERC argues that the social cost of greenhouse gas tool is only “appropriate []” for “regulators whose responsibilities are tied more directly” to “authoriz[ing] a quantity of coal, oil, or natural gas production from federal lands,” or “directly control[ling] whether some quantity of fossil fuels is burned.”¹⁴⁸ In contrast, FERC argues that its certifications have “no direct connection to the production or end use of natural gas.”¹⁴⁹

First, it is unclear why FERC believes that the Department of Energy’s appliance efficiency standards—which FERC cites as an appropriate context for the use of the social cost of greenhouse gases—are that different from FERC’s pipeline certifications. Contrary to FERC’s assertion, the Department of Energy does not “directly control whether some quantity of fossil fuels is burned.” Rather, appliance efficiency

¹⁴⁵ 40 C.F.R. § 1502.23.

¹⁴⁶ Though FERC is not bound by Executive Order 12,866, and though *Circular A-4* focuses on agencies’ regulatory analyses under Executive Order 12,866, the document nevertheless more generally has distilled best practices on economic analysis and is a useful guide to all agencies undertaking an assessment of costs and benefits.

¹⁴⁷ OMB, *Circular A-4* at 2 (2003).

¹⁴⁸ Sabal Remand Order, para. 37.

¹⁴⁹ *Id.* at para. 38.

standards alter how much energy is required to operate an appliance, thus changing the fuel cost to consumers per unit of operation. The appliance efficiency standards only change greenhouse gas emissions by changing consumer demand for energy, as mediated by changing prices and by the fuel mix of the electricity generators and other energy sources that supply the consumers. Quite similarly, FERC's pipeline certifications affect greenhouse gas emissions by changing the supply, price, and demand of natural gas. It is notable that the Department of Energy has routinely used the social cost of greenhouse gases to monetize the climate effects of its appliance efficiency standards, and the U.S. Court of Appeals for the Seventh Circuit has ruled that the Department of Energy's use of the social cost of greenhouse gas estimates in analyzing and setting such standards was reasonable.¹⁵⁰

Second, FERC is ignoring other uses of the social cost of greenhouse gas tool by agencies outside of direct authorizations of fossil fuel production or direct controls of combustion. For example, the Pipeline and Hazardous Materials Safety Administration has used the social cost of methane and social cost of carbon in analyses of regulations that will affect the accidental or intentional release or flaring of natural gas.¹⁵¹ The Army Corps of Engineers has used the social cost of carbon when its river management plans could affect hydropower generation and so indirectly "leads to an increase in thermal power generation to meet the demand, which increases carbon dioxide, methane, and nitrous oxide emissions."¹⁵² And the Environmental Protection Agency has used the social cost of carbon to assess its regulation of coal power plants' water pollution,¹⁵³ which does not "directly control" the air emissions from burning fossil fuels, but rather only changes the price of operations that combust fossil fuels. Agencies have appropriately used the social cost of greenhouse gas metrics in a variety of contexts where their actions will directly or indirectly affect climate change.

Ultimately, the question raised by FERC is one of quantification, not monetization: namely, how many tons of emissions should be attributed to FERC's certification reviews. If quantifiable changes in greenhouse gas emissions are appropriately attributed to actions taken by FERC, then the climate damages associated with those quantified emission changes should also be monetized.

As for the related implication that the social cost of greenhouse gas metrics may be used only in regulatory impact analyses,¹⁵⁴ that misunderstands the nature of the estimates. Though the federal Interagency Working Group originally developed its estimates of the social cost of greenhouse gases to harmonize the metrics used by agencies in their various regulatory impact analyses, there is nothing in the numbers' development that would limit applications to other decisionmaking contexts. The social cost of greenhouse gases measures the marginal cost of any additional unit of greenhouse gases emitted into the atmosphere. The government action that precipitated that unit of emissions—a regulation, the granting of a permit, or a project approval—is irrelevant to the marginal climate damages caused by the

¹⁵⁰ *Zero Zone v. Dept. of Energy*, 832 F.3d 654, 679 (7th Cir. 2016).

¹⁵¹ PHMSA, *Preliminary Regulatory Impact Assessment: Safety of Gas Transmission and Gathering Pipelines* (2016), <https://www.regulations.gov/document?D=PHMSA-2011-0023-0117>; PHMSA, *Regulatory Impact Analysis: Pipeline Safety: Expanding the Use of Excess Flow Valves in Gas Distribution Systems* (2015), <https://www.regulations.gov/document?D=PHMSA-2011-0009-0030>.

¹⁵² U.S. Army Corps, *Draft Missouri River Recovery Management Plan & Environmental Impact Statement* at 3-335 (2016), <https://cdm16021.contentdm.oclc.org/digital/collection/p16021coll7/id/3095> (further explaining that the "social cost of carbon (SCC) value was used to approximate a monetary value associated with carbon emissions").

¹⁵³ Effluent Limitation Guidelines and Standards for the Steam Electric Power Generating Point Source Category, 80 Fed. Reg. 67,838, 67,880 (finalized Nov. 3, 2015) (applying the social cost of carbon based on "the change in the profile of electricity generation due to the relatively higher cost to generate electricity at plants incurring compliance costs"); National Pollutant Discharge Elimination System: Cooling Water Intake Structures at Existing Facilities, 79 Fed. Reg. 48,300, 48,304 (Aug. 15, 2014).

¹⁵⁴ *Final Supplemental EIS for Southeast Market Pipelines Project* at 8 ("The SCC tool may be useful for rulemakings . . .")

emissions. Whether emitted by a leaking pipeline or the extraction process, whether emitted because of a regulation or a resource management decision, whether emitted in Alaska or Maine, the marginal climate damages per unit of emissions remain the same. Indeed, the social cost of greenhouse gases has been used by many federal and state agencies in environmental impact reviews¹⁵⁵ and in resource management decisions.¹⁵⁶

Uncertainty Supports Higher Social Cost of Greenhouse Gas Estimates, and Is Never a Reason to Abandon the Metric

FERC complains that “[w]ithout complete information,” the social cost of greenhouse gases is “based on multiple assumptions” and so is “[m]isleading.”¹⁵⁷ In fact, it would be much more misleading to not monetize climate damages and so risk treating them as worthless. More generally, uncertainty is *not* a reason to abandon the social cost of greenhouse gas methodologies;¹⁵⁸ 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. 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

¹⁵⁵ For example, in August 2017, the Bureau of Ocean Energy Management called the social cost of carbon “a useful measure to assess the benefits of CO2 reductions and inform agency decisions,” and applied the metric in an environmental impact statement to monetize the emissions difference of about 5 million metric tons per year between the proposed oil and gas development project and the no-action baseline, *Draft Environmental Impact Statement—Liberty Development Project in the Beaufort Sea, Alaska* at 3-129, 4-50 (2017). More generally, agencies have used IWG’s social cost of greenhouse gas estimates not only in scores of rulemakings but also in NEPA analyses for resource management decisions. See Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 Columbia J. Envtl. L. 203, 270-84 (2017) (listing all uses by federal agencies through July 2016).

¹⁵⁶ States have used the social cost of greenhouse gases in decisions about electricity planning. See Iliana Paul et al., *The Social Cost of Greenhouse Gases and State Policy: A Frequently Asked Questions Guide* (Policy Integrity Report, 2017), http://policyintegrity.org/files/publications/SCC_State_Guidance.pdf.

¹⁵⁷ Sabal Remand Order, para 41.

