Institute *for* Policy Integrity
NEW YORK UNIVERSITY SCHOOL OF LAW

November 23, 2020

To: Montana Department of Environmental Quality

Subject: Comments on Greenhouse Gas Emissions and Social Cost of Carbon in Draft Environmental Impact Statement for Area B at the Rosebud Mine

The Institute for Policy Integrity at New York University School of Law ("Policy Integrity")[1] respectfully submits the following comments on the Montana Department of Environmental Quality's (the "Department") Draft Environmental Impact Statement for the proposed fifth amendment to the operating permit for Area B at the Rosebud Mine (the "Proposed Amendment").[2] Policy Integrity is a non-partisan think tank dedicated to improving the quality of government decision-making through advocacy and scholarship in the fields of administrative law, economics, and public policy. We regularly submit comments to and testify before federal and state agencies on the assessment of climate impacts in administrative determinations, including through use of the Social Cost of Carbon.[3]

The Proposed Amendment would add over 9,000 acres to the permit area and extend the life of the Rosebud Mine by seven years.[4] Because the release of carbon dioxide into the atmosphere is a natural consequence of coal extraction and combustion, the Proposed Amendment would lead to considerable emissions of this greenhouse gas. As carbon dioxide traps heat and thereby warms the Earth's atmosphere, the Proposed Amendment would incrementally contribute to climate change and exacerbate its many consequences including harms to energy infrastructure and increases in energy demand, an increase in wildfire and extreme weather events, impacts to agriculture and water resources, and human health impacts including mortality from heat-related illness and changing disease vectors like malaria and

[1] This document does not purport to represent the views, if any, of New York University School of Law.

[2] MT. DEP'T OF ENV'T QUALITY, DRAFT ENVIRONMENTAL IMPACT STATEMENT, ROSEBUD MINE AREA B AM5 COLSTRIP, MONTANA (Sept. 2020) [hereinafter "DEIS"].

[3] A selection of Policy Integrity's state-level comments and testimony on the Social Cost of Carbon is available at https://costofcarbon.org/resources. States that Policy Integrity has engaged in include Colorado, Nevada, California, New Jersey, and others.

[4] DEIS at S-1.

dengue fever.[5] Despite these foreseeable and inevitable consequences of the Proposed Amendment, the Department does not discuss climate change in the Draft Environmental Impact Statement or project the carbon dioxide emissions that would result from the proposal.

The Department should estimate the carbon dioxide emissions resulting from the Proposed Amendment, both directly from mining operations and indirectly from coal combustion. Projecting carbon dioxide emissions from coal combustion is relatively straightforward. Here, the Department projects that the Proposed Amendment would yield 104.3 million short tons of additional subbituminous coal (beyond what the mine is already expected to produce).[6] According to emission factors published by the U.S. Environmental Protection Agency, each short ton of subbituminous coal yields 1,676 kilograms of carbon dioxide when combusted.[7] Thus, **total coal combustion resulting from the Proposed Amendment would produce about 175 billion kilograms—or 175 million metric tons—of carbon dioxide.**[8]

Simply projecting the volume of greenhouse gas emissions by itself does not meaningfully inform the climate-related harms that those emissions will cause. To project those impacts, federal and state policymakers typically turn to the Social Cost of Carbon. The Social Cost of Carbon is a metric designed to quantify and monetize climate damages, representing the net economic cost of carbon dioxide emissions. The tool provides a monetary estimate of the damage done by each ton of carbon dioxide that is released into the atmosphere. The methodology calculates how the emission of an additional unit of carbon dioxide affects atmospheric greenhouse concentrations, how that change in atmospheric concentrations changes temperature, and how that change in temperature incrementally contributes to the various social and economic damages described above.[9] The Social Cost of Carbon therefore captures the factors that actually affect public welfare and assesses the degree of impact to each factor.

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[5] For a more complete discussion 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).

[6] DEIS at 43, S-1 (explaining that the mine produces subbituminous coal.

[7] EPA, *Emissions Factors for Greenhouse Gas Inventories*, https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf (last modified Mar. 26, 2020). As this chart details, combustion of subbituminous coal also produces about 19,800 metric tons of methane and 292 metric tons nitrous oxide—both of which are more potent greenhouse gases than carbon dioxide.

[8] Another method to estimate greenhouse gas emissions is to apply the emissions factors from the U.S. Environmental Protection Agency's Greenhouse Gases Equivalencies Calculator explains that each railcar of coal (i.e. 90.89 metric tons) produces 181.85 metric tons of carbon dioxide upon combustion. *See* EPA Greenhouse Gases Equivalencies Calculator, https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator. Applying these emissions factors finds that total coal combustion resulting from the Proposed Amendment will produce about 189.3 million metric tons of carbon dioxide.

[9] Interagency Working Group on the Social Cost of Carbon, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis* 5 (2010).

Because it provides a comprehensive and easily discernible estimate of climate damages, the Social Cost of Carbon is incredibly useful for evaluating policies that affect greenhouse gas emissions. Monetization provides much-needed context for otherwise abstract consequences of climate change. It allows decision-makers and the public to weigh all costs and benefits of an action—and to compare alternatives—using the common metric of money. By monetizing and contextualizing the risks of climate change, the Social Cost of Carbon makes it far more difficult for decisionmakers and the public to ignore these risks, as it translates long-term costs into present values and thereby concretizes the harms of climate change and gives due weight to the potential of lower-probability but catastrophic outcomes. For these reasons, the tool has been used by numerous federal agencies for regulatory impact analysis and environmental impact assessment,[10] and over a dozen states also apply the Social Cost of Carbon in their decisionmaking including California, Colorado, Oregon, Nevada, and Washington.[11]

The best estimates of the Social Cost of Carbon were developed by the federal Interagency Working Group on the Social Cost of Carbon ("Working Group"), a coordinated effort among twelve federal agencies and White House offices. The Working Group released estimates in 2010 and updated them in 2016 to "provide a consistent approach for agencies to quantify [climate change] damage in dollars."[12] Many authorities endorse the Working Group's estimates of the Social Cost of Carbon, such as the National Academies of Sciences[13] as well as distinguished independent economists.[14] Federal courts have upheld agency reliance on these figures[15] and held up the Working Group's estimates as well-considered and reliable.[16]

The central value identified by the Working Group for the damages from one ton of carbon dioxide emitted in the year 2025 is $46 in 2007$,[17] which equates to $57 in today's value after adjusting for inflation. Simply multiplying this value by the projected emissions calculated above reveals that **the Proposed Amendment would produce roughly $10 billion in climate damages from carbon-dioxide emissions alone.**[18] This is a substantial number that should bear heavily on the Department's evaluation of the proposal.

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[10] *See* Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 COLUM. J. ENVTL. L. 203, 270–84 (2017) (listing all uses by federal agencies through mid-2016, including numerous assessments under the National Environmental Policy Act).

[11] States Using the SCC, https://costofcarbon.org/states.

[12] *Fla. Se. Connection, LLC*, 162 FERC ¶ 61,233, at P 45 (Mar. 14, 2018).

[13] Nat'l Acads. Sci., Eng'g & Med., *Valuing Climate Damages: Updating Estimates of the Social Cost of Carbon Dioxide* 3 (2017); Nat'l Acads. Sci., Eng'g & Med., *Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update* 1 (2016).

[14] *See* Richard L. Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 SCIENCE 655 (2017) (co-authored with Michael Greenstone, Michael Hanemann, Peter Howard, and Thomas Sterner).

[15] *Zero Zone, Inc. v. U.S. Dep't of Energy*, 832 F.3d 654, 678 (7th Cir. 2016).

[16] *California v. Bernhardt*, 2020 WL 4001480, at *25–28 (N.D. Cal. July 15, 2020) (endorsing Working Group's estimates of the social cost of methane and vacating a rulemaking that relied on alternate estimates); *High Country Conservation Advocates v. U.S. Forest Serv.*, 52 F. Supp. 3d 1174, 1190–93 (D. Colo. 2014) (describing Working Group's methodology and concluding that its estimates are applicable to project-level reviews).

[17] Interagency Working Group on the Social Cost of Carbon, *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis* 4 (2016).

[18] 175 million multiplied by $57 equals $9.975 billion. In a proper cost-benefit analysis, the emissions projected for each year would be valued at the Social Cost of Carbon value for that year, with future emission damages

The Social Cost of Carbon provides an estimate of incremental *global* climate damages. There is no Social Cost of Carbon estimate that reflects climate damages only to individual states. For one, models cannot accurately calculate a domestic-only, let alone a state-only Social Cost of Carbon. Moreover, it is in each state's interest to use an estimate of the global damages of a ton of carbon dioxide. This is because greenhouse gas pollution does not stay within geographic boundaries but rather mixes in the atmosphere and affects the climate worldwide. Each ton emitted by the United States or a particular U.S. state thus 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 and each individual U.S. state. A Policy Integrity report found that, as of 2015, climate policies worldwide—including efforts by Europe, Canada, and many other countries—could generate upwards of $2 trillion in direct benefits to the United States by 2030.[19]

To avoid a global "tragedy of the commons" that could irreparably damage all countries and political jurisdictions, including Montana, every government worldwide should ideally set policy according to the global Social Cost of Carbon.[20] All states, including Montana, benefit tremendously from actions of other states and other countries to mitigate climate change, and the use of a global social cost estimate helps encourage reciprocal policy choices. Montana's citizens and businesses also have financial and other interests that extend far beyond the state's physical borders. If all states or countries used jurisdiction-specific numbers, the result would be drastic under-regulation, harming the citizens of Montana in countless ways. Thus, every state that has applied the Social Cost of Carbon to its energy-planning decisions—California, Colorado, Connecticut, Illinois, Maine, Maryland, Minnesota, Nevada, New Jersey, New York, Oregon, Virginia, and Washington—has adopted a global framework for valuing climate damage.

Appended to these comments is a 2017 report from Policy Integrity titled "The Social Cost of Greenhouse Gases and State Policy," which offers further detail on the development and use of the Social Cost of Carbon and provides answers to frequently asked questions from states that have considered using it in their own policymaking. We also append comments that Policy Integrity jointly filed with seven other non-profit groups in March 2018 in response to the federal Office of Surface Mining's own proposal to expand the Rosebud Mine, which details why the Social Cost of Carbon was appropriate for assessing the impacts of that proposal.

For the reasons discussed above and detailed further in the appended documents, the Department should apply the Social Cost of Carbon to evaluate the climate damages that will result from the Proposed Amendment.

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discounted back to present value. Note that this social cost valuation does not include methane and nitrous oxide emissions from the Proposed Amendment, which can also be calculated using the Social Cost of Greenhouse Gases. *See* Iliana Paul et al., Inst. for Pol'y Integrity, *The Social Cost of Greenhouse Gases and State Policy* 21–22 (2017) (attached) (providing Working Group's valuations for the Social Cost of Methane and Social Cost of Nitrous Oxide).

[19] Peter Howard & Jason Schwartz, Inst. for Pol'y Integrity, *Foreign Action, Domestic Windfall: The U.S. Economy Stands to Gain Trillions from Foreign Climate Action* 2 (2015), http://policyintegrity.org/files/publications/ForeignActionDomesticWindfall.pdf.

[20] *See* Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243, 1244 (1968) ("[E]ach pursuing [only his or her] own best interest . . . in a commons brings ruin to all.").

Sincerely,

Iliana Paul, Senior Policy Analyst
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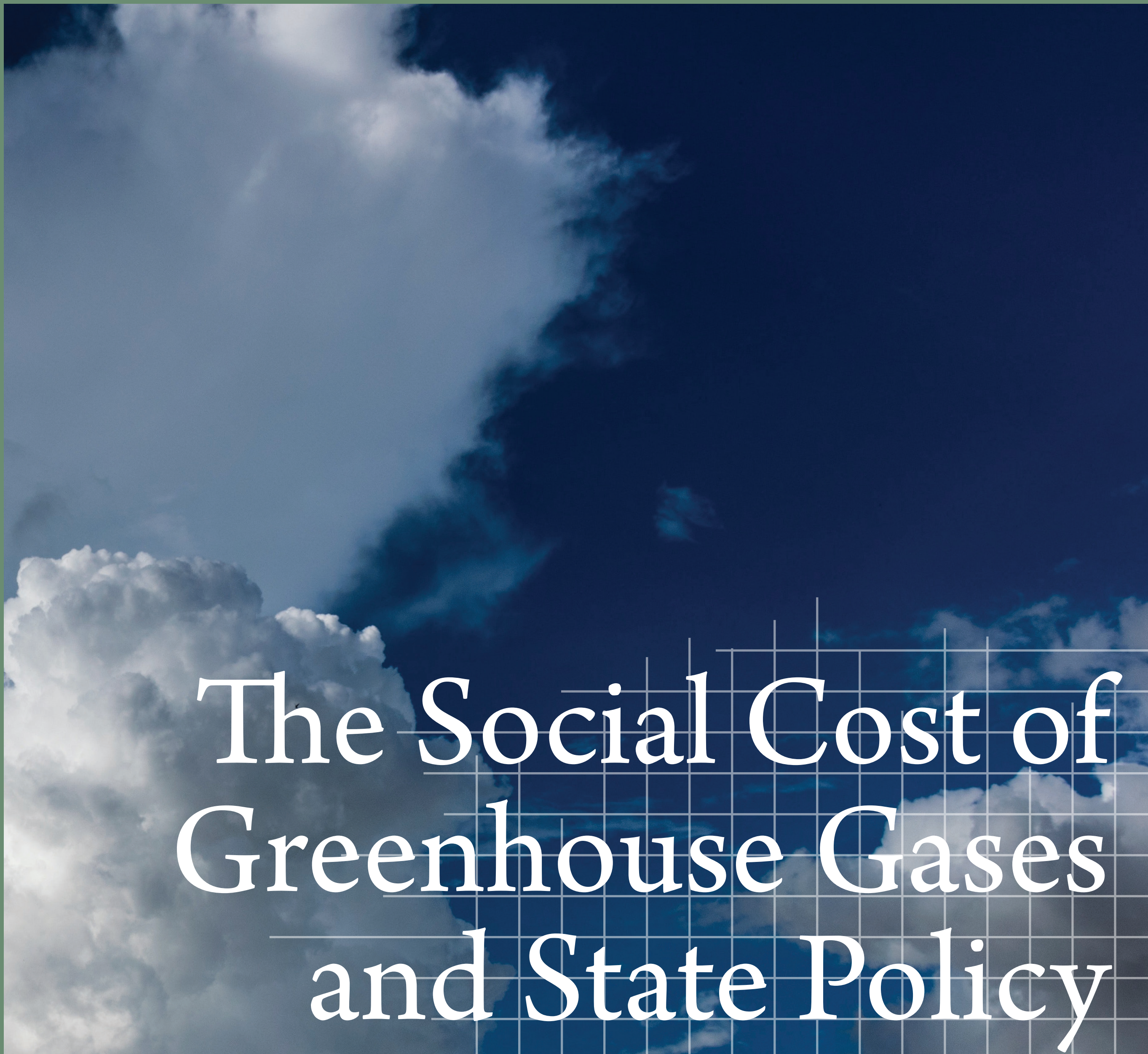
Appended:

1) Iliana Paul et al., Inst. for Pol'y Integrity, *The Social Cost of Greenhouse Gases and State Policy* (2017)
2) Inst. for Pol'y Integrity et al., Comments on the Failure to Use the Social Cost of Greenhouse Gases in the Draft Environmental Impact Statement for Western Energy Rosebud Mine Area F (Mar. 5, 2018)

Attachment 1



The Social Cost of Greenhouse Gases and State Policy

A Frequently Asked Questions Guide

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October 2017

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Executive Summary

Scientists predict that climate change will have, and in some cases has already had, severe consequences for society, like the spread of disease, decreased food security, and coastal destruction. These damages from emitting greenhouse gases are not reflected in the price of fossil fuels, creating what economists call "externalities." **The social cost of carbon (SCC) is a metric designed to quantify and monetize climate damages, representing the net economic cost of carbon dioxide emissions.** Simply, the SCC is a monetary estimate of the damage done by each ton of carbon dioxide that is released into the air. The SCC can be used to evaluate policies and guide decisions that affect greenhouse gas emissions.

At the federal level, the SCC has been used by numerous agencies for regulatory impact analysis and in environmental impact statements; however, the SCC can also be used across a range of other areas, including electricity ratemaking, resource management policy and royalty setting, setting emissions caps, and establishing a carbon price. States should use the SCC in a number of different contexts to aid in making rational policy decisions in a transparent manner. Many states are already using the SCC in their decisionmaking.

The best estimates of the SCC for states to draw from are currently the 2016 estimates from the federal government's Interagency Working Group on the Social Cost of Greenhouse Gases (IWG), despite the fact that this group was recently disbanded. The 2016 IWG estimates are based on the most up-to-date science and economics and were arrived at through an academically rigorous, transparent, and peer-reviewed process. The National Academies of Science, Engineering and Medicine (NAS) conducted a thorough review of the IWG estimates in 2016, and a group of scholars at the nongovernmental organization Resources for the Future has begun a project to update the SCC based on the NAS recommendations.

State decisionmakers can benefit from an understanding of several issues related to the SCC, including discount rates, time horizons, and the global nature of the IWG estimate. States should also know that the IWG calculated additional estimates specifically for the social cost of methane and the social cost of nitrous oxide, which are more precise quantifications of the social costs of emissions of those greenhouse gases than simply multiplying the SCC by the global warming potential of those gases, and can be used in all of the scenarios where the SCC can be used.

There are many misguided critiques of the SCC made by those who would prefer less regulation of greenhouse gases, but this should not deter decisionmakers from using the SCC. In fact, there are a wide range of resources that decisionmakers can use while exploring how and why to use the SCC.

What Is the SCC?

Scientists predict that climate change will have, and in some cases has already had, severe adverse consequences for society, like the spread of disease, decreased food security, and coastal destruction. These damages from emitting greenhouse gases are not reflected in the price of fossil fuels, creating what economists call "externalities." **The social cost of carbon (SCC) is a metric designed to quantify and monetize climate damages, representing the net economic cost of carbon dioxide emissions.** Simply, the SCC is a monetary estimate of the damage done by each ton of carbon dioxide[1] that is released into the air.

The SCC can be used to evaluate policies and guide decisions that affect greenhouse gas emissions.

What is the best estimate of the SCC for states to use?

The federal government's Interagency Working Group on the Social Cost of Greenhouse Gases (IWG), which operated from 2009-2017, remains the best source for SCC estimates. Its methodology, and why its estimates are the best available values for the SCC, are discussed below. Values for the social cost of other greenhouse gases are also discussed in a later section.

Table 1 is from the Interagency Working Group's 2016 Technical Support Document and shows the SCC estimates, in 2017 dollars, at five-year intervals. In all of the IWG technical support documents, their figures are given in 2007 dollars, but the values presented here in Table 1 are inflated to current (2017) dollars for ease of reference.

Table 1: Social Cost of CO_2 (in 2017 dollars per metric ton of CO_2)[2]

Year of Emission	Average estimate at 5% discount rate	Average estimate at 3% discount rate—IWG's Central Estimate	Average estimate at 2.5% discount rate	High Impact Estimate (95th percentile estimate at 3% discount rate)
2020	$14	**$50**	$74	$148
2025	$17	**$55**	$82	$166
2030	$19	**$60**	$88	$182
2035	$22	**$66**	$94	$202
2040	$25	**$72**	$101	$220
2045	$28	**$77**	$107	$236
2050	$31	**$83**	$114	$254

[1] Note that a metric ton (2,204 pounds, also known as the tonne) is slightly different from both a short ton (2,000 pounds) and a long ton (2,240 pounds). There are many ways to conceptualize a metric ton (2,204 pounds) of carbon dioxide. A metric ton of carbon dioxide is how much a typical car emits after 2,397 miles or about 15% of a typical home's emissions from electricity use for a year (*see* EPA Greenhouse Gas Equivalencies Calculator at https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator). An important distinction is that, because carbon dioxide consists of carbon and oxygen, 3.67 metric tons of carbon dioxide is equivalent to 1 metric ton of carbon.

[2] Interagency Working Grp. on Soc. Cost of Greenhouse Gases, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12,866 (2016) [hereinafter TSD 2016], at 4, *available at* https://www.obamawhitehouse.gov/sites/default/files/omb/inforeg/scc_tsd_final_clean_8_26_16.pdf.

Note that the value of the SCC increases over time. This is because the further in the future greenhouse gases are emitted, the greater the damages they will cause, due to the effects of accumulation. Therefore, it is important to calculate the full stream of climate effects, i.e., to take into consideration the emissions from every year of a policy, so that these increasing damages are reflected. The importance of calculating a full stream of future effects, rather than choosing only one year for analysis, is discussed in a later section.

What's included in the SCC number? What isn't?

The numbers in Table 1 reflect climate damages as estimated by combining three "Integrated Assessment Models"—specifically, DICE, FUND, and PAGE. These models translate carbon dioxide emissions into changes in atmospheric greenhouse concentrations, atmospheric concentrations into changes in temperature, and temperature changes into economic damages.[3]

DICE calculates the effect of temperature on the global economy using a global damage function that is not disaggregated by impacts to specific sectors.[4] Alternately, PAGE, looks at economic, noneconomic, and catastrophic damages. Finally, FUND considers a number of specific market and nonmarket sectors, including: agriculture, forestry, water, energy use, sea level rise, ecosystems, human health, and extreme weather.[5]

Quantified impacts represented in the models include: changes in energy demand (via cooling and heating); changes in agricultural output and forestry due to alterations in average temperature, precipitation levels, and CO_2 fertilization; property lost to sea level rise; increased coastal storm damage; changes in heat-related illnesses; some changes in disease vectors (e.g. malaria and dengue fever); changes in fresh water availability; and some general measures of catastrophic and ecosystem impacts.

It is important to note, however, that these models omit or poorly quantify some highly significant damage categories, and therefore, the SCC values in Table 1 should be considered lower-bound estimates of the actual costs of marginal carbon emissions. In fact, many experts believe the IWG SCC values are severe underestimates (even while endorsing their continued use for the time being as the best currently available estimates).

Damages that are poorly quantified or omitted from the IAMs are listed in Table 2.

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[3] Interagency Working Grp. on Soc. Cost of Carbon, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12,866 (2010) [hereinafter TSD 2010], at 5, *available at* https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf.

[4] TSD 2010, *supra* note 3, at 6.

[5] TSD 2010, *supra* note 3, at 7.

Table 2: Damages Omitted from the SCC[6]

Category	Specific Impacts Missing from the SCC*
Health	Respiratory illness from increased ozone pollution, pollen, and wildfire smoke
	Lyme disease
	Death, injuries, and illness from omitted natural disasters and mass migration
	Water, food, sanitation, and shelter
Agriculture	Weeds, pests, and pathogens
	Food price spikes
	Heat and precipitation extremes
Oceans	Acidification, temperature, and extreme weather impacts on fisheries, species extinction and migration, and coral reefs
	Storm surge interaction with sea level rise
Forests	Ecosystem changes such as pest infestations and pathogens, species invasion and migration, flooding and soil erosion
	Wildfire, including acreage burned, public health impacts from smoke pollution, property losses, and fire management costs (including injuries and deaths)
Ecosystems	Biodiversity***, habitat**, and species extinction**
	Outdoor recreation** and tourism
	Ecosystem services**
	Rising value of ecosystems due to increased scarcity
	Accelerated decline due to mass migration
Productivity and economic growth	Impacts on labor productivity and supply from extreme heat and weather, and multiple public health impacts across different damage categories
	Impacts on infrastructure, capital productivity, and supply from extreme weather events, and diversion of financial resources toward climate adaptation
	Impact on research and development from diversion of financial resources toward climate adaptation
Water	Availability and competing needs for energy production, sanitation, and other uses
	Flooding
Transportation	Changes in land and ocean transportation
Energy	Energy supply distributions
Catastrophic impacts and tipping points	Rapid sea level rise**
	Methane releases from permafrost**
	Damages at very high temperatures***
	Unknown catastrophic events

6 Peter Howard, Cost of Carbon Project. Omitted Damages: What's Missing From the Social Cost of Carbon (2014), *available at* http://costofcarbon.org/reports/entry/omitted-damages-whats-missing-from-the-social-cost-of-carbon [hereinafter "Omitted Damages"].

Category	Specific Impacts Missing from the SCC*
Inter- and intra-regional conflict	National security
	Increased violent conflicts from refugee migration from extreme weather, and food, water, and land scarcity

* Climate impacts that have been largely unquantified in the economics literature and are therefore omitted from SCC models.

** These impacts are represented in a limited way in one or more of the SCC models: 1) they may be included in some models, and not others; 2) they may be included only partially (e.g., only one or several impacts of many in the category are estimated); 3) they may be estimated using only general terms not specific to any one damage—in these instances, estimated damages are usually very small relative to their potential magnitude, and relative to the impacts explicitly estimated in the models. See complete report for details.

*** While technically represented in SCC models through extrapolations from small temperature changes, there are no available climate damage estimates for large temperature changes, and these may be catastrophic.

Is there a state-specific SCC we can use?

No, there is no SCC estimate that only reflects climate damages to individual states. No models can accurately calculate a domestic-only, let alone a state-only SCC (see more below). Furthermore, as detailed in the next section, it is in your state's best interest to use an estimate of the global damages of a ton of CO_2. Your state benefits tremendously from actions of other states and other countries to mitigate climate change, and for numerous reasons discussed below, the use of a global SCC helps encourage reciprocal policy choices. Your state's citizens and businesses also have financial and other interests that extend far beyond your physical borders. If all states or countries used jurisdiction-specific numbers, the result would be significant underregulation.

Why should our state use a global number?

Not only is it best economic practice 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 or complete. If a state agency is required to provide a domestic-only estimate, the existing, deficient methodologies must be supplemented to reflect international spillovers to the United States, U.S. benefits from foreign reciprocal actions, and the extraterritorial interests of U.S. citizens including financial interests and altruism. The same applies to any attempt to use a state-specific SCC value.

From 2010 through 2016, federal agencies based their regulatory decision and National Environmental Policy Act (NEPA) reviews on global estimates of the social cost of greenhouse gases. Though agencies often also disclosed a "highly speculative" range that tried to capture exclusively U.S. climate costs, emphasis on a global value was recognized as more accurate given the science and economics of climate change, economic practices, and consistency with U.S. strategic goals.[7]

To avoid a global "tragedy of the commons" that could irreparably damage all countries, including the United States, every government worldwide should ideally set policy according to the global social cost of greenhouse gases.[8] Because greenhouse pollution does not stay within geographic borders but rather mixes in the atmosphere and affects the climate

7 *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) [hereinafter "Howard & Schwartz 2017"].

8 *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."), 1244.

worldwide, each ton emitted by the United States or a particular U.S. state 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. A Policy Integrity report, "Foreign Action, Domestic Windfall," calculates that global actions on climate change—particularly by Europe, and including efforts of the United States and other countries—already benefited the United States by over $200 billion as of 2015. Furthermore, the report finds that, as of 2015, climate policies worldwide—including efforts by Europe, Canada, and many other countries, as well as U.S. policies from the time—could generate upwards of $2 trillion in direct benefits to the United States by 2030.[9]

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. The same concept would apply to state policies where global externalities are not taken into account. 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.[10]

Therefore, a rational tactical option in the effort to secure an economically efficient outcome is for the United States and individual states to continue using global social cost of greenhouse gas values.[11] The United States is engaged in a repeated strategic dynamic with several significant players—including the United Kingdom, Germany, Sweden, and others—that have already adopted a global framework for valuing the social cost of greenhouse gases.[12] For example, Canada and Mexico have explicitly borrowed the U.S. estimates of a global SCC to set their own fuel efficiency standards.[13] States have also entered into this international dynamic, with California coordinating with Canada on its cap-and-trade program and with a coalition of states and cities agreeing to uphold the pledges from the Paris Agreement. For the United States or any individual state to now depart from this collaborative dynamic by selecting to a domestic-only estimate could undermine the country's long-term interests and could jeopardize emissions reductions underway in other countries, which are already benefiting all 50 U.S. states and territories.

There are significant, indirect costs to trade, human health, and security likely to "spill over" to the United States as other regions experience climate change damages.[14] Due to its unique place among countries—both as the largest economy with trade- and investment-dependent links throughout the world, and as a military superpower—the United States is particularly vulnerable to effects that will spill over from other regions of the world. Spillover scenarios could entail a

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9 Peter Howard & Jason Schwartz, Inst. for Pol'y Integrity, Foreign Action, Domestic Windfall: The U.S. Economy Stands to Gain Trillions from Foreign Climate Action (2015), at 2, *available at* http://policyintegrity.org/files/publications/ForeignAction-DomesticWindfall.pdf.

10 *Id.*

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

12 *See* Howard & Schwartz 2017, *supra* note 7, at 260.

13 *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).

14 Indeed, the integrated assessment models used to develop the global SCC estimates largely ignore inter-regional costs entirely, *see* Omitted Damages, *supra* note 6; though some positive spillover effects are also possible, such as technology spillovers that reduce the cost of mitigation or adaptation, *see* S. Rao et al., *Importance of Technological Change and Spillovers in Long-Term Climate Policy*, 27 Energy J. 123, 123–39 (2006); overall spillovers likely mean that the U.S. share of the global SCC is underestimated, *see* Jody Freeman & Andrew Guzman, *Climate Change and U.S. Interests*, 109 Columbia L. Rev. 1531 (2009).

variety of serious costs to the United States as unchecked climate change devastates other countries. Correspondingly, mitigation or adaptation efforts that avoid climate damages to foreign countries will radiate benefits back to the United States as well.[15]

For more details on the justification for a global value of the social cost of greenhouse gases, see Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*.[16] Another strong defense of the global valuation as consistent with best economic practices appears in a letter published in the March 2017 issue of *The Review of Environmental Economics and Policy*, co-authored by Nobel laureate Kenneth Arrow.[17]

How and why states should use the SCC?

Why should my state use the SCC?

As noted above, the SCC is a tool for internalizing externalities; specifically, it provides a monetary value for the cost of carbon emissions that will result from a particular decision. Without having this value on hand, a decisionmaker is faced with imperfect, incomplete information and may struggle to make a policy choice that maximizes net social welfare. The economic literature supports monetizing climate effects to achieve these goals because monetization helps put the impact of climate damages in context.