¹⁵⁸ *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.”).

economic experts concludes that catastrophic outcomes are increasingly likely to occur.¹⁵⁹ Because the three integrated assessment models that the IWG’s methodology relied on are unable to systematically account for these potential catastrophic outcomes, a 95th percentile value was selected instead to account for such uncertainty. There are no similarly systematic biases pointing in the other direction which might warrant giving weight to a low-percentile estimate.

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

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.¹⁶⁰ 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, as required by Circular A-4.¹⁶¹

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.¹⁶²
- 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

¹⁵⁹ Policy Integrity, *Expert Consensus on the Economics of Climate Change 2* (2015), available at <http://policyintegrity.org/files/publications/ExpertConsensusReport.pdf> [hereinafter *Expert Consensus*] (“Experts believe that there is greater than a 20% likelihood that this same climate scenario would lead to a ‘catastrophic’ economic impact (defined as a global GDP loss of 25% or more).”). See also Robert Pindyck, *The Social Cost of Carbon Revisited* (National Bureau of Economic Research, No. w22807, 2016).

¹⁶⁰ 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.”).

¹⁶¹ Circular A-4 at 39.

¹⁶² 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 159, at 3 (citing 2009 survey).

balance, most uncertainties strongly point toward higher, not lower, social cost of greenhouse gas estimates.¹⁶³

- 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, as well as tipping points, catastrophic risks, and unknown unknowns—and because of other methodological choices.¹⁶⁴

Consequently, uncertainty suggests an even higher social cost of greenhouse gases and so is not a reason to abandon the metric, which would misleadingly suggest that climate damages are worthless. For more details, please see the attached technical appendix on uncertainty.

A Global Perspective on the Social Cost of Greenhouse Gases Is Required to Capture All Factors Bearing on U.S. Public Welfare

FERC has suggested that, following a recent executive order, perhaps a domestic-only estimate of the social cost of greenhouse gases would be required.¹⁶⁵ Even more extremely, FERC has suggested that because “[t]he ability to determine localized impacts from greenhouse gases by use of these models is not possible at this time,” therefore “[i]t would be inappropriate to run the integrated assessment models to estimate global and broad regional physical climate change impacts from the project.”¹⁶⁶ This is false. Not only is FERC statutorily required to consider the worldwide character of environmental problems, but attempting to calculate a domestic-only estimate of the social cost of greenhouse gases would ignore how U.S. welfare is directly impacted through international spillover effects, foreign reciprocity, and the extraterritorial interests of U.S. residents.

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.”¹⁶⁷ 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

¹⁶³ 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.”).

¹⁶⁴ See Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, *supra* note 163; Peter Howard, *Omitted Damages: What’s Missing from the Social Cost of Carbon* (Cost of Carbon Project Report, 2014); Frances C. Moore & Delavane B. Diaz, *Temperature Impacts on Economic Growth Warrant Stringent Mitigation Policy*, 5 NATURE CLIMATE CHANGE 127 (2015) (demonstrating SCC may be biased downward by more than a factor of six by failing to include the climate’s effect on economic growth).

¹⁶⁵ Sabal Remand Order, para. 46, 49.

¹⁶⁶ 163 FERC ¶ 61,128, para. 68-69 (New Market Project Order Denying Rehearing, May 18, 2018).

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

mankind's world environment."¹⁶⁸ 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 sometimes 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.¹⁶⁹

Opponents of climate regulation challenged the global number in court and other forums, and often attempted to use Circular A-4 as support.¹⁷⁰ 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."¹⁷¹ 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.¹⁷²

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

¹⁶⁹ *See generally* Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 *Columbia J. Envtl. L.* 203 (2017).

¹⁷⁰ 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).

¹⁷¹ 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.

¹⁷² *Zero Zone v. Dept. of Energy*, 832 F.3d 654, 679 (7th Cir. 2016).

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

[Y]ou cannot conduct a good regulatory analysis according to a formula. Conducting high-quality analysis requires competent professional judgment. ***Different regulations may call for different emphases*** in the analysis, ***depending on the nature and complexity*** of the regulatory issues and the sensitivity of the benefit and cost estimates to the key assumptions.¹⁷³

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,"¹⁷⁴ 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.¹⁷⁵

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.¹⁷⁶ 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.¹⁷⁷

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.¹⁷⁸ The United States is engaged in a repeated strategic dynamic with several significant players—including the United Kingdom, Germany, Sweden,

¹⁷³ Circular A-4 at 3 (emphasis added).

¹⁷⁴ *Id.* at 38 (counting international transfers as costs and benefits "as long as the analysis is conducted from the United States perspective").

¹⁷⁵ See Howard & Schwartz, *supra* note 169, at 268-69.

¹⁷⁶ 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.").

¹⁷⁷ 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>

¹⁷⁸ See Robert Axelrod, *The Evolution of Cooperation* 10-11 (1984) (on repeated prisoner's dilemma games).

and others—that have already adopted a global framework for valuing the social cost of greenhouse gases.¹⁷⁹ For example, Canada and Mexico have explicitly borrowed the IWG’s global SCC metric to set their own fuel efficiency standards.¹⁸⁰ 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.¹⁸¹ 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.¹⁸² 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.¹⁸³

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,

¹⁷⁹ See Howard & Schwartz, *supra* note 169, at Appendix B.

¹⁸⁰ 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).

¹⁸¹ Howard & Schwartz, *supra* note 169, at 220-21.

¹⁸² 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).

¹⁸³ *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”).

and other forces.¹⁸⁴ This is why the IWG characterized the domestic-only estimate from FUND as a “highly speculative” underestimate. Similarly, a domestic-only estimate based on some rigid conception of geographic borders or U.S. share of world GDP will fail to capture all the climate-related costs and benefits that matter to U.S. citizens.¹⁸⁵ 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.”¹⁸⁶ GDP therefore does not reflect significant U.S. ownership interests in foreign businesses, properties, and other assets, as well as consumption abroad including tourism,¹⁸⁷ or even the 8 million Americans living abroad.¹⁸⁸ 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.¹⁸⁹ However, not only has GNI fallen out of favor as a metric used in international economic policy,¹⁹⁰ 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.¹⁹¹ 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.¹⁹²

Of course, there already are and will continue to be significant, quantifiable, localized effects of climate change.¹⁹³ 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

¹⁸⁴ 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>.

¹⁸⁵ 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).

¹⁸⁶ 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).

¹⁸⁷ “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>.

¹⁸⁸ Assoc. of Americans Resident Overseas, <https://www.aaro.org/about-aaro/6m-americans-abroad>. Admittedly 8 million is only 0.1% of the total population living outside the United States.

¹⁸⁹ *GNI, Atlas Method (Current US\$)*, THE WORLD BANK, <http://data.worldbank.org/indicator/NY.GNP.ATLS.CD>.

¹⁹⁰ *Id.*

¹⁹¹ 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).

¹⁹² 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).”).