If an analysis only qualitatively discusses the effects of global climate change, decisionmakers and the public will tend to overly discount that specific action's potential contribution. Without context, it is difficult for decisionmakers and the public to assess the magnitude and climate consequences of a proposed action. Quantification of these emissions and the monetization of their effects makes it easier to compare costs and benefits.

Monetization provides much-needed context for otherwise abstract consequences of climate change. It allows decision-makers and the public to weigh all costs and benefits of an action—and to compare alternatives—using the common metric of money. Monetizing climate costs, therefore, better informs the public and helps "brings those effects to bear on [an agency's] decisions."[18] The tendency to ignore non-monetized effects is the result of common but irrational mental heuristics like probability neglect. For example, the phenomenon of probability neglect causes people to reduce small probabilities entirely down to zero, resulting in these probabilities playing no role in the decision-making process.[19] This heuristic applies even to events with long-term certainty or with lower-probability but catastrophic consequences, so long as their effects are unlikely to manifest in the immediate future. Weighing the real risks that, decades or centuries from now, climate change will fundamentally and irreversibly disrupt the global economy, destabilize earth's ecosystems, or compromise the planet's ability to sustain human life is challenging; without a tool to contextualize such risks, it is far easier to ignore them. Monetization tools like the social cost of carbon (and the social cost of other greenhouse gases) are designed to solve this problem: by translating long-term costs into present values, concretizing the harms of climate change, and giving due weight to the potential of lower-probability but catastrophic harms.

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15 *See* Freeman & Guzman, *supra* note 14, at 1563-93.

16 Howard & Schwartz 2017, *supra* note 7.

17 Richard Revesz, Kenneth Arrow et al., *The Social Cost of Carbon: A Global Imperative*, 11 Review of Environmental Economics and Policy 172 (2017).

18 *See* Baltimore G. & E. Co. v. NRDC, 462 U.S. 87 (U.S. 1983) at 96.

19 Cass R. Sunstein, *Probability Neglect: Emotions, Worst Cases, and Law* (John M. Olin Law & Economics, Working Paper No. 138, 2001), *available at* http://ssrn.com/abstract=292149.

Finally, the SCC enables regulators and policymakers to take into account the effect of their decisions on society as a whole, as climate change is a global problem. This consideration can encourage reciprocal actions from other actors, including other U.S. states and other countries. We discuss more above why the "global" SCC estimates are the best ones.

What are the possible applications of the SCC in state policymaking?

Even though the IWG estimates were developed for use in regulatory analysis, there is wide support for use of the SCC in other contexts. The SCC is useful for evaluating nearly all energy regulations and environmental rules and actions. In general, using the SCC allows us to compare the costs of limiting carbon dioxide pollution to the costs of climate change. The SCC should be used in all appropriate instances, including but not limited to rulemaking that addresses greenhouse gas emissions, electricity ratemaking and regulation, natural resource valuation and royalty setting, regulatory cost-benefit analysis for climate actions, environmental impact statements, and setting carbon emissions caps or taxes.

In market-based emissions reduction schemes, the SCC should be fully internalized to allow the environmental attributes of clean energy resources to be more accurately valued and to ensure carbon-free resources are not under-valued. For states that are members of the Regional Greenhouse Gas Initiative (RGGI), for example, a state-level effort to price carbon should take into account the SCC minus the RGGI price of carbon. Note that if the RGGI carbon price were as high as the SCC, then this additional step would not be necessary.

The SCC can also allow state policymakers to compare the costs and benefits of a proposal or set the stringency of a regulation. If a state wants to set a greenhouse gas emissions cap, for example, legislators can use the SCC to determine what the cap should be. Overall, using the SCC gives states information on which measures will ultimately improve societal well-being vis-à-vis climate change.

Finally, using the SCC to gauge the climate impacts of coal and natural gas leases can help determine new royalty rates, helping the states to improve their leasing programs. Using the SCC can help ensure that taxpayers get a fair deal out of the use of their state's lands, rather than having a disproportionate amount of benefits fall to privates companies while costs fall to the public.

The emissions from my state/this leasing decision/this regulation/this project are so small, does the SCC still apply?

The SCC absolutely still applies. The argument that individual projects are too small to monetize misunderstands the tools available for valuing climate effects. The social cost of greenhouse gases 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 ton of greenhouse gas emissions.[20] The integrated assessment models used to derive the estimates work by first running a climate-economic-damage calculation for a baseline scenario, and then adding a single additional unit of greenhouse gas emissions to the model and rerunning the calculation. The approach assumes that the marginal damages from increased emissions will remain constant for small emissions increases relative to gross global emissions.[21] In other words, the monetization tools are in fact perfectly suited to measuring the marginal effects—that is, the effects of one additional unit—of emissions from smaller-scale decisions, as well as from nationwide policies.

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20 TSD 2010, *supra* note 3, at 1.

21 *Id.* at 2.

Which states are already using the SCC, and how?

It may be helpful for state decisionmakers to understand how other states have begun to use the SCC to date. States including—but not limited to—California, Colorado, Illinois, Minnesota, Maine, New York, and Washington have all begun using the federal SCC in energy-related analysis, recognizing that the SCC is the best available estimate of the marginal economic impact of carbon emission reductions. Several states and municipalities have used the SCC in the context of renewable energy decisionmaking, and Illinois and New York State have used the SCC to assess the value of the avoided carbon emissions from using nuclear generation rather than fossil fuel generation.

California

California uses the SCC in the Air Resources Board's scoping plan for the state's updated climate change policy. In the January 2017 draft of the scoping plan, the economic analysis uses the IWG SCC with a range of discount rates (2.5-percent to 5-percent).[22] Two companion bills were passed in the California legislature in the summer of 2016 to renew the policy, one of which mandates the Air Resources Board to consider the "social costs of greenhouse gases" in the analysis that underlies the new policy's accompanying regulations.[23] The Board is still finalizing the scoping plan as of October 2017.

The use of the SCC is also being discussed in a proceeding on the value of integrated distributed energy resources at the California's Public Utilities Commission.[24]

Colorado

In March 2017, the Colorado Public Utilities Commission ordered that the Public Service Company of Colorado, also knowns as Xcel Energy, take into account the IWG's social cost of carbon in its Energy Resource Plan (ERP).[25] ERPs include information on costs associated with generation resources, as well as alternatives. Advocates for the use of the "federally developed" SCC noted that the Colorado PUC had considered externalities, like public health effects, in other ERP proceedings. The PUC has authority under §40-2-123(1)(b), C.R.S to include such considerations in resource planning. One SCC advocate, Western Resource Advocates (WRA), argued that §40-2-123(1)(b) should be read to permit the Colorado PUC to "consider two distinct categories: (1) the likelihood of new environmental regulation; and (2) the risk of higher future costs associated with the emission of greenhouse gas pollution." The Colorado PUC ultimately agreed with WRA's reading and cited it as support for their decision.[26]

Illinois

Illinois has recently used the SCC in its "zero emissions credit" (ZEC) policy. In late 2016, the state legislature passed a comprehensive energy bill, which included provisions for valuing the social benefits of energy from zero-emissions

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22 Cal. Air Res. Bd., The 2017 Climate Change Scoping Plan Update: The Proposed Strategy for Achieving California's 2030 Greenhouse Gas Target (Jan. 20, 2017).

23 Cal. Health & Safety Code §§ 38562.5 & 38562.7.

24 Rulemaking to Create a Consistent Regulatory Framework for the Guidance, Planning, and Evaluation of Integrated Distributed Energy Resources ("IDER") (Rulemaking No. 14-10-003).

25 Colorado PUC, Decision No. C17-0316, In the Matter of the Application of Public Service Company of Colorado for Approval of its 2016 Electric Rersource Plan, Proceeding No. 16A-0396E, *available at* https://www.dora.state.co.us/pls/efi/efi_p2_v2_demo.show_document?p_dms_document_id=863402.

26 *Id*. at 84.

facilities. This bill uses the SCC to make this calculation, using an SCC value of $16.50/MWh, based on the IWG SCC estimates.[27]

Maine[28]

Maine enacted the Act to Support Solar Energy Development in Maine during its 2014 legislative session.[29] Section 1 of the Act states that it is "in the public interest to develop renewable energy resources, including solar energy, in a manner that protects and improves the health and well-being of the citizens and natural environment of the State while also providing economic benefits to communities, ratepayers and the overall economy of the State."[30] Section 2 of the Act instructs the Public Utilities Commission to determine the value of distributed solar energy generation in the State, evaluate implementation options, and deliver a report to the Legislature. Maine has a statute that calls for calculating "the societal value of the reduced environmental impacts of the energy."[31] Maine uses the federal SCC, as well as other monetized costs and benefits, to make this calculation. Because carbon costs are already partially embedded in existing energy valuation as a result of carbon emissions caps under RGGI, the net SCC is calculated by subtracting the embedded carbon allowance costs from the total SCC. The Maine Public Utilities Commission uses the federal SCC, with a "central" 3-percent discount rate estimate.

Maine's statute requires the PUC to assess how to maximize social welfare in its policy options. Maine addresses this requirement by weighing market costs and benefits with the monetized values of societal benefits in a cost-benefit analysis.[32]

Minnesota

The Minnesota Public Utilities Commission is statutorily mandated to consider externalities for all proceedings.[33] Between 1993, when this provision was enacted, and 2014, Minnesota used its own methodology to determine the costs of $PM_{2.5}$, SO_2, NO_x, and CO_2.[34] In 2014, after environmental advocacy groups filed a motion requesting that the Minnesota Public Utility Commission update these figures, the commission referred the issue to the Office of Administrative Hearings to assess how to value externalities, including whether the state should use the federal SCC.[35]

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27 20 I.L.C.S. 3855 §§ 1-75(d-5)(1)(B). ("(i) Social Cost of Carbon: The Social Cost of Carbon is $16.50 per megawatthour, which is based on the U.S. Interagency Working Group on Social Cost of Carbon's price in the August 2016 Technical Update using a 3% discount rate, adjusted for inflation for each year of the program. Beginning with the delivery year commencing June 1, 2023, the price per megawatthour shall increase by $1 per megawatthour, and continue to increase by an additional $1 per megawatthour each delivery year thereafter.")

28 For more details, *see* Maine Public Utilities Commission, Maine Distributed Solar Valuation Study (2015) [hereinafter "MPUC Distributed Solar Valuation Study"], *available at* http://www.maine.gov/mpuc/electricity/elect_generation/documents/MainePUCVOS-FullRevisedReport_4_15_15.pdf .

29 Maine P.L ch. 562 (Apr. 24, 2014) (codified at 35-A M.R.S.A. §§ 3471-3474).

30 *Id.* at § 3472(1).

31 *Id.* at § 2(1).

32 MPUC Distributed Solar Valuation Study, *supra* note 28, at 4.

33 ("The [Public Utilities] commission shall, to the extent practicable, quantify and establish a range of environmental costs associated with each method of electricity generation. A utility shall use the values established by the commission in conjunction with other external factors, including socioeconomic costs, when evaluating and selecting resource options in all proceedings before the commission, including resource plan and certificate of need proceedings.") 2016 Minnesota Stat. § 216B.2422 subd. 3.

34 State of Minnesota, Office of Administrative Hearings, In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minnesota Statutes Section 216B.2422, Subdivision 3, Docket No. OAH 80-2500-31888, MPUC E-999/CI-14-643, Findings of Fact, Conclusions, and Recommendations: Carbon Dioxide Values, 2-3 (Apr. 15, 2016) [hereinafter "Minnesota Opinion"].

35 *Id.* at 4.

The Administrative Judge who reviewed the matter[36] recommended that "the Commission adopt the Federal Social Cost of Carbon as reasonable and the best available measure to determine the environmental cost of CO_2, establishing a range of values including the 2.5 percent, 3.0 percent, and 5 percent discount rates . . . ."[37]

The decision to use the federal SCC, with some adjustments, was recently upheld, and the Minnesota PUC will use a range of $9.05 to $43.06 per short ton by 2020. Notably, Minnesota has decided to adjust the federal SCC estimates by using a range between the IWG's "central" 3-percent estimate and a lower bound that uses a 5-percent discount rate and a shortened timeline of only 100 years. As discussed below, uncertainty does not support the argument for shortening the time horizon for the SCC.

New York

The New York Public Service Commission first used the SCC in January 2016 in the benefit-cost analysis order for the Reforming the Energy Vision proceeding. The PSC chose the SCC, as opposed to other methods suggested by commenters, as the tool to monetize marginal climate damage costs in the benefit-cost analysis of a resource portfolio. New York's Clean Energy Standard and accompanying Zero Emissions Credit ("ZEC") take into account the SCC in calculating the value of using emission-free nuclear power, rather than carbon-emitting fossil fuel power.[38] The New York Public Service Commission's program is designed to compensate nuclear plants based directly on the value of the carbon-free attributes of their generation.[39]

The commission recognized that the federal SCC is the "best available estimate of the marginal external damage of carbon emissions."[40] It then designed the ZEC based upon the difference between the average April 2017 through March 2019 projected SCC, as published by the IWG in July 2015 and a fixed baseline portion of the cost that is already captured in the market revenues received by the eligible nuclear facilities under RGGI.[41] The New York Public Service Commission uses the federal SCC, with a "central" 3-percent discount rate estimate.[42] This approach was upheld in June 2017 by the United States District Court for the Southern District of New York.[43]

Washington

In April 2014, Governor Jay Inslee issued an executive order on climate change. Executive Order 14-04 on Washington Carbon Pollution Reduction and Clear Energy Action requires the state's agencies to "[e]nsure the cost-benefit tests for energy-efficiency improvements include full accounting for the external cost of greenhouse gas emissions."[44] With these requirements in mind, the Washington State Energy Office, in consultation with the Washington State Department of Ecology, recommended that all state agencies use the federal SCC estimates.

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36 The Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minnesota Statutes Section 216B.2422, Subdivision 3.

37 Minnesota Opinion, *supra* note 34, at 123.

38 *See* Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard, New York Public Service Comm'n Case No. 15-E-0302, Order Establishing a Clean Energy Standard 131 (Aug. 1, 2016) [hereinafter "CES Order"].

39 Denise Grab & Burcin Unel, "New York's Clean Energy Standard Is a Key Step Toward Pricing Carbon Pollution Fairly," Utility Dive (Aug.18, 2016), *available at* http://www.utilitydive.com/news/new-yorks-clean-energy-standard-is-a-key-step-toward-pricing-carbon-pollut/424741/.

40 CES Order, *supra* note 38, at 134.

41 *Id.* at 129.

42 New York State Department of Public Service's Staff White Paper on Benefit-Cost Analysis in the Case No. 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision.

43 Coalition For Competitive Electricity et al v. Zibelman et al. (S.D.N.Y., Jul. 27, 2017).

44 State of Washington, Exec. Order 14-04 at 6, *available at* http://www.governor.wa.gov/sites/default/files/exe_order/eo_14-04.pdf.

The Energy Office noted that the federal SCC estimates do not capture the total cost of emitting carbon dioxide into the atmosphere (total future climate damages), and because of omitted damages and uncertainty about the full scope of the consequences of climate change, the Office recommended using the lower 2.5-percent discount rate.[45]

The Energy Office supports using the 2.5-percent discount rate for a number of reasons.[46] First, the 2.5-percent discount most closely matches with the existing Office of Financial Management real discount rate of 0.9 percent. Second, the IWG models focus only on the damages of climate change that can be easily monetized and since the trend seems to be that additional impacts are monetized with each federal SCC update, Washington can stay ahead of this trend by choosing the lowest IWG discount rate. Third, because the discount rate applied to greenhouse gas emissions is an "intergenerational" discount rate applied to society as a whole, the discount rate used in this context should be substantially lower than private sector discount rates. Fourth, there is a higher risk associated with underestimating the SCC than with overestimating it. Fifth, Washington State wants to lead on climate issues, so it makes sense for the Energy Office to put forth the higher associated SCC.