¹⁹³ See generally U.S. Global Change Research Program, *Climate Science Special Report: Fourth National Climate Assessment* (2017) (substantiating that significant climate impacts are already underway in the United States and are project to worsen); see also, e.g., Union of Concerned Scientists, *Underwater: Rising Seas, Chronic Floods, and the Implications for U.S. Coastal Real Estate* (2018).

trillion in damages U.S. coastal property.¹⁹⁴ 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.”¹⁹⁵ Similarly, the NAS recently concluded that current IAMs cannot accurately estimate the domestic social cost of greenhouse gases, and that estimates based on U.S. share of global GDP would be likewise insufficient.¹⁹⁶ 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.”¹⁹⁷ 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.¹⁹⁸

III. FERC Should Use the Interagency Working Group’s 2016 Estimates of the Social Cost of Carbon, Methane, and Nitrous Oxide

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).¹⁹⁹ Agencies must continue to use estimates of a similar or higher²⁰⁰ value in their analyses and decisionmaking. A recent Executive Order disbanding the IWG does not change the fact that the IWG estimates still reflect the best available data and methodologies.

IWG’s Methodology Is Rigorous, Transparent, and Based on Best Available Data

Beginning in 2009, the IWG assembled experts from a dozen federal agencies and White House offices to “estimate the monetized damages associated with an incremental increase in carbon emissions in a

¹⁹⁴ EPA, *Climate Change in the United States: Benefits of Global Action* (2015); see also EPA, *Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment* (2017) (quantifying physical and economic damages to multiple U.S. sectors, but acknowledging that only a “small portion of the impacts of climate change are estimated”).

¹⁹⁵ In November 2013, OMB requested public comments on the social cost of carbon. In 2015, OMB along with the rest of the Interagency Working Group issued a formal response to those comments. Interagency Working Group on the Social Cost of Carbon, *Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12,866* at 36 (July 2015) [hereinafter, OMB 2015 Response to Comments].

¹⁹⁶ Nat’l Acad. Sci., *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide* at 53 (2017).

¹⁹⁷ William Nordhaus, *Revisiting the Social Cost of Carbon*, 114 PNAS 1518, 1522 (2017).

¹⁹⁸ Richard Revesz, Kenneth Arrow et al., *The Social Cost of Carbon: A Global Imperative*, 11 REEP 172 (2017).

¹⁹⁹ 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>.

²⁰⁰ 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).

given year” based on “a defensible set of input assumptions that are grounded in the existing scientific and economic literature.”²⁰¹ IWG’s methods combined three frequently used models built to predict the economic costs of the physical impacts of each additional ton of carbon.²⁰² The models together incorporate such damage categories as: agricultural and forestry impacts, coastal impacts due to sea level rise, impacts from extreme weather events, impacts to vulnerable market sectors, 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.²⁰³ IWG ran these models using a baseline scenario including inputs and assumptions drawn from the peer-reviewed literature, and then ran the models again with an additional unit of carbon emissions to determine the increased economic damages.²⁰⁴ IWG’s social cost of carbon estimates were first issued in 2010 and have been updated several times to reflect the latest and best scientific and economic data.²⁰⁵

Following the development of estimates for carbon dioxide, the same basic methodology was used in 2016 to develop the social cost of methane and social cost of nitrous oxide—estimates that captures the distinct heating potential of methane and nitrous oxide emissions.²⁰⁶ These additional metrics used the same economic models, the same treatment of uncertainty, and the same methodological assumptions that IWG applied to the social cost of carbon, and these new estimates underwent rigorous peer-review.²⁰⁷

IWG’s methodology has been repeatedly endorsed by reviewers. In 2014, the U.S. Government Accountability Office concluded that IWG had followed a “consensus-based” approach, relied on peer-reviewed academic literature, disclosed relevant limitations, and adequately planned to incorporate new information through public comments and updated research.²⁰⁸ In 2016 and 2017, the National Academies of Sciences issued two reports that, while recommending future improvements to the methodology, supported the continued use of the existing IWG estimates.²⁰⁹ And in 2016, the U.S. Court of Appeals for the Seventh Circuit held that the Department of Energy’s reliance on IWG’s social cost of carbon was reasonable.²¹⁰ It is, therefore, unsurprising that leading economists and climate policy experts have endorsed the Working Group’s values as the best available estimates.²¹¹

²⁰¹ IWG, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (2010) (“2010 TSD”). Available at <https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf>.

²⁰² *Id.* at 5. These models are DICE (the Dynamic Integrated Model of Climate and the Economy), FUND (the Climate Framework for Uncertainty, Negotiation, and Distribution), and PAGE (Policy Analysis of the Greenhouse Effect).

²⁰³ *Id.* at 6-8.

²⁰⁴ *Id.* at 24-25.

²⁰⁵ IWG, *Technical Update of the Social Cost of Carbon* at 5–29 (2016). Available at https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc_tsd_final_clean_8_26_16.pdf.

²⁰⁶ See 2016 IWG Addendum at 2.

²⁰⁷ *Id.* at 3.

²⁰⁸ Gov’t Accountability Office, *Regulatory Impact Analysis: Development of Social Cost of Carbon Estimates* 12-19 (2014). Available at <http://www.gao.gov/assets/670/665016.pdf>.

²⁰⁹ Nat’l Acad. Sci., Engineering & Med., *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide 3* (2017), <https://www.nap.edu/read/24651/chapter/1>; Nat’l Acad. Sci., Engineering & Med., *Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update* 1–2 (2016); <https://www.nap.edu/read/21898/chapter/1>.

²¹⁰ *Zero Zone*, 832 F.3d at 679.

²¹¹ See, e.g., Richard Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 Science 655 (2017); Michael Greenstone et al., *Developing a Social Cost of Carbon for U.S. Regulatory Analysis: A Methodology and Interpretation*, 7 Rev. Envtl. Econ. & Pol’y 23, 42 (2013); Richard L. Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, 508 Nature 173 (2014) (co-authored with Nobel Laureate Kenneth Arrow, among others).

A Recent Executive Order Does Not Change the Requirements to Monetize Climate Damages

In March 2017, President Trump disbanded the IWG and withdrew their technical support documents.²¹² 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.”²¹³ Consequently, while 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 environmental impact statements. 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.²¹⁴ The Executive Order does not preclude agencies from using the same range of estimates as developed by the IWG, so long as the agency explains that the data and methodology that produced those estimates are consistent with Circular A-4 and, more broadly, with standards for rational decisionmaking.

Similarly, the Executive Order’s withdrawal of the Council on Environmental Quality’s guidance on greenhouse gases,²¹⁵ does not—and legally cannot—remove agencies’ statutory requirement to fully disclose the environmental impacts of greenhouse gas emissions. As the Council on Environmental Quality 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.”²¹⁶ In other words, when the guidance originally recommended the appropriate use of the social cost of greenhouse gases in environmental impact statements,²¹⁷ 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.²¹⁸ And in July 2017, the Department of Energy used the IWG’s estimates for

²¹² Exec. Order No. 13,783 § 5(b), 82 Fed. Reg. 16,093 (Mar. 28, 2017).

²¹³ *Id.* § 5(c).

²¹⁴ See Richard L. Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 SCIENCE 6352 (2017) (explaining that, even after Trump’s Executive Order, the social cost of greenhouse gas estimate of around \$50 per ton of carbon dioxide is still the best estimate).

²¹⁵ Exec. Order 13,783 § 3(c)

²¹⁶ 82 Fed. Reg. 16,576, 16,576 (Apr. 5, 2017).

²¹⁷ 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 (“[A]lthough 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.”).

²¹⁸ *Draft Environmental Impact Statement—Liberty Development Project in the Beaufort Sea, Alaska* at 3-129.

carbon and methane emissions to analyze energy efficiency regulation, describing the social cost of methane as having “undergone multiple stages of peer review.”²¹⁹

As FERC has noted,²²⁰ two agencies have developed new “interim” values of the social cost of greenhouse gases following the Executive Order. Relying on faulty economic theory, these “interim” estimates drop the social cost of carbon from \$50 per ton in year 2020 down to as little as \$1 per ton, and drop the social cost of methane from \$1420 per ton in year 2020 down to \$58. These “interim” estimates are inconsistent with accepted science and economics; the IWG’s 2016 estimates remain the best available estimates. The IWG’s methodology and estimates have been repeatedly endorsed by reviewers as transparent, consensus-based, and firmly grounded in the academic literature. By contrast, the “interim” estimates ignore the interconnected, global nature of our climate-vulnerable economy, and obscure the devastating effects that climate change will have on younger and future generations. The problems with these approaches to the discount rate and the global estimate are discussed above, and for more on the myriad problems with EPA’s interim numbers, see our Joint Comments to EPA on Flawed Estimates of the Social Cost of Carbon in the Proposed Repeal of Carbon Pollution Emission Guidelines for Existing Stationary Sources.²²¹

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

²¹⁹ 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).

²²⁰ Sabal Order Remand, para 46.

²²¹ Available at http://policyintegrity.org/documents/042618_Joint_SCC_Comment_on_CPP.pdf.

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.²²² 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.²²³ 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.²²⁴ Rather than being a reason not to take action, uncertainty increases the SCC and should lead to more stringent policy to address climate change.²²⁵

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.²²⁶ Stochastic uncertainty is persistent randomness in the economic-climate system, including various environmental phenomena such as volcanic eruptions and sun spots.²²⁷ 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).²²⁸

²²² 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.").

²²³ Richard SJ Tol, Safe policies in an uncertain climate: an application of FUND, 9 *Global Environmental Change* 221-232 (1999); Peterson 2006 *supra* note 222.

²²⁴ 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).

²²⁵ See *cites supra* note 224.

²²⁶ 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).

²²⁷ A potential third type of uncertainty arises due to ethical or value judgements: normative uncertainty. Peterson (2006) *supra* note 222; 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 226 and Golub et al. *supra* note 224.

²²⁸ Peterson (2006), *supra* note 222; Pindyck (2007), *supra* note 224; Heal & Millner 2014, *supra* note 227.

When modeling climate change uncertainty, scientists and economists have long emphasized the importance of accounting for the potential of catastrophic climate change.²²⁹ Catastrophic outcomes combine several overlapping concepts including unlucky states of the world (i.e., bad draws), deep uncertainty, and climate tipping points and elements.²³⁰ 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.²³¹ 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.²³² Given the general opinion that bad surprises are likely to outweigh good surprises in the case of climate change,²³³ modelers capture deep uncertainty by selecting probability distributions with a fat upper tail which reflects the greater likelihood of extreme events.²³⁴ 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).²³⁵

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.²³⁶ 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.²³⁷ Tipping point examples include the reorganization of the Atlantic meridional overturning circulation (AMOC) and a shift to a more persistent El Niño regime in the Pacific Ocean.²³⁸ Social tipping points—including climate-induced migration and conflict—also exist.

²²⁹ 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).

²³⁰ Kopp et al. (2016), *supra* note 229.

²³¹ *Id.*

²³² 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).

²³³ 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).

²³⁴ Weitzman (2011), *supra* note 232, 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.”

²³⁵ 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 232; Weitzman (2011), *supra* note 232.

²³⁶ 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 229.

²³⁷ *Id.*

²³⁸ *Id.*; Elmar Kriegler, Jim W. Hall, Hermann Held, Richard Dawson, and Hans Joachim Schellnhuber, *Imprecise probability assessment of tipping points in the climate system*, 106 *Proceedings of the national Academy of Sciences* 5041-5046 (2009);

These various tipping points interact, such that triggering one tipping point may affect the probabilities of triggering other tipping points.²³⁹ 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.²⁴⁰ 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 model²⁴¹ 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.²⁴² Tol, Anthoff, and Hope employ this technique in FUND and PAGE—as did the IWG (2010, 2013, and 2016)²⁴³—by specifying probability distributions for the climate and economic parameters in the models. These models are especially helpful for assessing the net effect of different parametric and stochastic uncertainties. For instance, both the costs of mitigation and the damage from climate change are uncertain. Higher costs would warrant less stringent climate policies, while higher damages lead to more stringent policy, so theoretically, the effect of these two factors on climate policy could be ambiguous. Uncertainty propagation in an IAM calibrated to empirically motivated distributions, however, shows that climate damage uncertainty outweighs the effect of cost uncertainty, leading to a stricter policy when uncertainty is taken into account than when it is ignored.²⁴⁴

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 229, for a full list of known tipping elements and points.

²³⁹ Krieger et al. (2009), *supra* note 238; 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 229.

²⁴⁰ 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 229.

²⁴¹ See Nordhaus, W., & Sator, P. (2013). DICE 2013R: Introduction and user's manual.

²⁴² In alternative calculation method, the modeler “performs optimization of policies for a large number of possible parameter combinations individually and estimates their probability weighted sum.” Golub et al. *supra* note 224. 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.

²⁴³ 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).

²⁴⁴ Tol (1999), *supra* note 223, in characterizing the FUND model, states, “Uncertainties about climate change impacts are more serious than uncertainties about emission reduction costs, so that welfare-maximizing policies are stricter under uncertainty than under certainty.”

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

The IWG was rigorous in addressing uncertainty. First, it conducted Monte Carlo simulations over the above IAMs specifying different possible outcomes for climate sensitivity (represented by a right skewed, fat tailed distribution to capture the potential of higher than expected warming). It also used scenario analysis: five different emissions growth scenarios and three discount rates. Second, the IWG (2016)²⁴⁵ 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.²⁴⁶ 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.²⁴⁷ 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.²⁴⁸ Recent work in stochastic dynamic programming tends to better integrate fat tails – particularly with respect to tipping points (see below) – and address additional aversion to this type of uncertainty (also known as ambiguity aversion); doing so can further increase the SCC under uncertainty.²⁴⁹

²⁴⁵ IWG (2016) *supra* note 243.

²⁴⁶ IWG (2010) *supra* note 243.

²⁴⁷ Howard (2014), *supra* note 240. 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.

²⁴⁸ Weitzman (2011), *supra* note 232; Kopp et al. (2016) *supra* note 229.

²⁴⁹ Derek Lemoine & Christian P. Traeger, *Ambiguous tipping points*, 132 *Journal of Economic Behavior & Organization* 5-18 (2016); Lemoine & Rudik (2017), *supra* note 224. IAM modelers currently assume that society is equally averse to known unknown and known unknowns. Lemoine & Traeger, *id.*

In contrast to their approach to fat tails, the IAMs used by the IWG (2010; 2013; 2016) sometimes address climate tipping points, though they do not apply state-of-the-art methods for doing so. In early versions of DICE (DICE-2010 and earlier), Nordhaus implicitly attributes larger portions of the SCC to tipping points by including certainty equivalent damages of catastrophic events - representing two-thirds to three-quarter of damages in DICE – calibrated to an earlier Nordhaus (1994) survey of experts.²⁵⁰ 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.²⁵¹ 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.²⁵² Despite the obvious methodological basis for addressing tipping points, the latest versions of DICE²⁵³ 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.²⁵⁴

The IWG approach also fails to include a risk premium—that is, the amount of money society would require in order to accept the uncertainty (i.e., variance) over the magnitude of warming and the resulting damages from climate change relative to mean damages (IWG, 2010; IWG, 2015)). The mean of a distribution, which is a measure of a distribution’s central tendency, represents only one descriptor or “moment” of a distribution’s shape. Each IAM parameter and the resulting SCC distributions have differing levels of variance (i.e., spread around the mean), skewness (i.e., a measure of asymmetry), and

²⁵⁰ William Nordhaus & Joseph Boyer, *Warning the World: Economic Models of Global Warming* (2000); Nordhaus (2008) *supra* note 264; Howard (2014), *supra* note 240; Kopp et al. (2016) *supra* note 229.