Washington state agencies have begun following the recommendation of the state's energy office and using a 2.5-percent discount rate for their economic analyses involving greenhouse gas emissions. The Department of Ecology uses the 2010 IWG estimates, with a value of $78 per metric ton for 2020 emissions.[47]

My state already has a climate policy or a renewable energy policy in place, so why should we still use the SCC?

There is nothing that should prevent a state from using the SCC, even if there is already a climate or renewable energy policy, like a renewable portfolio standard (RPS) or clean energy standard (CES). In fact, states can use the SCC in setting RPSs or CESs or other renewable resource mandates. RPSs and CESs alone can be economically problematic, as such policies effectively "'pick winners" in electricity markets. The first-best public policy tool to promote clean energy resources and achieve greenhouse gas reductions is to use a carbon price that would lead the power generators that use dirtier energy resources to internalize the externalities caused by greenhouse gas emissions fully. Using a carbon price to achieve greenhouse gas reductions would be the least-cost way of achieving carbon emission reductions compared to other alternatives.[48] However, using the SCC to set the standard can make RPSs or CESs more efficient. When state agencies are determining standards, the SCC and other externalities, including other societal costs and benefits, should be incorporated into the analysis. We elaborate on this process below.

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[45] Washington State Department of Commerce, Social Cost of Carbon: Washington State Energy Office Recommendation for Standardizing the Social Cost of Carbon When Used for Public Decision-Making Processes, at 3 (2014).

[46] *Id.* at 3-5.

[47] *See, e.g.,* State of Washington, Department of Ecology, Preliminary Cost-Benefit and Least-Burdensome Alternative Analysis: Chapter 173-442 WAC Clean Air Rule & Chapter 173-441 WAC Reporting of Emissions of Greenhouse Gases (2016), at 38, *available at* https://fortress.wa.gov/ecy/publications/documents/1602008.pdf; inflated from 2007 dollars to 2017 dollars.

[48] Erik Paul Johnson, *The Cost Of Carbon Dioxide Abatement From State Renewable Portfolio Standards*, 36 Res. Energy Econ. 332, 349–50 (2014); Karen Palmer & Dallas Burtraw, *Cost-Effectiveness Of Renewable Electricity Policies*, 27 Energy Econ. 873, 893 (2005); Carolyn Fischer, Richard G. Newell, Environmental And Technology Policies For Climate Migration, 55 J. of Envtl. Econ. Mgmt. 142, 160 (2008) (finding that lowest cost emissions reductions come from a combination of an emissions price with a small "learning subsidy").

Are the federal IWG numbers still the best?

The "central" SCC estimate of around $50 per ton of CO_2[49] is the best currently available estimate for the external cost of carbon dioxide emitted in the year 2020. Of course, there is uncertainty over the science and economics of climate change. This uncertainty is due to the complexity of the climate system, the difficulty of placing a monetary value on environmental services, the long time horizon over which climate change occurs, and the unprecedented amount of carbon emissions that have entered the atmosphere since the industrial revolution. As science and economics improve and progress, this uncertainty will decline, but uncertainty can never be fully eliminated from future predictions. The fact that there is uncertainty does not mean that there is no social cost of carbon dioxide emissions. If anything, this uncertainty implies that we should take stronger action, as discussed in the below section on uncertainty.[50]

We discuss at length below why the IWG estimates still represent the best methodology and are based on the best available science and economics. Recent executive orders do not change this fact.

How were the IWG numbers developed?

A federal court ruling spurred the development of the SCC. A 2008 ruling by the U.S. Court of Appeals for the Ninth Circuit required the federal government to account for the economic effects of climate change in a regulatory impact analysis of fuel efficiency standards.[51] As a result, President Obama convened the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) in 2009 to develop an SCC value for use in federal regulatory analysis.

The SCC was developed through an academically rigorous, regularly-updated, and peer-reviewed process. The SCC values were developed using the three most widely cited climate economic impact models that link physical impacts to the economic damages of carbon dioxide emissions. All of these IAMs—DICE, FUND, and PAGE[52]—have been extensively peer reviewed in the economic literature.[53] The newest versions of the models were also published in peer-reviewed literature.[54] The IWG gives each model equal weight in developing the SCC values.[55] The IWG also used peer-reviewed inputs to run these models.[56] The IWG conducted an "extensive review of the literature . . . to select three sets of input parameters for these models: climate sensitivity, socio-economic and emissions trajectories, and discount rates."[57] For each parameter, the IWG documented the inputs it used, all of which are based on peer-reviewed literature.[58]

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49 For 2020 emissions in 2017 dollars, from TSD 2016, Table 2, inflated with the Bureau of Labor Statistics Inflation Calculator, *available at* https://data.bls.gov/cgi-bin/cpicalc.pl.

50 William D. Nordhaus, *Projections and Uncertainties about Climate Change in an Era of Minimal Climate Policies*. National Bureau of Economic Research (2016), *available at*: http://www.nber.org/papers/w22933.pdf.

51 Ctr. for Biological Diversity v. Nat'l Highway Traffic and Safety Admin., 538 F.3d 1172 (9th Cir. 2008).

52 More specifically: DICE (Dynamic Integrated Climate and Economy), developed by William D. Nordhaus (more information *available at* http://www.econ.yale.edu/~nordhaus/); PAGE (Policy Analysis of the Greenhouse Effect), developed by Chris Hope; and FUND (Climate Framework for Uncertainty, Negotiation, and Distribution), developed by Richard Tol (more information *available at* http://www.fund-model.org/). *See* TSD 2010, *supra* note 3, at 5.

53 *See* TSD 2010, *supra* note 3, at 4-5.

54 *See* TSD 2016, *supra* note 2, at 6; *see also* William Nordhaus, *Estimates of the Social Cost of Carbon: Concepts and Results from the DICE-2013R Model and Alternative Approaches*, 1 J. Ass'n Envtl. & Resource Economists 273 (2014).

55 TSD 2016, *supra* note 2, at 5.

56 *Id.* at 5-29.

57 *Id.* at 6.

58 *See* TSD 2010, *supra* note 3, at 12-23.

The analytical methods that the IWG applied to its inputs were also peer-reviewed, and the IWG's methods have been extensively discussed in academic journals.[59]

The IWG's analytical process in developing the SCC was transparent and open, designed to solicit public comment and incorporate the most recent scientific analysis. Beginning in 2009, the Office of Management and Budget and the Council of Economic Advisers established the IWG, composed of scientific and economic experts from the White House, Environmental Protection Agency, and Departments of Agriculture, Commerce, Energy, Transportation, and Treasury, to develop a rigorous method of valuing carbon dioxide reductions resulting from regulations.[60] In February 2010, the IWG released estimated SCC values, and an accompanying Technical Support Document that discussed the IAMs, their inputs, and the assumptions used in generating the SCC estimates.[61] In May 2013, after all three IAMs had been updated and used in peer-reviewed literature, the IWG released revised SCC values, with another Technical Support Document.[62] The U.S. Government Accountability Office examined the IWG's 2010 and 2013 processes, and found that these processes were consensus-based, relied on academic literature and modeling, disclosed relevant limitations, and incorporated new information via public comments and updated research.[63]

To further enhance the academic rigor of the process, the IWG requested that the NAS undertake a review of the latest research on modeling the economic aspects of climate change to help the IWG assess the technical merits and challenges of potential approaches for future updates to the SCC.[64] In mid-2016, the NAS issued an interim report to the IWG that recommended against conducting an update to the SCC estimates in the near term, but that included recommendations about enhancing the presentation and discussion of uncertainty regarding particular estimates.[65] The IWG responded to these recommendations in its most recent Technical Support Document from 2016,[66] which included an addendum on the social cost of methane and the social cost of nitrous oxide.[67] The NAS issued a report in January 2017 that contained a roadmap for how SCC estimates should be updated.[68] In the 2017 report, the NAS recommended future improvements to the IWG three-model methodology, but in the meantime, the NAS supported the continued near-term use of the existing social cost of greenhouse gas estimates based on the DICE, FUND, and PAGE models, as used by federal agencies to

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59 *See, e.g.*, 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 (2013); Frank Ackerman & Elizabeth Stanton, *Climate Risks and Carbon Prices: Revising the Social Cost of Carbon*, Econ.: The Open-Access, Open-Assessment E-Journal (Apr. 2012), at 6 (reviewing the IWG's methods and stating, "[T]he Working Group analysis is impressively thorough.")

60 TSD 2010, *supra* note 3, at 2-3.

61 *See generally* TSD 2010, *supra* note 3.

62 *See* Interagency Working Group on the Social Cost of Carbon, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (2013) [hereinafter TSD 2013].

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

64 *See* TSD 2016, *supra* note 2, at 2.

65 National Academies of Sciences, Engineering and Medicine, Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update (2016) [hereinafter NAS First Report].

66 TSD 2016, *supra* note 2.

67 Interagency Working Group on Social Cost of Greenhouse Gases, United States Government, Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide (2016) [hereinafter "TSD 2016 Addendum"], *available at* https://www.obamawhitehouse.gov/sites/default/files/omb/inforeg/august_2016_sc_ch4_sc_n2o_addendum_final_8_26_16.pdf.

68 The National Academy of Sciences accepted public comment during its review process. Policy Integrity submitted comments during that process. Institute for Policy Integrity, Recommendations for Changes to the Final Phase 1 Report on the Social Cost of Carbon, and Recommendations in Anticipation of the Phase 2 Report on the Social Cost of Carbon (Apr. 29, 2016) [hereinafter "Policy Integrity NAS comments"] *available at* http://policyintegrity.org/documents/Comments_to_NAS_on_SCC.pdf.

date.[69] The SCC estimates will need to be updated over time to reflect the best-available science and changing economic conditions, and, as we discuss below, a nongovernmental organization Resources for the Future plans to undertake this project based on the NAS 2016 and 2017 recommendations.

How have the IWG numbers been used to date?

The IWG numbers have been used extensively in federal regulatory analysis, on more than one hundred occasions since the first estimates were published in 2010.[70] In fact, the mandate for federal agencies to use the IWG SCC values was ended only recently, on March 28, 2017, with Executive Order 13,783. The SCC has, in fact, been used in a range of contexts aside from federal regulatory impact analysis, which we discuss above.

Who has endorsed the IWG numbers?

The IWG SCC numbers have been endorsed or otherwise supported by the NAS, the Government Accountability Office, and the federal courts. The NAS has supported the continued near-term use of the existing social cost of greenhouse gas estimates based on the DICE, FUND, and PAGE models, as federal agencies have done to date.[71] Additionally, the Government Accountability Office found in 2014 that the estimates derived from these models and used by federal agencies are consensus-based, rely on peer-reviewed academic literature, disclose relevant limitations, and are designed to incorporate new information via public comments and updated research.[72] In fact, the social cost of greenhouse gas estimates used in federal regulatory proposals and EISs have been subject to approximately 100 distinct public comment periods.[73] The economics literature confirms that estimates based on these three IAMs remain the best available estimates.[74] Finally, in 2016, the U.S. Court of Appeals for the Seventh Circuit held the estimates used to date by agencies are "reasonable," and other courts have supported agencies' use of these values.[75]

Did a recent Trump Executive Order delegitimize the IWG numbers?

Absolutely not. While the IWG was disbanded and its guidance was withdrawn, which is unfortunate, the IWG still used the best data, the best models, and the best methodologies that are currently available. Accordingly, the IWG estimates are still the best numbers for states to use and still the only numbers endorsed by the NAS.

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69 Specifically, NAS concluded that a near-term update was not necessary or appropriate and the current estimates should continue to be used while future improvements are developed over time. NAS First Report, *supra* note 66.

70 Howard & Schwartz 2017, Appendix A; Jane A. Leggett. *Federal Citations to the Social Cost of Greenhouse Gases*, Congressional Research Service (Mar 21, 2017), *available at* https://fas.org/sgp/crs/misc/R44657.pdf.

71 Specifically, NAS concluded that a near-term update was not necessary or appropriate and the current estimates should continue to be used while future improvements are developed over time. NAS First Report, *supra* note 66.

72 Gov't Accountability Office, *supra* note 63.

73 Howard & Schwartz 2017, *supra* note 7, at Appendix A.

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

75 *See e.g.* Zero Zone v. Dept. of Energy, No. 14-2147 (7th Cir., Aug. 8, 2016), at 44 (finding that the agency "acted reasonably" in using global estimates of the social cost of carbon, and that the estimates chosen were not arbitrary or capricious); High Country Conservation Advocates v. U.S. Forest Service (D. Colo., June 27, 2014); Western Organization of Resource Councils v. U.S. Bureau of Land Management (D. Mont., Jan. 25, 2017).

If the Trump administration comes out with a new number, should we use it?

Only if the number is consistent with best practices and reflects the best available literature and the recommendations of the NAS panel. If a new number uses a discount rate higher than 5-percent, selects only one of the three IAMs used by the IWG or an IAM that does not take into account nonmarket damages, if it only uses a domestic number, or if it dramatically shortens the time horizon, for example, that would be inconsistent with best practices and should not be followed by the states.

How will the numbers be updated?

In May 2017, the environmental economics think tank, Resources for the Future (RFF), launched a program to update the SCC based on the recommendations made by the NAS.[76] The new initiative contains several key elements. RFF will create a new integrated framework for the estimation process and revise some of the socioeconomic projections to better reflect uncertainty. RFF will also convene domestic and international actors and conduct educational outreach on how to use the SCC. States should consider looking to RFF for new SCC estimates in the coming years.

Are there other estimates of the SCC?

While states should be careful not to cherry-pick a single estimate from the literature, it is noteworthy that various estimates in the literature are consistent with the numbers derived from a weighted average of DICE, FUND, and PAGE—namely, with a central estimate of about $50 per ton of carbon dioxide, and a high-percentile estimate of about $148, for year 2020 emissions (in 2017 dollars, at a 3-percent discount rate). The latest central estimate from DICE's developers is $104 (at a 3-percent discount rate);[77] from FUND's developers, $14;[78] and from PAGE's developers, $148, with a high-percentile estimate of $386.[79]

Similarly, a comparison of international estimates of the social cost of greenhouse gases suggests that a central estimate of $50 per ton of carbon dioxide is a very conservative value. Sweden places the long-term valuation of carbon dioxide at $168 per ton; Germany calculates a "climate cost" of $171 per ton of carbon dioxide in the year 2030; the United Kingdom's "shadow price of carbon" has a central value of $118 by 2030; Norway's social cost of carbon is valued at $106 per ton for year 2030 emissions; and various corporations have adopted internal shadow prices as high as $82 per ton of carbon dioxide.[80]

All of this—not to mention the omitted damages that are not included in the SCC—suggests, again, that the IWG estimates, while still the most reliable and most endorsed numbers for federal and state-level U.S. policymaking, should be treated as a lower bound.