²⁵¹ Hope (2006) also calibrated a discontinuous damage function in PAGE-99 used by IWG (2010); see Chris Hope, *The Marginal Impact of CO₂ from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern*, 6 *INTEGRATED ASSESSMENT J.* 19 (2006). Howard (2014), *supra* note 240.

²⁵² Kopp et al. (2016) *supra* note 229.

²⁵³ 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).

²⁵⁴ Using FUND, Link and Tol (2011) find that a collapse of the AMOC would decrease GDP (and thus increase the SCC) by a small amount. Earlier modeling of this collapse in DICE find a more significance increase. P. Michael Link & Richard SJ Tol, *Estimation of the economic impact of temperature changes induced by a shutdown of the thermohaline circulation: an application of FUND*, 104 *Climatic Change* 287-304 (2011); Klaus Keller, Kelvin Tan, François MM Morel, & David F. Bradford, *Preserving the Ocean Circulation: Implications for Climate Policy*, 47 *Climatic Change* 17-43 (2000); Michael D Mastrandrea & Stephen H. Schneider, *Integrated assessment of abrupt climatic changes*, 1 *Climate Policy* 433-449 (2001); Klaus Keller, Benjamin M. Bolker, & David F. Bradford, *Uncertain climate thresholds and optimal economic growth*, 48 *Journal of Environmental Economics and management* 723-741 (2004). With respect to thawing of the permafrost, Hope and Schaefer (2016) and Gonzalez-Eguino and Neumann (2016) find increases in damages (and thus an increase in the SCC) when integrating this tipping element into the PAGE09 and DICE-2013R, respectively. Chris Hope & Kevin Schaefer, *Economic impacts of carbon dioxide and methane released from thawing permafrost*, 6 *Nature Climate Change* 56-59 (2016); Mikel González-Eguino & Marc B. Neumann, *Significant implications of permafrost thawing for climate change control*, 136 *Climatic Change* 381-388 (2016). Looking at the collapse of the West Antarctic Ice sheet, Nicholls et al. (2008) find a potential for significant increases in costs (and thus the SCC) in FUND. Robert J Nicholls, Richard SJ Tol, & Athanasios T. Vafeidis, *Global estimates of the impact of a collapse of the West Antarctic ice sheet: an application of FUND*, 91 *Climatic Change* 171-191 (2008). Ceronsky et al. (2011) model three tipping points (collapse of the Atlantic Ocean Meridional Overturning Circulation, large scale dissociation of oceanic methane hydrates; and a high equilibrium climate sensitivity parameter), and finds a large increase in the SCC in some cases. Megan Ceronsky, David Anthoff, Cameron Hepburn, and Richard SJ Tol, *Checking the price tag on catastrophe: The social cost of carbon under non-linear climate response* (ESRI working paper No. 392, 2011).

kurtosis (which, like skewness, is another descriptor of a distribution's tail) as well as means.²⁵⁵ 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.²⁵⁶ 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,²⁵⁷ current IAM assumptions,²⁵⁸ 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).²⁵⁹ 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 CO₂ emissions.²⁶⁰ Option value reflects the value of future flexibility due to uncertainty and irreversibility; in this case, the irreversibility of CO₂ emissions due to their long life in the atmosphere.²⁶¹ 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

²⁵⁵ 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 243.

²⁵⁶ 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.

²⁵⁷ IWG, 2010 *supra* note 243, at fn 22; Cai et al., 2016, *supra* note 239, at 521.

²⁵⁸ 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 241; Anthoff & Tol (2013) *supra* note 247; 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.

²⁵⁹ According to Heal and Millner (2014) *supra* note 227, 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.

²⁶⁰ 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:

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

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

²⁶¹ Even if society drastically reduced CO₂ emissions, CO₂ concentrations would continue to rise in the near future and many impacts would occur regardless due to lags in the climate system. Robert S Pindyck, *Uncertainty in environmental economics*, 1 *Review of environmental economics and policy* 45-65 (2007).

behavior.”²⁶² 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.²⁶³ 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.²⁶⁴ 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),²⁶⁵ the stochastic dynamic optimization model must also account for a potential counteracting abatement cost irreversibility – the sunk costs of investing in abatement technology if we learn that climate change is less severe than expected – by the nature of being on the optimal emissions path that balances the cost of emissions and abatement. In the optimal case, uncertainty and irreversibility of abatement *can theoretically* lead to a lower optimal emissions tax, unlike the social cost of carbon. The difference in the implication for the optimal tax and the SCC means that the stochastic dynamic modeling results are less applicable to the SCC.

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

Bearing in mind the limitations of stochastic dynamic modeling, some new research provides valuable insights that are relevant to calculation of the social cost of greenhouse gases. The new and growing stochastic dynamic optimization literature implies that the IWG’s SCC estimates are downward biased. The literature is made up of three models – real option, finite horizon, and infinite horizon models – of which the infinite time horizon (i.e., stochastic dynamic programming (SDP)) models are the most comprehensive for analyzing the impact of uncertainty on optimal sequential abatement policies.²⁶⁶ 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

²⁶² Pindyck (2007) *supra* note 224.

²⁶³ Kann & Weyant *supra* note 226; Pindyck (2007) *supra* note 224; Golub et al. (2014) *supra* note 224.

²⁶⁴ 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).

²⁶⁵ 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.

²⁶⁶ Kann & Weyant *supra* note 226; Pindyck (2007) *supra* note 224; Golub et al. (2014) *supra* note 224.

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.²⁶⁷

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.²⁶⁸ For SDP models, uncertainty tends to strengthen the optimal emissions path relative to the determinist case even without tipping points,²⁶⁹ and these results are strengthened under realistic preference assumptions.²⁷⁰ Given that there is no counter-balancing tipping abatement cost,²⁷¹ the complete modeling of climate uncertainty – which fully accounts for tipping points and fat tails – increases the optimal tax. Uncertainty leads to a stricter optimal emissions policy even if with irreversible mitigation costs, highlighting that the SCC would also increase when factoring in risk aversion and irreversibility given that abatement costs are very low on the BAU emissions path.

Second, given the importance of catastrophic impacts under uncertainty (as shown in the previous paragraph), the full and accurate modeling of tipping points and unknown knowns is critical when modeling climate change. The most sophisticated climate-economic models of tipping points – which include the possibility of multiple correlated tipping points in stochastic dynamic IAMs – find an increase in the optimal tax by 100%²⁷² to 800%²⁷³ 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.²⁷⁴ Recent research has shown that accurate estimation of decisions under

²⁶⁷ Kann & Weyant *supra* note 226; Pindyck (2007) *supra* note 224; Golub et al. (2014) *supra* note 224; Lemoine & Rudik 2017 *supra* note 224. 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*).

²⁶⁸ 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 224), 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 224; Golub et al 2014 *supra* note 224). 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 224).

²⁶⁹ 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 224; Lemoine & Rudik 2017 *supra* note 224). 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.

²⁷⁰ Pindyck (2007) *supra* note 224; Golub et al. (2014) *supra* note 224; Lemoine & Rudik 2017 *supra* note 224.

²⁷¹ Pindyck (2007) *supra* note 224.

²⁷² Derek Lemoine & Christian P. Traeger, *Economics of tipping the climate dominoes*. 6 NAT. CLIM. CHANG. 514-519 (2016).

²⁷³ Cai et al. 2016 *supra* note 239.

²⁷⁴ Cai et al. 2016 *supra* note 239; 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

uncertainty crucially depends on distinguishing between risk and time preferences.²⁷⁵ 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.²⁷⁶ 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.²⁷⁷ 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.²⁷⁸ Current omission of key features of the climate problem under uncertainty (the risk and climate premiums, option value, and fat tailed probability distributions) and incomplete modeling of tipping points imply that the SCC will further increase with the improved modeling of uncertainty in IAMs.

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 239 replace the DICE risk aversion of 1.45 and elasticity parameter of 1/1.45 with values of 3.066 and 1.5, respectively.

²⁷⁵ James Andreoni & Charles Sprenger, *Risk Preferences Are Not Time Preferences*, 102 *AM. ECON. REV.* 3357–3376 (2012).

²⁷⁶ Lemoine & Traeger (2016) *supra* note 307.

²⁷⁷ 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).

²⁷⁸ Golub et al. (2014) *supra* note 224 states “The most important general policy implication from the literature is that despite a wide variety of analytical approaches addressing different types of climate change uncertainty, none of those studies supports the argument that no action against climate change should be taken until uncertainty is resolved. On the contrary, uncertainty despite its resolution in the future is often found to favor a stricter policy.” See also Comments from Robert Pindyck, to BLM, on the Social Cost of Methane in the Proposed Suspension of the Waste Prevention Rule (submitted Nov. 5, 2017) (“Specifically, my expert opinion about the uncertainty associated with Integrated Assessment Models (IAMs) was used to justify setting the SC-CH4 to zero until this uncertainty is resolved. That conclusion does not logically follow and I have rejected it in the past, and I reiterate my rejection of that view again here. While at this time we do not know the Social Cost of Carbon (SCC) or the Social Cost of Methane with precision, we do know that the correct values are well above zero...Because of my concerns about the IAMs used by the now-disbanded Interagency Working Group to compute the SCC and SC-CH4, I have undertaken two lines of research that do not rely on IAMs...[They lead] me to believe that the SCC is larger than the value estimated by the U.S. Government.”

TECHNICAL APPENDIX: DISCOUNTING

The Underlying IAMs All Use a Consumption Discount Rate

Employing a consumption discount rate would also ensure that the U.S. government is consistent with the assumptions employed by the underlying IAM models: DICE, FUND, and PAGE. Each of these IAMs employs consumption discount rates calibrated using the standard Ramsey formula (Newell, 2017). In DICE-2010, the elasticity of the pure rate of time preference is 1.5 and an elasticity of the marginal utility of consumption (η) of 2.0. Together with its assumed per capita consumption growth path, the average discount rate over the next three hundred years is 2.4%.²⁷⁹ However, more recent versions of DICE (DICE-2013R and DICE-2016) update η to 1.45; this implies an increase of the average discount rate over the timespan of the models to between 3.1% and 3.2% depending on the consumption growth path.²⁸⁰ In FUND 3.8 and (the mode values in) PAGE09, both model parameters are equal to 1.0. Based on the assumed growth rate of the U.S. economy (without climate damages), the average U.S. discount rate in FUND 3.8 is 2.0% over the timespan of the model (without considering climate damages). Unlike FUND 3.8, PAGE09 specifies triangular distributions for both parameters with a pure rate of time preference of between 0.1 and 2 with a mean of 1.03 and an elasticity of the marginal utility of consumption of between 0.5 and 2 with a mean 1.17. Using the PAGE09's mode values (without accounting for climate damages), the average discount rate over the timespan of the models is approximately 3.3% with a range of 1.2% to 6.5%. Rounding up the annual growth rate over the last 50 years to approximately 2%,²⁸¹ the range of best estimates of the SDR implied in the short-run by these three models is approximately 3% (PAGE09's mode estimate and FUND 3.8) to 4.4% (DICE-2016), though the PAGE09 model alone implies a range of 1.1% to 6.0% with a central estimate of 3%. The range of potential consumption discount rates in these IAMs is relatively consistent with IWG (2010; 2013; 2016) in the short-run, though the discount rates of the IAMs employed by the IWG decline over time (due to declining growth rates over time) implying a potential upward bias to the IWG consumption discount rates.

A Declining Discount Rate is Justified to Address Discount Rate Uncertainty

A strong consensus has developed in economics that the appropriate way to discount intergenerational benefits is through a declining discount rate (Arrow et al., 2013; Arrow et al., 2014; Gollier & Hammitt, 2014; Cropper et al., 2014).²⁸² Not only are declining discount rate theoretically correct, they are actionable (i.e., doable given our current knowledge) and consistent with OMB's *Circular A-4*. Perhaps the best reason to adopt a declining discount rate is the simple fact that there is considerable uncertainty around which discount rate to use. The uncertainty in the rate points directly to the need to use a declining rate, as the impact of the uncertainty grows exponentially over time such that the

²⁷⁹ Due to a slowing of global growth, DICE-2010 implies a declining discount rate schedule of 5.1% in 2015, 3.9% from 2015 to 2050; 2.9% from 2055 to 2100; 2.2% from 2105 to 2200, and 1.9% from 2205 to 2300. This would be a steeper decline if Nordhaus accounted for the positive and normative uncertainty underlying the SDR.

²⁸⁰ Due to a slowing of global growth, DICE-2016 implies a declining discount rate schedule of 5.1% in 2015, 4.7% from 2015 to 2050; 4.1% from 2055 to 2100; 3.1% from 2105 to 2200, and 2.5% from 2205 to 2300.

²⁸¹ According to the World Bank, the average global and United States per capita growth rates were 1.7% and 1.9%, respectively.

²⁸² Arrow et al. (2014) at 160-161 states that "We have argued that theory provides compelling arguments for using a declining certainty-equivalent discount rate," and concludes the paper by stating "Establishing a procedure for estimating a [declining discount rate] for project analysis would be an improvement over the OMB's current practice of recommending fixed discount rates that are rarely updated."

correct discount rate is not an arithmetic average of possible discount rates.²⁸³ Uncertainty about future discount rates could stem from a number of sources particularly salient in the context of climate change, including uncertainty about future economic growth, consumption, the consumption rate of interest, and preferences. Additionally, economic theory shows that if there is debate or disagreement over which discount rate to use, this should lead to the use of a declining discount rate (Weitzman, 2001; Heal & Millner, 2014). Though, the range of potential discount rates is limited by theory to potential consumption discount rates (see earlier discussion), which is certainly less than 7%.