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76 Resources for the Future, "Updating and Improving the Social Cost of Carbon," *available at* http://www.rff.org/research/collection/updating-and-improving-social-cost-carbon; Nat'l Acad. Sci., Eng. & Medicine, Valuing Climate Damages: Updating Estimates of the Social Cost of Carbon Dioxide 3 (2017) [hereinafter "NAS Second Report"].

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

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

79 C. Hope, *The social cost of CO_2 from the PAGE09 model*, 39 Economics (2011); C. Hope, *Critical issues for the calculation of the social cost of CO_2*, 117 Climatic Change, 531 (2013). Values inflated to 2017 dollars.

80 *See* Howard & Schwartz 2017, *supra* note 7, at Appendix B. All figures in 2017 USD.

What methodological choices went into the IWG numbers?

Which models?

Economists estimate the SCC by linking together a global climate model and a global economic model. The resulting models are called Integrated Assessment Models, or IAMs. This integration helps economists take a unit of carbon emissions and translate that into an estimate of the cost of the impact that emissions have on our health, well-being, and quality of life in terms of dollars. The models are based on the best available science and economics from peer-reviewed publications.

The IWG uses the three most–cited models, which are William Nordhaus' DICE model (Yale University), Richard Tol's FUND model (Sussex University), and Chris Hope's PAGE model (Cambridge University).

Why did the IWG select a 3% discount rate as a "central" estimate?

The IWG produced four different SCC estimates by using different discount rates. According to the IWG's 2010 Technical Support Document, the 3-percent discount rate estimate is considered the central estimate because it uses the central (i.e., middle) discount rate and is based on an average or mean, rather than worse-than-expected, climate outcome. The use of this "central" discount rate is supported by surveys of experts.[81] The IWG further argues that the 3% is consistent with OMB's Circular A-4 guidance, corresponds to the correct discounting concept (i.e., the consumption rate of interest) when damages are measured in consumption-equivalent units, and roughly corresponds to the after-tax riskless interest rate.

The central estimate is an "average" or mean estimate in the sense that the IWG ran its models thousands of times using slightly varying assumptions to reflect uncertainty, and equally weighted the results to produce a mean average. It is important to note that the SCC is an average estimate of marginal damages, and not an average estimate of average damages. In other words, the SCC is the average estimate of the marginal impacts caused by an additional unit of greenhouse gases. It is not appropriate to interpret the SCC as an estimate of the average damages of all greenhouse gases ever emitted. It is how much the next unit of emissions will cost us.

First, what is a discount rate?

It is easiest to explain the idea of discount rates with a simple example: If offered $1 now or $1 in a year, almost everyone would choose to receive the $1 now. Most individuals would only wait until next year if they were offered more money in the future. The discount rate is how much more you would have to receive to wait until next year. Similarly, if individuals were asked to pay $1 now or $1 next year, most individuals would choose to pay $1 later. Most individuals would only pay now if they were asked to pay more money in the future. The discount rate is how much more you would have to pay in the future to be willing to pay $1 in the present.

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[81] Peter Howard & Derek Sylvan, *Expert Consensus on the Economics of Climate Change, Institute for Policy Integrity Report* (Dec. 2015); 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%).

Why is the discount rate important?

The discount rate is one of the most important inputs in models of climate damages, with plausible assumptions easily leading to differences of an order of magnitude in the SCC. The climate impacts of present emissions will unfold over hundreds of years. When used over very long periods of time, discounting penalizes future generations heavily due to compounding effects. For example, at a rate of 1 percent, $1 million 300 years hence equals over $50,000 today; at 5 percent it equals less than 50 cents.[82] The discount rate changed by a factor of five, whereas the discounted value changed by more than five orders of magnitude. Depending on the link between climate risk and economic growth risk, even a rate of 1 percent may be too high.[83] Uncertainty around the correct discount rate pushes the rate lower still.[84]

Why is the IWG correct to exclude a 7% discount rate?

The IWG correctly excluded a 7-percent discount rate, a typical private sector rate of return on capital, for several reasons. First, typical financial decisions, such as how much to save in a bank account or invest in stocks, focus on private decisions and use private rates of return. However, here we are concerned with social discount rates because emissions mitigation is a public good, where individual emissions choices affect public well-being broadly. Rather than evaluating an optimal outcome from the narrow perspective of investors alone, economic theory would require that we make the optimal choices based on societal preferences (and social discount rates). Second, climate change is expected to affect primarily consumption, not traditional capital investments.[85] Guidelines of the federal Office of Management and Budget note that in this circumstance, consumption discount rates are appropriate.[86] Third, 7 percent is considered much too high for reasons of discount rate uncertainty and intergenerational concerns (further discussed below). Fourth, interest rates are at historic lows, with no indication of increasing, so traditional rates of return used to guide discount rate selection are too high at the present time.[87]

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[82] Dallas Burtraw & Thomas Sterner, *Climate Change Abatement: Not "Stern" Enough?* (Resources for the Future Policy Commentary Series, Apr. 4, 2009), *available at* http://www.rff.org/Publications/WPC/Pages/09_04_06_Climate_Change_Abatement.aspx.

[83] "If climate risk dominates economic growth risk because there are enough potential scenarios with catastrophic damages, then the appropriate discount rate for emissions investments is lower tha[n] the risk-free rate and the current price of carbon dioxide emissions should be higher. In those scenarios, the "beta" of climate risk is a large negative value and emissions mitigation investments provide insurance benefits. If, on the other hand, growth risk is always dominant because catastrophic damages are essentially impossible and minor climate damages are more likely to occur when growth is strong, times are good, and marginal utility is low, then the "beta" of climate risk is positive, the discount rate should be higher than the risk-free rate, and the price of carbon dioxide emissions should be lower." Robert B. Litterman, *What Is the Right Price for Carbon Emissions?*, Regulation, Summer (2013) 38-43, at 41 *available at* http://www.cato.org/sites/cato.org/files/serials/files/regulation/2013/6/regulation-v36n2-1-1.pdf.

[84] *See* "Isn't there too much uncertainty around the SCC to use it?" on page 23.

[85] "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, at 33.

[86] *See* Office of Mgmt. & Budget, *Circular A-4*, Nat'l Archives (Sept. 17, 2003), *available at* https://georgewbush-whitehouse.archives.gov/omb/circulars/a004/a-4.html [https://perma.cc/GSV8-TAUR], at 33.

[87] 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) [hereinafter "CEA Brief"], *available at* https://obamawhitehouse.archives.gov/sites/default/files/ page/files/201701_cea_discounting_issue_brief.pdf.

What is a declining discount rate?

The IWG chose as one of its discount rates an estimate based upon declining discount rates. The 2.5-percent discount rate was included by IWG as a constant-rate approximation of a declining discount rate.[88] Since the IWG undertook its initial analysis, a consensus has emerged among leading climate economists that a declining discount rate should be used for climate damages to reflect long-term uncertainty in interest rates.[89] Arrow *et al* (2013) presents several arguments that strongly support the use of declining discount rates for long-term benefit-cost analysis.

But perhaps the best reason is the simple fact that there is considerable uncertainty around which interest rate to use: uncertainty in the rate points directly to the need to use a declining rate, as the impact of the uncertainty grows exponentially over time.[90] The uncertainty about future discount rates could stem from a number of reasons particularly salient to climate damages, including uncertainties in future economic growth, consumption, and the interest rate used by consumers.

Why should the central IWG estimate be interpreted as a lower bound?

A number of factors might result in using a SCC value that is higher than the estimate based on a 3-percent discount rate. Recent research has shown that the appropriate discount rate for intergenerational analysis may be even lower than that reflected in the SCC analysis, which would result in a higher SCC.[91] A jurisdiction might decide that the uncertainty associated with climate damages warrants using a discount rate that declines over time, leading to a higher SCC.[92] A consensus has emerged among leading climate economists that a declining discount rate should be used for climate damages to reflect long-term uncertainty in interest rates, and the NAS January 2017 recommendations to the IWG support this approach.[93] Furthermore, a number of types of damage from climate change are missing or poorly quantified in the federal SCC estimates, meaning that **the federal SCC estimate associated with a 3-percent discount rate should be interpreted as a lower bound on the central estimate**.[94]

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88 TSD 2010, *supra* note 3, at 23 ("The low value, 2.5 percent, is included to incorporate the concern that interest rates are highly uncertain over time. It represents the average certainty-equivalent rate using the mean-reverting and random walk approaches from Newell and Pizer (2003) starting at a discount rate of 3 percent. Using this approach, the certainty equivalent is about 2.2 percent using the random walk model and 2.8 percent using the mean reverting approach. Without giving preference to a particular model, the average of the two rates is 2.5 percent. Further, a rate below the riskless rate would be justified if climate investments are negatively correlated with the overall market rate of return. Use of this lower value also responds to certain judgments using the prescriptive or normative approach and to ethical objections that have been raised about rates of 3 percent or higher.")

89 The arguments here are primarily based on: 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); Richard G. Newell & William A. Pizer, *Discounting the Distant Future: How Much Do Uncertain Rates Increase Valuations?*, 46 J. Envtl. Econ. & Mgmt. 52 (2003); Maureen L. Cropper *et al., Declining Discount Rates*, American Economic Review: Papers and Proceedings (2014); S.K. Rose, D. Turner, G. Blanford, J. Bistline, F. de la Chesnaye, and T. Wilson. *Understanding the Social Cost of Carbon: A Technical Assessment*. EPRI Report #3002004657 (2014).

90 Martin L. Weitzman, *Gamma Discounting*, 91 Am. Econ. Rev. 260, 270 (2001) [hereinafter "Weitzman 2001"].

91 CES Order, *supra* note 38; CEA Brief, *supra* note 87.

92 *See* Weitzman 2001, *supra* note 90. 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?*, 8 Rev Environ Econ Policy 1 (2014); Maureen L. Cropper *et al., Declining Discount Rates*, 104 Am. Econ. Rev. 538 (2014); Christian Gollier & Martin L. Weitzman, *How Should the Distant Future Be Discounted When Discount Rates Are Uncertain?* 107 Economics Letters 3 (2010). Policy Integrity further explores the use of declining discount rates in its recent comments to the National Academies of Sciences. Policy Integrity NAS comments, *supra* note 68.

93 NAS Second Report, *supra* note 76.

94 *See* Omitted Damages, *supra* note 6; Revesz *et al.* 2014, *supra* note 74.

As we discussed above, Washington State agencies have begun following the recommendation of the state's energy office and using a 2.5-percent discount rate for their economic analyses involving greenhouse gas emissions, for a number of reasons, including that the damages omitted from the IWG estimates and the uncertainty surrounding climate consequences warrant more dramatic action.[95]

Why did the IWG select a 300-year time horizon?

In 2017, NAS issued a report stressing the importance of a longer time horizon for calculating the social cost of greenhouse gases, the rationale for which is also included in the 2016 IWG Technical Support Document. The report states that, "[in 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."[96] 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."[97] In other words, after selecting the appropriate discount rate based on theory and data (in this case, 3 percent 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 percent 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.[98]

The best available science and economics thus supports a 300-year time horizon for climate effects. We note that, so far one state, Minnesota, has chosen a different time horizon. For the reasons above, this should not be considered a best practice.[99]

Why did the IWG recommend a global rather than domestic estimate?

As we discussed above, the IWG recommends using a global estimate for a number of reasons. Generally, a global number is appropriate because climate change is a global phenomenon and emissions that occur in one part of the world affect other parts of the world. The same is true for avoided emissions. Simply, 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 economically inefficient policies.

Why did the IWG develop separate numbers for methane and nitrous oxide, rather than just adjusting by their global warming potential?

The IWG has also developed robust federal estimates of the **social cost of methane (SCM)** and **social cost of nitrous oxide (SCN_2O)**. Methane and nitrous oxide are two important, and potent, greenhouse gases. Prior to the IWG's work

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[95] *See*, e.g., State of Washington, Department of Ecology, Preliminary Cost-Benefit and Least-Burdensome Alternative Analysis: Chapter 173-442 WAC Clean Air Rule & Chapter 173-441 WAC Reporting of Emissions of Greenhouse Gases 38 (2016), *available at* https://fortress.wa.gov/ecy/publications/documents/1602008.pdf.

[96] NAS Second Report, *supra* note 76, at 77.

[97] *Id.*

[98] NAS First Report, *supra* note 66, at 32.

[99] See for more information, "Isn't there too much uncertainty around the SCC to use it?" on page 23.

on social costs for the emission of these pollutants, the SCC was multiplied by the Global Warming Potential (GWP) of each gas.[100] But, according to the IWG:

> "While GWPs allow for some useful comparisons across gases on a physical basis, using the [SCC]…to value the damages associated with changes in CO_2-equivalent emissions is not optimal…because non-CO_2 GHGs differ not just in their potential to absorb infrared radiation over a given time frame, but also in the temporal pathway of their impact on radiative forcing, which is relevant for estimating their social cost but not reflected in the GWP."[101]

In other words, because the GWP of each GHG changes over the lifetime of the gas, multiplying the SCC by the GWP in any particular year is inaccurate. The SCM and SCN_2O methodologies build directly on the IWG's SCC methodology, and replace the less accurate methodology of multiplying the SCC by these gases' relative global warming potential. The same rigorous, consensus-based, transparent process used for the federal SCC has shaped the federal SCM and federal SCN_2O estimates. Just as the federal SCC likely underestimates the true social cost of carbon, the federal SCM and SCN_2O are **likely to underestimate the true social cost of these other greenhouse gases** due to omitted damages and uncertainties regarding the scope of the effects in the underlying models.[102] Nonetheless, **the 2016 IWG SCM and SCN_2O are the best available estimates of the social costs associated with the emission of those greenhouse gases**.

Table 3: Social Cost of Methane Estimates (in 2017 dollars per metric ton)[103]

Year of Emission	Average estimate at 5% discount rate	Average estimate at 3% discountrate—IWG's Central Estimate	Average estimate at 2.5% discount rate	95th percentile estimate at 3% discount rate
2020	$648	**$1440**	$1920	$3839
2025	$780	**$1680**	$2159	$4439
2030	$912	**$1920**	$2399	$5039
2035	$1080	**$2159**	$2759	$5879
2040	$1200	**$2399**	$3119	$6598
2045	$1440	**$2759**	$3359	$7318
2050	$1560	**$2999**	$3719	$8038

[100] TSD 2016 Addendum, *supra* note 67, at 2 ("The potential of these gases to change the Earth's climate relative to CO_2 is commonly represented by their 100-year global warming potential (GWP). GWPs measure the contribution to warming of the Earth's atmosphere resulting from emissions of a given gas (i.e., radiative forcing per unit of mass) over a particular timeframe relative to CO_2. As such, GWPs are often used to convert emissions of non-CO_2 GHGs to CO_2-equivalents to facilitate comparison of policies and inventories involving different GHGs.")

[101] TSD 2016 Addendum, *supra* note 67, at 2.

[102] Alex L. Marten et al, *Incremental CH_4 and N_2O Mitigation Benefits Consistent with the U.S. Government's SC-CO_2 Estimates*. 15 Climate Policy 272 (2015). 15(2): 272-298 (2015, published online, 2014) [hereinafter "Marten et al."]; Environmental Defense Fund, Institute for Policy Integrity at New York University School of Law, Natural Resources Defense Council, and Union of Concerned Scientists Comments on EERE-2015-BT-STD-0016, Energy Conservation Standards for WICF Refrigeration System and EERE-2014-BT-STD-0031, Energy Conservation Standards for Residential Furnaces (Nov. 7, 2016).