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

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

Economists have recently highlighted two main motivations for using a declining discount rate, which we elaborate on in what follows. First, if the discount rate for a project is fixed but uncertain, then the certainty-equivalent discount rate will decline over time, meaning that benefits should be discounted using a declining rate.²⁸⁴ Second, uncertainty about the growth rate of consumption or output also implies that a declining discount rate should be used, so long as shocks to consumption are positively correlated over time.²⁸⁵ In addition to these two arguments, other motivations for declining discount rates have long been recognized. For instance, if the growth rate of consumption declines over time, the Ramsey rule²⁸⁶ for discounting will lead to a declining discount rate.²⁸⁷

In the descriptive setting adopted by the IWG (2010), economists have demonstrated that calculating the expected net present value of a project is equivalent to discounting at a declining certainty

²⁸³ Karp (2005) states that mathematical “intuition for this result is that as [time] increases, smaller values of r in the support of the distribution are relatively more important in determining the expectation of e^{-rt} ” where r is the constant discount rate.” Or as Hepburn et al. (2003) puts it, “The intuition behind this idea is that scenarios with a higher discount rate are given less weight as time passes, precisely because their discount factor is falling more rapidly” over time.

²⁸⁴ This argument was first developed in Weitzman (1998) and Weitzman (2001).

²⁸⁵ See, e.g., Gollier (2009).

²⁸⁶ The Ramsey discount rate equation for the social discount rate is $r = \delta + \eta * g$ where r is the social discount rate, δ is the pure rate of time preference, η is the aversion to inter-generational inequality, and g is the growth rate of per capita consumption. For the original development, see, Ramsey, F. P. (1928). A Mathematical Theory of Saving. *The Economic Journal*, 38(152).

²⁸⁷ Higher growth rates lead to higher discounting of the future in the Ramsey model because growth will make future generations wealthier. If marginal utility of consumption declines in consumption, then, one should more heavily discount consumption gains by wealthier generations. Thus, if growth rates decline over time, then the rate at which the future is discounted should also decline. See, e.g., Arrow et al. (2014) at 148. It is standard in IAMs to assume that the growth rate of consumption will fall over time. See, e.g., Nordhaus (2017) at 1519, “Growth in global per capita output over the 1980–2015 period was 2.2% per year. Growth in global per capita output from 2015 to 2050 is projected at 2.1% per year, whereas that to 2100 is projected at 1.9% per year.” Similarly, Hope (2011) at 22 assumes that growth will decline. For instance, in the U.S., growth is 1.9% per year in 2008 and declines to 1.7% per year by 2040. Using data provided by Dr. David Anthoff (one of the founders of FUND), FUND assumes that the global growth rate was 1.8% per year from 1980–2015 period, 1.4% per year from 2015 to 2050 and 2015 to 2100, and then dropping to 1.0% from 2100 to 2200 and then 0.7% from 2200 to 2300.

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

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

If the normative approach to discounting is used in the future (i.e., the current approach of IAMs), economists have demonstrated that an extended Ramsey rule²⁸⁸ implies a declining discount rate when (1) the growth rate of per capita consumption is stochastic,²⁸⁹ and (2) consumption shocks are positively correlated over time (or their mean or variances are uncertain) (Arrow et al., 2013; Arrow et al., 2014; Gollier & Hammitt, 2014; Cropper et al., 2014).²⁹⁰ While a constant adjustment downwards (known as the precautionary effect²⁹¹) can be theoretically correct when growth rates are independent and identically distributed (Cropper et al., 2014), empirical evidence supports the two above assumptions for the United States, thus implying a declining discount rate (Cropper et al., 2014; Arrow et al., 2014; IPCC,

²⁸⁸ If the future growth of consumption is uncertainty with mean μ and variance σ^2 , an extended Ramsey equation $r = \delta + \eta * \mu - 0.5\eta^2\sigma^2$ applies where r is the social discount rate, δ is the pure rate of time preference, η is the aversion to inter-generational inequality, and g is the growth rate of per capita consumption. Gollier (2012, Chapter 3) shows that we can rewrite the extended discount rate as $r = \delta + \eta * g - 0.5\eta(\eta + 1)\sigma^2$ where g is the growth rate of expected consumption and $\eta + 1$ is prudence.

²⁸⁹ The IWG assumption of five possible socio-economic scenarios implies an uncertain growth path.

²⁹⁰ The intuition of this result requires us to recognize that the social planner is prudent in these models (i.e., saves more when faces riskier income). When there is a positive correlation between growth rates in per capita consumption, the representative agent faces more cumulative risk over time with respect to the “duration of the time spent in the bad state.” (Gollier et al., 2008). In other words, “the existence of a positive correlation in the changes in consumption tends to magnify the long-term risk compared to short-term risks. This induces the prudent representative agent to purchase more zero-coupon bonds with a long maturity, thereby reducing the equilibrium long-term rate.” (Gollier, 2007). Mathematically, the intuition is that under prudence, the third term in the extended Ramsey equation (see footnote 323) is negative, and a “positive [first-degree stochastic] correlation in changes in consumption raises the riskiness of consumption at date T, without changing its expected value. Under prudence, this reduces the interest rate associated to maturity T” (Gollier et al., 2007) by “increasing the strength of the precautionary effect” in the extended Ramsey equation (Arrow et al., 2014; Cropper et al., 2014).

²⁹¹ The precautionary effect measures aversion to future “wiggles” in consumption (i.e., preference for consumption smoothing) (Traeger, 2014).

2014).²⁹² We should further expect this positive correlation to strengthen over time due to the negative impact of climate change on consumption, as climate change causes an uncertain permanent reduction in consumption (Gollier, 2009).²⁹³

Several papers have estimated declining discount rate schedules for specific values of the pure rate of time preference and elasticity of marginal utility of consumption (e.g., Arrow et al., 2014), though recent work demonstrates that the precautionary effect increases and discount rates decrease further when catastrophic economic risks (such as the Great Depression and the 2008 housing crisis) are modeled (Gollier & Hammitt, 2014; Arrow et al., 2014). It should be noted that this decline in discount rates due to uncertainty in the global growth path is in addition to that resulting from a declining central growth path over time (Nordhaus, 2014; Marten, 2015).²⁹⁴

Additionally, a related literature has developed over the last decade demonstrating that normative uncertainty (i.e., heterogeneity) over the pure rate of time preference (δ)—a measure of impatience—also leads to a declining social discount rate (Arrow et al., 2014; Cropper et al., 2014; Freeman and Groom, 2016). Despite individuals differing in their pure rate of time preference (Gollier and Zeckhauser, 2005), an equilibrium (consumption) discount exists in the economy. In the context of IAMs, modelers aggregate social preferences (often measured using surveyed experts) by calibrating the preferences of a representative agent to this equilibrium (Millner and Heal, 2015; Freeman and Groom, 2016). The literature generally finds a declining social discount rate due to a declining collective pure rate of time preference (Gollier and Zeckhauser, 2005; Jouini et al., 2010; Jouini and Napp, 2014; Freeman and Groom, 2016).²⁹⁵ The heterogeneity of preferences and the uncertainty surrounding economic growth hold simultaneously (Jouini et al., 2010; Jouini and Napp, 2014), leading to potentially two sources of declining discount rates in the normative context.

Declining Rates are Actionable and Time-Consistent

There are multiple declining discount rate schedules from which the U.S. government can choose, of which several are provided in Arrow et al. (2014) and Cropper et al. (2014). One possible declining interest rate schedule for consideration by the IWG is the one proposed by Weitzman (2001).²⁹⁶ It is derived from a broad survey of top economists in context of climate change, and explicitly incorporates

²⁹² Essentially, the precautionary effect increases over time when shocks to the growth rate are positively correlated, implying that future societies require higher returns to face the additional uncertainty (Cropper et al., 2014; Arrow et al., 2014; IPCC, 2014).