[103] TSD 2016 Addendum, *supra* note 67, at 7.

Table 4: Social Cost of Nitrous Oxide Estimates (in 2017 dollars per metric ton)[104]

Year of Emission	Average estimate at 5% discount rate	Average estimate at 3% discountrate—IWG's Central Estimate	Average estimate at 2.5% discount rate	95th percentile estimate at 3% discount rate
2020	$5639	**$17,996**	$26,393	$46,788
2025	$6598	**$20,395**	$28,793	$52,787
2030	$7558	**$22,794**	$32,392	$58,785
2035	$8878	**$25,194**	$34,791	$65,984
2040	$10,078	**$27,593**	$38,390	$71,982
2045	$11,397	**$29,993**	$40,790	$79,180
2050	$13,197	**$32,392**	$44,389	$86,379

The SCM and SCN_2O were developed more recently, so have a shorter history of being used by federal—or state—agencies, but the figures were approved by the IWG and appear in an addendum to the group's 2016 Technical Support Document. They were also peer-reviewed by the EPA and by academic journals.[105] For other greenhouse gases beyond methane and nitrous oxide, adjusting the SCC with the gases global warming potential is fine. In fact, for now, it is the best option for state decisionmakers.

Common (but misguided) critiques of the SCC

Aren't there benefits of carbon dioxide emissions?

There are benefits to carbon dioxide, and some of these benefits, such as potential increases in agricultural yields, are captured in the SCC estimate. These benefits reduce the magnitude of the SCC. Other benefits that are the result of climate change are omitted, including the lower cost of supplying renewable energy from wind and wave sources, the increased availability of oil due to higher temperatures in the Arctic, and fewer transportation delays from snow and ice. However, omitted negative impacts almost certainly overwhelm omitted benefits.[106] As a consequence, $50 should be interpreted as a lower-bound central estimate.

The other benefits from the use of carbon fuels that are unrelated to climate change (such as economic output) are omitted from the SCC, but they are always included in any analysis in which the SCC is used. In a benefit-cost analysis, the cost of regulations, such as the potential loss of output, is always balanced against the benefits of carbon reductions as partially measured by the SCC.

If we adapt to climate change or develop new technologies, then won't the value of avoiding emissions be zero?

No. Adaptation and technological change are included in the IAMs already, explicitly or implicitly. In fact, DICE and FUND may overestimate the potential for adaptation by assuming high levels of costless adaptation. Additional research

[104] *Id.*
[105] Marten et al., *supra* note 102.
[106] Revesz *et al.* 2014, *supra* note 74; Omitted Damages, *supra* note 6.

on adaptation—particularly the ability of technological change and climate impacts to lower and raise, respectively, the cost of adaptation—is necessary. According to the 2010 IWG Technical Support Document,[107] future research may lead to an increase or decrease in future damages. But even under the overly optimistic assumptions about adaptation made by some models, in none of the IAMs is adaptation effective enough to significantly eliminate climate damages.

Isn't there too much uncertainty around the SCC to use it?

Absolutely not. Decisionmakers should not throw up their hands because of uncertainty. As the Ninth Circuit has held: "[W]hile the record shows that there is a range of values, the value of carbon emissions reduction is certainly not zero."[108] On the whole, uncertainty suggests an even higher SCC than estimated.

Uncertainty around climate change generally warrants more stringent climate policy and raises the SCC. Current integrated assessment models (IAMs) 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.[109] Even so, IAMs still underestimate the impact of uncertainty on the SCC by ignoring fundamental features of the climate problem: the irreversibility of climate change, society's aversion to risk and other social preferences, and many catastrophic impacts.[110] The next generation of numerical models designed to capture these features of the climate problem currently focus on the optimal tax (i.e., the SCC on the optimal emissions path) and require key simplifying assumptions, though existing results indicate that uncertainty leads to an increase in the optimal tax under uncertainty for realistic parameter values. Rather than being a reason not to take action, if anything, uncertainty increases the SCC and should lead to more stringent policies to address climate change.

While the 2016 IWG estimate is the best available SCC figure, it likely represents a lower bound for the costs of climate change because the models that are used to get the estimates leave out several categories of climate damages, which we discussed earlier. Again, damages currently omitted from the models include, but are not limited to, the effects of climate change on fisheries; the effects of increased pest, disease, and fire pressures on agriculture and forests; and the effects of climate-induced migration. Additionally, these models omit the effects of climate change on economic growth and the rise in the future value of environmental services due to increased scarcity.[111]

Uncertainty is also no reason to shorten the SCC time horizon. In 2017, NAS 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." 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

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[107] TSD 2010, *supra* note 3, at 30. *Also see*, Omitted Damages, *supra* note 6, at 42-43.

[108] *Ctr. for Biological Diversity* 548 F.3d, *supra* note 51, at 1200.

[109] Richard S. Tol, *Safe policies in an uncertain climate: an application of FUND*, Global Environmental Change, 9(3), 221-232 (1999); Peterson, S. (2006). Uncertainty and economic analysis of climate change: A survey of approaches and findings. Environmental Modeling & Assessment, 11(1), 1-17; TSD 2016, *supra* note 2.

[110] Robert S. Pindyck, *Uncertainty in environmental economics*, Review of Environmental Economics and Policy (2007), 1(1), 45-65; A. Golub *et al.* Uncertainty in integrated assessment models of climate change: Alternative analytical approaches. Environmental Modeling & Assessment (2014), 19(2), 99-109; D. Lemoine, & I. Rudik. Managing Climate Change Under Uncertainty: Recursive Integrated Assessment at an Inflection Point. Annual Review of Resource Economics(2017) 9:18.1-18.26.

[111] *See* Omitted Damages, *supra* note 6, for a more complete list.

horizons allow for representation and evaluation of longer-run geophysical system dynamics, such as sea level change and the carbon cycle." 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.[112]

Didn't the noted economist Robert Pindyck say the SCC numbers were flawed?

Not really, because he actually wants higher numbers. Robert Pindyck wrote a brief article[113] and released a working paper[114] shortly after the 2013 update to the IWG's SCC estimates, in which he criticizes the SCC. However, Pindyck actually advocates for an even higher SCC. He says: "My criticism of IAMs should not be taken to imply that because we know so little, nothing should be done about climate change right now, and instead we should wait until we learn more. Quite the contrary." He goes on to explain that being proactive will benefit society in the longterm. "One can think of a GHG abatement policy as a form of insurance: society would be paying for a guarantee that a low-probability catastrophe will not occur (or is less likely)."[115] Pindyck actually enforces the idea we discussed above, namely that the uncertainty underlying the SCC is no reason to not use the IWG estimates, but rather that decisionmakers who are interested in taking into account the climate effects of particular options should use the SCC as a starting point. In fact, Pindyck's own best estimate of the SCC is between $80 to $100, and goes up to $200.[116] Many groups cite Pindyck when criticizing the SCC, but fail to mention that his conclusion actually supports a robust accounting of climate damage externalities in decisionmaking.

Technical guidance: how do we apply the SCC in our analyses?

What should we choose as our central estimate?

The IWG SCC estimates are not a single number, but instead a range of four estimates, based on three discount rates, plus a 95th percentile estimate that represents catastrophic, low-probability outcomes.[117] Discount rates allow economists to measure the value of money over time—the tradeoff between what a dollar is worth today and what a dollar would be worth in the future.[118] Higher discount rates result in a lower SCC; if future climate damages are discounted at a high rate,

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112 NAS Second Report, *supra* note 76.

113 Robert S. Pindyck, *Pricing Carbon When We Don't Know the Right Price*, Regulation (Summer 2013). *Available at* https://object.cato.org/sites/cato.org/files/serials/files/cato-video/2013/6/regulation-v36n2-1-2.pdf.

114 Robert Pindyck, "Climate Change Policy: What do the Models Tell Us?" Working Paper 19244. National Bureau of Economic Research (July 2013), *available at* http://www.nber.org/papers/w19244.pdf.

115 *Id.* at 16.

116 *Id.*

117 TSD 2010, *supra* note 3; TSD 2013, *supra* note 62; Interagency Working Group on the Social Cost of Carbon, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (2015); TSD 2016, *supra* note 2.

118 If offered $1 now or $1 in a year, almost everyone would choose to receive the $1 now. Most individuals would only wait until next year if they were offered more money in the future. The discount rate is how much more you would have to receive to wait until next year.

we would be placing less value on avoiding those damages today. The IWG uses discount rates of 5, 3, and 2.5 percent.[119] The fourth value is taken from the 95th percentile of the SCC estimates corresponding to the 3-percent discount rate, which represents catastrophic but unlikely situations.[120] Note that application of the 95th percentile value was not part of an effort to show the probability distribution around the 3-percent 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.

Frequently, agencies will conduct their economic analyses using a range of SCC values.[121] Often, other analyses focus on a "central" estimate of the SCC.[122] The IWG recommends using a 3% discount rate. However, Washington State, for example, selected the 2.5% discount rate as its "central" estimate, for reasons discussed above.

Choosing the most appropriate discount rate is crucial to obtaining the best SCC estimate. A policymaker might decide that the uncertainty associated with climate damages warrants using a discount rate that declines over time, leading to a higher SCC. A consensus has emerged among leading climate economists that a declining discount rate should be used for climate damages, to reflect long-term uncertainty in interest rates.[123] The National Academy of Sciences January 2017 recommendations to the IWG support this approach.[124] Furthermore, as noted above, **the federal SCC estimate associated with a 3-percent discount rate should be interpreted as a lower bound**.[125]

Can we just calculate damages from a single year of emissions?

No. The values of the SCC in the IWG analysis are calculated by adding up the streams of future effects from a ton of emissions in the year of anticipated release, with discount rates reflecting the passage of time between the anticipated release and the future effects. It is necessary to include in the analysis emissions for each year that a plan, action or project is in place, because the SCC increases over time.

How does discounting work?

The IWG's SCC values represent the damages associated with each additional ton of carbon dioxide emissions released *from the perspective of the year of emission*. It is necessary when conducting a policy analysis *at the present time* about policies that affect greenhouse gas releases *in the future* to make sure that the SCC values are translated into the *perspective*

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[119] The IWG correctly excluded a 7% discount rate, a standard private sector rate of return on capital, in its SCC calculations for two main reasons. First, typical financial decisions, such as how much to save in a bank account, focus on private decisions and use private rates of return. However, in the context of climate change, analysts are concerned with social discount rates because emissions mitigation is a public good, where individual emissions choices affect public well-being broadly. Second, climate change is expected to primarily affect consumption, not traditional capital investments.

[120] *See* Environmental Defense Fund, Institute for Policy Integrity at New York University School of Law, Natural Resources Defense Council, and Union of Concerned Scientists. Comments on Proposed Exception to the Colorado Roadless Rule (RIN 0596-AD26) and Supplemental Draft Environmental Impact Statement (November 2015) to Forest Service; Council on Environmental Quality; Office of Information and Regulatory Affairs to describe importance of 95th percentile value.

[121] *See, e.g.,* Energy Conservation Program: Energy Conservation Standards for Miscellaneous Refrigeration Products, 81 Fed. Reg. 75,194 (Oct. 26, 2016); Cross-State Air Pollution Rule Update for the 2008 Ozone NAAQS, 81 Fed. Reg. 74,504 (Oct. 26, 2016).

[122] *See, e.g.,* Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision, Order Establishing the Benefit Cost Analysis Framework, New York Public Service Comm'n Case No. 14-M-0101 (Jan. 21, 2016) ["BCA Order"].

[123] *See* Weitzman 2001, *supra* note 90; Kenneth J. Arrow *et al.* 2013, *supra* note 92; Kenneth J. Arrow *et al.*, 2014, *supra* note 92; Maureen L. Cropper *et al.* 2014, *supra* note 92; Christian Gollier & Martin L. Weitzman 2010, *supra* note 92. Policy Integrity comments to NAS, *supra* note 68.

[124] NAS Second Report, *supra* note 76.

[125] *See* Omitted Damages, *supra* note 6; Richard L. Revesz *et al.* 2014, *supra* note 74.

of the year of the policy decision. The proper way to accomplish this translation is by using the discount rate to convert the effects of emissions from the year of release into the present value.

Imagine a policy has costs today and would decrease emissions in the year 2025. The IWG estimates for 2025 are how much those reductions are worth to people in year 2025, looking at cumulative effects over a 300-year period and discounting back to the year 2025. But because we prefer present consumption over future consumption, how we'd value that today isn't the same as how people in year 2025 would value it. Still, we need to discount from year 2025 back to today.

What about inflation?

Separate from the discounting considerations, which reflect the resource tradeoffs facing the actors in the relevant year of action, currency tends to inflate over time. The IWG's calculations for the SCC are based upon 2007 dollars, but the purchasing power of the dollar has gone down since then, meaning that $1 in 2007 is worth $1.20 in 2017.[126] It is important to ensure that the analysis is consistent across time frames and makes sense to decisionmakers. Thus, before any calculations are done, the analysts should account for inflation by converting all of the SCC values from 2007 dollars into dollars for the year the analysis is taking place (currently, 2017).

So once we multiply emissions by the SCC and discount back, are we done?

Not quite. It is still best to include a qualitative description of omitted damages. Best practices for regulatory analysis require including all costs and benefits, even the hard-to-monetize ones. Include a qualitative description to emphasize that the SCC is a lower bound on damages.

And what are all of the steps put together?

To make the calculation, the SCC figure should be multiplied by the projected avoided emissions to provide a figure for the monetized benefits of an action's or project's avoided greenhouse gas emissions. Specifically, you should:

1. Convert the SCC values from 2007 dollars to the year of analysis, using a consumer price index inflation calculator[127] (if the values have not yet been converted);
2. Determine the avoided emissions for each Year X between the effective date and the end date of 2030;
3. Multiply the quantity of avoided emissions in Year X by the corresponding SCC in Year X,[128] to calculate the monetary value of damages avoided by avoiding emissions in Year X;[129]
4. Apply the same discount rate used to calculate the SCC to calculate the present value of future effects of emissions from Year X;[130]

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[126] *See* CPI Inflation Calculator, http://data.bls.gov/cgi-bin/cpicalc.pl?cost1=1&year1=2007&year2=2017.

[127] *See* CPI Inflation Calculator, http://data.bls.gov/cgi-bin/cpicalc.pl.

[128] In general, the SCC goes up over time because greenhouse gases accumulate, exacerbating the effects of climate change—and therefore the harm from each additional unit of emissions—over time. TSD 2010, *supra* note 3, at 28.

[129] The SCC for a given year encompasses the effects that a ton of carbon dioxide, once emitted in that year, will have stretching into the future over a 300-year time frame. TSD 2010, *supra* note 3, at 25.

[130] Using a consistent discount rate for both the SCC (assessed from the perspective of the actors in the year of emission) and the net present value calculation (assessed from the perspective of the decisionmaker) is important to ensure that the decisionmaker is treating emissions in each time frame similarly. The decisionmaker should not be overvaluing or undervaluing emissions in the present as compared to emissions in the future. NAS First Report, *supra* note 66.

5. Sum these values for all relevant years between the effective date and the end date to arrive at the total monetized climate benefits of the plan's avoided emissions;[131] and
6. Qualitatively describe in the final discussion of the climate benefits all of the other damages that have been omitted from the SCC.

State agencies could conduct these calculations with a single, central discount rate for the SCC, or the agency could conduct the analysis several times, using a range of discount rates for the SCC, being sure to use the selected discount rate in step 4 for each different iteration.

Because the SCC has been used in a number of federal regulatory impact analyses and environmental impact statements, there are a number of examples from which states can learn how to conduct their own SCC analysis.[132]

How is the SCC used in an analysis with other discount rates?

In its Phase 1 report, NAS recommended that the SCC be used with a "consistent" discount rate in cost-benefit analysis.[133] "Consistent" should be interpreted to mean "compatible" and based on the same theoretically-sound methodology (i.e., theoretically consistent): for example, applying a higher discount rate (say 3%) to other costs and benefits may be "consistent" with a lower discount rate (say 2.5%) for the SCC, to account for the greater uncertainty with respect to climate change relative to more short-run benefits and costs. This approach is appropriate when climate uncertainty exceeds the short-run uncertainty captured by most benefit-cost analysis in which the SCC is applied.

What other resources exist?

- Omitted Damages: What's Missing from the Social Cost of Carbon (2014) by Peter Howard
- Think Global, International Reciprocity as Justification for a Global Social Cost of Carbon (2016) by Jason Schwartz and Peter Howard
- Best cost estimates of greenhouse gases (2017) by Richard Revesz, Michael Greenstone, Michael Hanemann, Thomas Sterner, Peter Howard, Jason Schwartz
- Global Warming: Improve Economic Models of Climate Change (2014) by Richard L. Revesz, Kenneth Arrow *et al.*
- The Social Cost of Carbon: A Global Imperative (2017) by Richard L. Revesz, Jason A. Schwartz, Peter H. Howard, Kenneth Arrow, Michael A. Livermore, Michael Oppenheimer, and Thomas Sterner
- Flammable Planet: Wildfires and the Social Cost of Carbon (2014), by Peter Howard
- Recent comments by Policy Integrity, EDF, NRDC, and Union of Concerned Scientists on the SCC
- Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update (2016), National Academies of Sciences

[131] Steps 4 and 5 combined are equivalent to calculating the present value of the stream of future monetary values using the same discount rate as the SCC discount rate.

[132] *See, e.g.*, Energy Conservation Program: Energy Conservation Standards for Commercial Refrigeration Equipment 79 Fed. Reg. 17,726, at 17,728, 17,773, 17,779, 17,811 (Mar. 28, 2014); U.S. Department of Energy, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment 12-22, 13-4 to 13-5, 14-2 (2014).

[133] NAS First Report, *supra* note 66, at 49.

- Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide (2017), National Academies of Sciences
- Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (2010), Interagency Working Group on the Social Cost of Greenhouse Gases
- Revised: Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (2013), 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 (2016), Interagency Working Group on the Social Cost of Greenhouse Gases Under Executive Order 12866 Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide (2016), Interagency Working Group on the Social Cost of Greenhouse Gases

For more information, contact one of Policy Integrity's experts on the social cost of carbon in decisionmaking:

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Attachment 2

March 5, 2018

To: Office of Surface Mining Reclamation and Enforcement, U.S. Department of the Interior

Subject: Comments on the Failure to Use the Social Cost of Greenhouse Gases in the Draft Environmental Impact Statement for Western Energy Rosebud Mine Area F

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

This draft environmental impact statement (DEIS), prepared by the Office of Surface Mining and Reclamation Enforcement (OSM), on Western Energy's Rosebud Mine Area F, proposes expanding an existing surface coal mine in Montana that has been in operation since the 1970s, extending its operations by an additional 8 years and producing 70.8 million tons of coal.[2] While the DEIS quantifies the tons of greenhouse gas emissions related to this project, OSM fails to use the social cost of greenhouse gas metric to fully account for the climate effects of these emissions. OSM explicitly chose not to monetize the impact of emissions by using the social costs of greenhouse gases in its analysis for a number of flawed reasons. The agency's refusal is arbitrary and unlawful in light of a growing body of case law holding that failure to monetize a project's costs is impermissible if the agency relies on the project's monetized benefits to justify its action. The refusal is also arbitrary in light of the growing consensus around the appropriate social cost of greenhouse gas values to use in environmental impact statements.

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

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

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[1] Our individual organizations may separately submit other comments regarding other aspects of the DEIS.

[2] Montana Dept. of Envtl. Quality & Office of Surface Mining Reclamation and Enforcement, *Western Energy Company's Rosebud Mine Area F Draft Environmental Impact Statement* at S-1 (2017) (hereinafter "DEIS").

3. The Interagency Working Group's 2016 estimates of the social cost of greenhouse gases remain the best available values for federal agencies to use in analyses.
4. OSM fails to consider whether and to what extent this permit could increase downstream emissions by increasing the total supply of coal, thereby lowering the commodity's price and increasing demand.

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

OSM fails to discuss the actual climate impacts of the project, even though it quantifies the tons of greenhouse gas emissions from the mine's present and future operations. OSM neither quantitatively nor qualitatively discusses the damages to which these additional tons of greenhouse gases would contribute. Meanwhile, OSM has monetized effects like hundreds of millions of dollars' worth in annual economic output and royalties,[3] which the agency presents as the "benefits" of the project. Failing to similarly monetize the climate costs of the project is inconsistently arbitrary and deprives the public and decisionmakers of the information and context they need to weigh all the project's potential effects.

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

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

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

[3] DEIS at 599-603.

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

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

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

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

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

carbon protocol.[9] Similarly, in *Montana Environmental Information Center v. Office of Surface Mining* (*MEIC v. OSM*), the U.S. District Court of Montana followed the lead set by *High Country* and likewise held an environmental assessment to be arbitrary and capricious because it quantified the benefits of action (such as employment payroll, tax revenue, and royalties) while failing to use the social cost of carbon to quantify the costs.[10] That decision is particularly salient to this DEIS because that case likewise centered on an OSM-granted coal mine permit in Montana. The permit in that case, for a Signal Peak Energy mine expansion, was for a project that was expected to result in an additional 23.16 million metric tons of greenhouse gases per year (measured in CO_2e);[11] the Western Energy Rosebud Mine Area F expansion proposed in this DEIS would account, directly and indirectly, for more than 12 million metric tons of greenhouse gases per year (CO_2e).[12] The two projects are of comparable magnitudes and both would make significant contributions to global emissions.

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

In this DEIS, OSM monetizes the same economic benefits as in *MEIC v. OSM*—hundreds of millions of dollars' worth in annual economic output, taxes, and royalties[17]—and so is required to be consistent in monetizing other significant effects, including climate costs. OSM seemingly tries to skirt the precedent set by *MEIC v. OSM* by identifying these economic benefits as "economic impacts." The DEIS reads, "any increased economic activity, in terms of revenue, employment, labor income, total value added, and output . . . is simply an economic impact, rather than an economic benefit, inasmuch as such impacts might be viewed by another person as negative or undesirable impacts."[18] However, in *MEIC v. OSM*, the District Court of the District of Montana dismissed this same argument as "a distinction without a difference."[19] Tellingly, elsewhere in this DEIS, OSM prominently presents these same impacts as the

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[9] *Id.*

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

[11] *Id.* at 35.

[12] DEIS at 487.

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

[14] 538 F.3d 1172, 1203 (9th Cir. 2008).

[15] *Id.* at 1199.

[16] *Id.* at 1198.

[17] DEIS at 602.

[18] *Id.* at 491 ("any increased economic activity, in terms of revenue, employment, labor income, total value added, and output, that is expected to occur with the proposed action is simply an economic impact, rather than an economic benefit, inasmuch as such impacts might be viewed by another person as negative or undesirable impacts due to potential increase in local population, competition for jobs, and concerns that changes in population will change the quality of the local community").

[19] *Supra* note 7 at 40, n.9.

"*[b]enefits*" of the project.[20] Despite OSM's attempts to use terminology to distinguish the impacts it wants to monetize from those impacts it would prefer not to monetize, NEPA regulations group all these impacts under the same category of "effects": economic and social impacts are listed as "effects" alongside ecological and health impacts, and all these effects must be discussed in as much detail as possible in an environmental impact statement.[21] It is arbitrary to apply inconsistent protocols for analysis of some effects compared to others, and to monetize some effects but not others that are equally monetizeable.

Moreover, in obligating agencies to take "hard look" at projects' climate impacts, NEPA requires more than simply disclosing the volume of anticipated emissions.[22] As discussed further below, under NEPA, agencies must provide details on discrete effects of a project's impacts within the relevant context. The social cost of greenhouse gases provides this critical information.

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

OSM argues that "the SCC [social cost of carbon] protocol does not measure the actual incremental impacts of a project on the environment."[23] This statement reveals a deep misunderstanding of the design and proper application of the social cost of greenhouse gases. Not only is the social cost of greenhouse gas methodology ideally suited for valuing the marginal climate damages of individual projects, but the monetization directly reflects the "actual incremental impacts" of emissions on climate change. Monetization is actually a more useful way under NEPA to present the information to decisionmakers and the public than a qualitative description of discrete effects or a mere tallying of the tons of emissions.

The social cost of greenhouse gases directly reflects the discrete effects of climate change.[24] The three integrated assessment models used to calculate the social cost of greenhouse gases together incorporate such damage categories as: agricultural and forestry impacts, coastal impacts due to sea level rise, impacts to the energy and water sectors, impacts from extreme weather events, vulnerable market sectors impacted by changes in energy use, human health impacts including malaria and pollution, outdoor recreation impacts and other non-market amenities, impacts to human settlements and ecosystems, and some catastrophic impacts.[25] Though some important damage categories are currently omitted due to insufficient data and modeling,[26] the integrated assessment models do a reasonable job of capturing many of the discrete climate effects that decisionmakers and the public care about.

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[20] DEIS at 11 ("The project would provide the following federal, state, and local benefits: An ongoing fuel source (70.8 million tons of coal) for the Colstrip Power Plant (Units 3 and 4) and the Rosebud Power Plant; Continued employment for workers at the mine; An ongoing tax base to federal, state, and local governments; Ongoing royalty payments to mineral resource owners; Continued support to local businesses; An ongoing source of income to Western Energy and its shareholders; Reliable electric power for an additional 8 years.").

[21] 40 C.F.R. §1508.8.

[22] *Supra* notes 4-5.

[23] DEIS at 491.

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

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

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

Monetizing climate damages provides the informational context required by NEPA, while a purely quantitative estimate of tons or a qualitative description of discrete climate effects like sea-level rise provide little context. Courts review NEPA documents "under an arbitrary and capricious standard," which requires "a reasonably thorough discussion of the significant aspects of the probable environmental consequences," to "foster both informed decisionmaking and informed public participation."[27] In particular, "the impact of greenhouse gas emissions on climate change is precisely the kind of cumulative impact analysis that NEPA requires," and it is arbitrary to fail to "provide the necessary contextual information about the cumulative and incremental environmental impacts."[28]

To "provide the necessary contextual information," economic theory shows that one useful tool is monetization of environmental impacts. As Professor Cass Sunstein has explained, drawing from the work of recent Nobel laureate economist Richard Thaler, a well-documented mental heuristic called "probability neglect" causes people to irrationally reduce small probability risks entirely down to zero.[29] In this case, for example, many decisionmakers and interested citizens would wrongly reduce down to zero the climate risks associated with the 0.0016% of total U.S. emissions that OSM calculates will be emitted directly from the Rosebud Mine project, or the 0.19% emitted indirectly,[30] simply due to the leading zeros before the decimals. Yet the monetized expected cost of the climate risks associated with those same emissions—hundreds of millions of dollars—is less likely overlooked. As the Environmental Protection Agency's website explains, "abstract measurements" of so many tons of greenhouse gases can be rather inscrutable for the public, unless "translat[ed] . . . into concrete terms you can understand."[31] Monetization contextualizes the significance of the additional tons of emissions.

Similarly, non-monetized effects are often irrationally treated as worthless.[32] On several occasions, courts have struck down administrative decisions for failing to give weight to non-monetized effects.[33] 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."[34]

OSM is required by NEPA to provide enough context to ensure that the public and decisionmakers would not overlook the associated climate risks. Monetization is one way that OSM could provide the necessary context to foster both informed decisionmaking and informed public participation.[35] As the OSM itself has explained in a previous environmental impact statement from 2015, including the social cost of greenhouse gases in a NEPA document "provide[s] further context and enhance[s] the discussion

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

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

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

[30] DEIS at 489-490.

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

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

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

[34] 538 F.3d at 1199.

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

of climate change impacts in the NEPA analysis."[36] In that 2015 EIS, OSM noted that the social cost of greenhouse gases is representative of "net" climate-induced effects, meaning the estimates take into account both costs and benefits from climate change.[37] OSM's use of the social cost of greenhouse gases in 2015 proves that the metric is readily available and appropriate for NEPA analyses of this type of action.

Finally, the social cost of greenhouse gas metric provides useful context even without a full cost-benefit analysis. OSM argues that without a complete cost-benefit analysis, including the so-called "social benefits of energy production" from coal combustion, applying the social cost of greenhouses gases would be inappropriate and inaccurate.[38] OSM is wrong. To begin, while the agency does not define what it means by "the social benefits of energy production," basic economic theory dictates that the value of coal in the marketplace already is the best approximation of how much consumers value the welfare they derive from using the energy generated by coal. And the DEIS already includes several monetized metrics relating to the value of coal in the marketplace. OSM includes a calculation of "economic output" from the project, including about $126 million per year in direct economic output,[39] but it is unclear if this figure reflects the value of coal or is only a measure of income from project-related employment. The DEIS never defines the term "economic output" either. The ambiguity about what that figure measures is particularly problematic because OSM has failed to publish the underlying analysis from BBC Research and Consulting[40] on which the OSM relies for much of its economic assessment. It is therefore impossible for the public to meaningfully review and comment on OSM's calculations of economic output. That said, OSM also calculates $16.6 million in federal and state royalties[41] which, assuming a 12.5% royalty rate on surface coal, would imply an approximate value in the marketplace of the coal produced at around $133 million (a figure fairly close to the direct economic output calculated). In short, the DEIS already contains monetized values relating to the value to consumers of the coal to be mined.

Regardless, whether or not an agency attempts to conduct a full cost-benefit analysis, NEPA requires that agencies disclose environmental effects with sufficient detail and context. As this section has explained, simply tallying the volume of emissions fails to give the public and decisionmakers the required information about the magnitude of discrete climate effects from those emissions. The social cost of greenhouse gas metric provides that necessary context. OSM's inadequate transparency regarding the exact economic output from the coal mined cannot serve as a justification for further obscuring the economic and environmental impacts of this proposal by omitting use of the social cost of greenhouse gas metrics.

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

[36] Office of Surface Mining Reclamation and Enforcement, *Final Environmental Impact Statement—Four Corners Power Plant and Navajo Mine Energy Project* at 4.2-26 to 4.2-27 (2015), *available at* https://web.archive.org/web/20180212182839/https:/www.wrcc.osmre.gov/initiatives/fourCorners/documents/FinalEIS/Section 4.2 - Climate Change.pdf.

[37] *Id.* at 4.2-25 ("The social cost of carbon (SCC) is a monetization of the effects associated with an incremental increase in carbon emissions. It is intended to quantify climate change-induced effects to net agricultural productivity, human health, property damage from increased flood risk, the value of ecosystem services and other factors.").