²⁹³ Due to the deep uncertainty characterizing future climate damages, some analysts argue that the stochastic processes underlying the long-run consumption growth path cannot be econometrically estimated (Weitzman, 2007; Gollier, 2012). In other words, economic damages, and thus future economic growth, are ambiguous. Agents must then form subjectivity probabilities, which may be better interpreted as a belief (Cropper et al., 2014). Again, theory shows that ambiguity leads to a declining discount rate schedule by Jensen's inequality (Cropper et al., 2014).

²⁹⁴ A common assumption in IAMs is that global growth will slow over time leading to a declining discount rate schedule over time; see footnote 7. Uncertainty over future consumption growth and heterogeneous preferences (discussed below) would lead to a more rapid decline in the social discount rate.

²⁹⁵ The intuition for declining discount rates due to heterogeneous pure rates of time preference is laid out in Gollier and Zeckhauser (2005). In equilibrium, the least patient individuals trade future consumption to the most patient individuals for current consumption, subject to the relative value of their tolerance for consumption fluctuations. Thus, while public policies in the near term mostly impact the most impatient individuals (i.e., the individuals with the most consumption in the near term), long-run public policies in the distant future are mostly going to impact the most patient individuals (i.e., the individuals with the most consumption in the long-run).

²⁹⁶ Weitzman (2001)'s schedule is as follows: 4% for 1-5 years; 3% for 6-25 years; 2% for 26-75 years; 1% for 76-300 years; and 0% for 300+ years.

arguments around interest rate uncertainty.²⁹⁷ Other declining discount rate schedules include Newell and Pizer (2003); Groom et al. (2007); Freeman et al. (2015). Many leading economists support the United States government adopting a declining discount rate schedule (Arrow et al., 2014; Cropper et al., 2014). Moreover, the United States would not be alone in using a declining discount rate. It is standard practice for the United Kingdom and French governments, among others (Gollier & Hammitt, 2014; Cropper et al., 2014). The U.K. schedule explicitly subtracts out an estimated time preference.²⁹⁸ France's schedule is roughly similar to the United Kingdom's. Importantly, all of these discount rate schedules yield lower present values than the constant 2.5% discount rate employed by IWG (2010), suggesting that even the lowest discount rate evaluated by the IWG is too high.²⁹⁹ The consensus of leading economists is that a declining discount rate schedule should be used, harmonious with the approach of other countries like the United Kingdom. Adopting such a schedule would likely increase the SCC substantially from the administration's 3% estimate, potentially up to two to three fold (Arrow et al., 2013; Arrow et al., 2014; Freeman et al., 2015).

A declining discount rate motivated by discount rate or growth rate uncertainty avoids the time inconsistency problem that can arise if a declining pure rate of time preference (δ) is used. *Circular A-4* cautions that “[u]sing the same discount rate across generations has the advantage of preventing time-inconsistency problems.”³⁰⁰ A time inconsistent decision is one where a decision maker changes his or her plan over time, solely because time has passed. For instance, consider a decision maker choosing whether to make an investment that involves an up-front payment followed by future benefits. A time consistent decision maker would invest in the project if it had a positive net-present value, and that decision would be the same whether it was made 10 years before investment or 1 year before investment. A time inconsistent decision maker might change his or her mind as the date of the investment arrived, despite no new information becoming available. Consider a decision maker who has a declining pure rate of time preference (δ) trying to decide whether to invest in a project that has large up-front costs followed by future benefits. 10 years prior to the date of investment, the decision maker will believe that this project is a relatively unattractive investment because both the benefits and costs would be discounted at a low rate. Closer to the date of investment, however, the costs would be relatively highly discounted, possibly leading to a reversal of the individual's decision. Again, the discount rate schedule is time consistent as long as δ is constant.

The arguments provided here for using a declining consumption discount rate are not subject to this time inconsistency critique. First, time inconsistency occurs if the decision maker has a declining pure rate of time preference, not due to a decreasing discount rate term structure.³⁰¹ Second, uncertainty

²⁹⁷ Freeman and Groom (2014) demonstrate that this schedule only holds if the heterogeneous responses to the survey were due to differing ethical interpretations of the corresponding discount rate question. A recent survey by Drupp et al. (2015) – which includes Freeman and Groom as co-authors – supports the Weitzman (2001) assumption.

²⁹⁸ The U.K. declining discount rate schedule that subtracts out a time preference value is as follows (Lowe, 2008): 3.00% for 0-30 years; 2.57% for 31-75 years; 2.14% for 76-125 years; 1.71% for 126-200 years; 1.29% for 201-300 years; and 0.86% for 301+ years.

²⁹⁹ Using the IWG's 2010 SCC model, Johnson and Hope (2012) find that the U.K. and Weitzman schedules yield SCCs of \$55 and \$175 per ton of CO₂, respectively, compared to \$35 at a 2.5% discount rate. Because the 2.5% discount rate was included by the IWG (2010) to proxy for a declining discount rate, this result indicates that constant discount rate equivalents may be insufficient to address declining discount rates.

³⁰⁰ *Circular A-4* at 35.

³⁰¹ Gollier (2012) states “It is often suggested in the literature that economic agents are time inconsistent if the term structure of the discount rate is decreasing. This is not the case. What is crucial for time consistency is the constancy of the rate of impatience, which is a cornerstone of the classic analysis presented in this book. We have seen that this assumption is compatible with a declining monetary discount rate.”

about growth or the discount rate avoids time inconsistency because uncertainty is only resolved in the future, after investment decisions have already been made. As the NAS (2017) notes, “One objection frequently made to the use of a declining discount rate is that it may lead to problems of time inconsistency....This apparent inconsistency is not in fact inconsistent....At present, no one knows what the distribution of future growth rates...will be; it may be different or the same as the distribution in 2015. Even if it turns out to be the same as the distribution in 2015, that realization is new information that was not available in 2015.”³⁰²

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

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

There is a strong consensus among economists that it is theoretically correct to use consumption discount rates in the intergenerational setting of climate change, such as in the calculation of the SCC. Similarly, there is a strong consensus that a capital discount rate is inappropriate according to “good economics” (Newell, 2017).³⁰³ This consensus holds across panels of experts on the social cost of carbon (NAS, 2017); surveys of experts on climate change and discount rates (Weitzman, 2001; Drupp et al., 2015; Howard and Sylvan, 2015; and Pindyck, 2016); the three most commonly cited IAMs employed in calculating the federal SCC; and the government’s own analysis (IWG, 2010; CEA, 2017). For more analysis of this issue, see the discussion in the main body our Comments on the inappropriateness using a discount rate premised on the return to capital in intergenerational settings.

³⁰² NAS Second Report, *supra* note 62, at 182.

³⁰³ The former co-chair of the National Academy of Sciences’ Committee on Assessing Approaches to Updating the Social Cost of Carbon – Richard Newell (2017) – states that “[t]hrough the addition of an estimate calculated using a 7 percent discount rate is consistent with past regulatory guidance under OMB *Circular A-4*, there are good reasons to think that such a high discount rate is inappropriate for use in estimating the SCC...It is clearly inappropriate, therefore, to use such modeling results with OMB’s 7 percent discount rate, which is intended to represent the historical before-tax return on private capital...This is a case where unconsidered adherence to the letter of OMB’s simplified discounting approach yields results that are inconsistent with and ungrounded from good economics.”