[38] DEIS at 491.

[39] *Id.* at 598.

[40] *Id.* at 596 (mentioning reliance on the BBC report); *id.* at 721 (citing as a reference: BBC Research & Consulting (BBC). 2017. IMPLAN Analysis of Economic Effects of the Rosebud Mine with Area F Expansion. Memorandum to ERO Resources Corporation).

[41] *Id.* at 602.

OSM next offers various arguments against using the social cost of greenhouse gases in this particular EIS. OSM claims that the metric is only appropriate for rulemakings; that there is no way to tell if this action's effects are significant enough to warrant use of the metric; and that the metric measures long-term effects and so applying it to an 8-year mine extension would result in uncertainties. Each of these attacks fundamentally misunderstands the social cost of greenhouse gas metric.

First, despite OSM's claims that the social cost of greenhouse gases only apply to rulemakings,[42] 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. In fact, as recently as 2015, OSM reaffirmed in a different EIS that, though the metric was first developed for cost-benefit analysis in federal rulemaking, it was nonetheless useful and appropriate for NEPA analyses.[43]

Second, OSM claims there is no impact threshold to characterize the significance of a single action on global climate change.[44] While there may not be a bright-line test for significance, the emissions OSM estimates for this project—hundreds of thousands of tons per year in direct emissions plus several million tons per year in indirect emissions[45]—are clearly significant and warrant monetization. This is especially true since, once emissions have been quantified (as they have been here), the additional step of monetization through application of the Interagency Working Group's 2016 estimates entails nothing more than a simple arithmetic calculation.[46]

In *High Country*, the District Court for the District of Colorado found that it was arbitrary for the Forest Service not to monetize the "1.23 million tons of carbon dioxide equivalent emissions [from methane] the West Elk mine emits annually."[47] That suggests that emissions in quantities far below what OSM estimates here are significant and warrant monetization. In *Montana Environmental Information Center*, the 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;[48] the over 12 million metric tons per year at stake here are in the same ballpark. In *Center for Biological Diversity*, the Ninth Circuit found that it was arbitrary for the Department of Transportation not to monetize the 35 million metric ton difference in lifetime emissions

[42] *Id.* at 491.

[43] Four Corners EIS, *supra* note 36, at 4.2-25.

[44] DEIS at 474 ("There are no impact and intensity thresholds available to characterize the significance of the effect of a single action on global climate change.").

[45] *Id.* at 487.

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

[47] 52 F. Supp. 3d at 1191 (quoting an e-mail comment on the draft statement for the quantification of tons).

[48] 15-106-M-DWM, at 36-37.

from increasing the fuel efficiency of motor vehicles:[49] given the estimated lifetime of vehicles sold in the years 2008-2011 (sometimes estimated at about 15 years on average), this could represent as little two million metric tons per year, well below the annual emissions at stake here. In a recent environmental impact statement from the Bureau of Ocean Energy Management published in August 2017, the agency explained that the social cost of carbon was "a useful measure" to apply to a NEPA analysis of an action anticipated to have a difference in greenhouse gas emissions compared to the no-action baseline of about 25 million metric tons over a 5-year period,[50] or about 5 million metric tons per year. Once again, OSM's estimate for the Rosebud mine project and its downstream emissions is much higher.

Under any reasonable social cost of greenhouse gases, the direct and indirect emissions from the Rosebud mine expansion will cause hundreds of millions of dollars in climate damages. Tellingly, OSM had no problem monetizing, for example, the $1,185,100 in induced economic output for the Northern Cheyenne Reservation or the $21,700 in induced output for Treasure County (in addition to millions of dollars estimated for other monetized economic benefits).[51] Certainly, a potential climate cost of hundreds of millions of dollars is also significant, particularly in the context of a document the very purpose of which is to evaluate a project's *environmental* impacts.

Finally, OSM argues that because the social cost of carbon protocol was designed to estimate impacts "over long time frames," there are too many "uncertainties associated with assigning a specific and accurate SCC resulting from 8 additional years of operation" at Rosebud mine.[52] This statement misunderstands both the social cost of carbon and the nature of uncertainty around the estimate. While the social cost of greenhouse gases does calculate the economic impacts of climate damages stretching out for several centuries over the lifespan of carbon emissions, the methodology estimates a specific value for the cost of emissions from each individual year. There are year-by-year estimates for the per-ton cost of emissions for each of the 8 additional years of operation at Rosebud mine.

As for uncertainty, agencies in general—and OSM in this particular instance—should remember that uncertainty is *not* a reason to abandon the social cost of greenhouse gas methodologies;[53] quite the contrary, uncertainty supports higher estimates of the social cost of greenhouse gases, because most uncertainties regarding climate change entail tipping points, catastrophic risks, and unknown unknowns about the damages of climate change. Because the key uncertainties of climate change include the risk of irreversible catastrophes, applying an options value framework to the regulatory context strengthens the case for ambitious regulatory action to reduce greenhouse gas emissions. There are numerous well-established, rigorous analytical tools available to help agencies characterize and quantitatively assess uncertainty, such as Monte Carlo simulations, and the IWG's social cost of greenhouse gas protocol incorporates those tools. For more details, please see the attached technical appendix on uncertainty.

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

One of OSM's justifications for not using the social cost of greenhouse gases is the disbandment of the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) and the withdrawal of the

[49] 538 F.3d at 1187.

[50] 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).

[51] DEIS at 601.

[52] *Id.* at 491.

[53] *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.").

group's guidance on using the social cost of greenhouse gases metric. OSM also claims that the IWG's social cost of greenhouse gases estimates fail to take into account the benefits of coal-generated energy. However, as we explain below, the IWG's social cost of greenhouse gas estimates remain the best available assessments for federal agencies to use in evaluating climate impacts.

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

Executive Order 13,783 officially disbanded the IWG and withdrew its technical support documents that underpinned their range of estimates.[54] 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."[55] Consequently, while OSM and other federal agencies no longer benefit from ongoing technical support from the IWG on use of the social cost of greenhouse gases, by no means does the new Executive Order imply that agencies should not monetize important effects in their regulatory analyses or environmental impact statements. In fact, Circular A-4 instructs agencies to monetize costs and benefits whenever feasible.[56] 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.[57] The Executive Order does not preclude agencies from using the same range of estimates as developed by the IWG, so long as the agency explains that the data and methodology that produced those estimates are consistent with Circular A-4 and, more broadly, with standards for rational decisionmaking.

Similarly, the Executive Order's withdrawal of the CEQ guidance on greenhouse gases does not —and legally cannot—remove agencies' statutory requirement to fully disclose the environmental impacts of greenhouse gas emissions. As CEQ explained in its withdrawal, the "guidance was not a regulation," and "[t]he withdrawal of the guidance does not change any law, regulation, or other legally binding requirement."[58] In other words, when the guidance originally recommended the appropriate use of the social cost of greenhouse gases in environmental impact statements,[59] 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.

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

[55] *Id.* § 5(c).

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

[57] 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).

[58] 82 Fed. Reg. 16,576, 16,576 (Apr. 5, 2017).

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

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,[60] and in July 2017, the Department of Energy used the Interagency Working Group's 2016 estimates for carbon and methane emissions to analyze energy efficiency regulation, describing the social cost of methane as having "undergone multiple stages of peer review."[61]

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

Omitted Categories of Damages Should Be Discussed Qualitatively

OSM faults the social cost of carbon for failing to include "all damages or benefits from carbon emissions."[62] Alleged benefits of carbon emissions, such as from increased fertilization, are in fact already included in the IWG's estimates and are probably even overstated in those estimates. Many of the assumptions about climate benefits built into the integrated assessment models used by the IWG are now outdated; for example, recent work demonstrates that the benefits to agriculture from climate change assumed by the developers of FUND are, in fact, far lower.[63] Other research has also shown that the predicted amenity benefits from climate change, like agricultural benefits, are also highly controversial.[64]

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

Nevertheless, the fact that this metric does not capture the entire scope of greenhouse gas impacts does *not* mean that federal agencies should not use it. Rather, agencies should qualitatively discuss any significant omitted category of costs or benefits while continuing to use the IWG estimates as a lower bound of the costs of greenhouse gas emissions.[65]

4. OSM Fails to Consider Whether and to What Extent This Permit Could Increase Downstream Emissions

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

61 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).

62 DEIS at 491.

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

64 Howard, *Omitted Damages, supra* note 26; W.M. Hannemann, *What Is the Economic Cost of Climate Change?* (2008); D. Maddison & K. Rehdanz, *The impact of climate on life satisfaction*, 70 Ecological Economics 2437-2445 (2011); K. Rehdanz & D. Maddison, *Climate and happiness*, 52 Ecological Economics 111-125 (2005).

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

OSM assumes that, regardless of whether this permit for mine expansion is approved, power plants that use coal from the Rosebud mine will continue to operate at the same levels.[66] Consequently, OSM concludes that indirect greenhouse gas emissions will not differ significantly between the proposed action and the no action alternative.[67] OSM further assumes, without analysis, that any coal production from this new permit will ton-for-ton reduce production at other areas of Rosebud mine.[68] These assumptions are problematic and unsupported, and may dramatically underestimate the true downstream emissions caused by this project.

Even if OSM is correct that shipping coal from the new permit area to anywhere but local power plants would be uneconomical, other areas of Rosebud mine have, according to OSM, shipped by rail as recently as 2010.[69] If the new permit is able to supply local power plants with coal, the existing areas of the mine will not necessarily decrease their output; instead, those areas could just as easily continue to produce and ship their coal. As OSM admits, the mine and local power plants are not inextricably interdependent: Rosebud can ship to other power plants, and the Colstrip power plant can get coal from other mines.[70] This permit will add 70.8 million tons of coal to the global supply,[71] and this addition could affect prices in ways that ultimately increase demand and emissions.

Basic principles of supply and demand predict that increasing the supply of a commodity like coal will lower prices, and that lower prices will lead to increased demand for and consumption of that commodity.[72] If the increased consumption of coal due to the increased supply from the Rosebud mine project comes at the expense of energy conservation or of cleaner energy sources like natural gas and renewables, the end result would be an increase in greenhouse gas emissions.

Multiple courts have recognized the need for agencies to assess such demand effects and energy substitution patterns in their environmental impact statements. Most recently, the U.S. Court of Appeals for the Tenth Circuit explained that it is irrational for an agency to fail to consider how, if its action will help increase the supply of fossil fuels, then the price for that commodity will also drop, demand will rise, and greenhouse gas emissions will increase.[73]

Other agencies' environmental impact statements routinely assess the effects of their approvals on fossil fuel supply, price, demand, energy substitutes, and consequential greenhouse gas emissions. For example, the Bureau of Ocean Energy Management uses sophisticated modeling to calculate the change

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[66] DEIS at 474, 490.
[67] *Id.* at S-24.
[68] *Id.* at 595.
[69] *Id.* at S-3, 110.
[70] *Id.* at 595.
[71] *Id.* at S-1.
[72] *See* N. Gregory Mankiw, *Principles of Economics* 74–78, 80–81 (5th ed. 2008).
[73] *WildEarth Guardians v. Bureau of Land Management*, No. 15-8109 at 24 (10th Cir., Sept. 15, 2017) ("this perfect substitution assumption [is] arbitrary and capricious because the assumption itself is irrational (i.e., contrary to basic supply and demand principles).").

Other courts have also addressed this issue. *See Ctr. for Sustainable Economy v. Jewell*, 779 F.3d 588, 609 (D.C. Cir. 2015) ("forgoing additional leasing on the [outer continental shelf] would cause an increase in the use of substitute fuels such as renewables, coal, imported oil and natural gas, and a reduction in overall domestic energy consumption from greater efforts to conserve in the face of higher prices"); *see also Mid States Coal. for Progress v. Surface Transp. Bd.*, 345 F.3d 520, 549–550 (8th Cir. 2003) ("the increased availability of inexpensive coal will at the very least make coal a more attractive option to future entrants into the utilities market"); *Montana Envtl. Info. Ctr.*, 2017 WL 3480262, at *15 (holding that it was "illogical" for the agency to assume that choosing not to approve federal coal leases would have no effect on coal supply, demand, or consumption, because "other coal would be burned in its stead"); *High Country Conservation Advocates*, 52 F. Supp. 3d at 1197 (recognizing that increased production of coal could affect "the demand for coal relative to other fuel sources, and coal that otherwise would have been left in the ground will be burned" (quotation marks omitted)).

in greenhouse gas emissions resulting from the effects on demand of either approving or not approving individual oil and gas leases.[74]

Under the requirement of NEPA, OSM may not ignore the impact that increased production could have on the availability of coal, the price of coal relative to other energy resources, and the downstream emissions that could result from those changes. Nor may OSM hide behind the excuse that potential future purchases from Rosebud by other entities are "outside the scope of this analysis." OSM must analyze whether this permit approval will change demand for coal in ways that will further increase downstream greenhouse gas emissions, and so increase the total climate costs of the project.

Sincerely,

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

Attached: Joint Comments to the Bureau of Land Management on the Social Cost of Greenhouse Gases

[74] Bureau of Ocean Energy Mgmt., Dep't of Interior, *Draft Environmental Impact Statement: Liberty Development Project* at 4-50 (Aug. 2017); *see also* BOEM, *Proposed Final Outer Continental Shelf Oil & Gas Leasing Program 2012-2017*, 110 (2012) (calculating that if the offshore acreage were not leased, 6% of the forgone oil and gas would be replaced by energy conservation).

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.[75] 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.[76] 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.[77] Rather than being a reason not to take action, uncertainty increases the SCC and should lead to more stringent policy to address climate change.[78]

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.[79] Stochastic uncertainty is persistent randomness in the economic-climate system, including various environmental phenomena such as volcanic eruptions and sun spots.[80] 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).[81]

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

[76] Tol, R. S. (1999). Safe policies in an uncertain climate: an application of FUND. *Global Environmental Change*, *9*(3), 221-232; Peterson, S. (2006). Uncertainty and economic analysis of climate change: A survey of approaches and findings. *Environmental Modeling & Assessment*, *11*(1), 1-17; Interagency Working Group on the Social Cost of Greenhouse Gases, Technical Update (2016) (hereinafter 2016 TSD).

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

[78] *See* cites *supra* note 77.

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

[80] Kann, A., & Weyant, J. P. (2000). Approaches for performing uncertainty analysis in large-scale energy/economic policy models. *Environmental Modeling & Assessment*, *5*(1), 29-46; Peterson (2006), *supra* note 75; Golub et al. *supra* note 77.

A potential third type of uncertainty arises due to ethical or value judgements: normative uncertainty. Peterson (2006) *supra* note 75; Heal, G., & Millner, A. (2014). Reflections: Uncertainty and decision making in climate change economics. *Review of Environmental Economics and Policy*, *8*(1), 120-137. For example, there is some normative debate over the appropriate consumption discount rate to apply in climate economics, though widespread consensus exists that using the social opportunity cost of capital is inappropriate (see earlier discussion). Preference uncertainty should be modeled as a declining discount rate over time (see earlier discussion), not using uncertain parameters. Kann & Weyant, *supra* note 80.

[81] Peterson (2006), *supra* note 75; Pindyck (2007), *supra* note 77; Heal & Millner, *supra* note 80.

When modeling climate change uncertainty, scientists and economists have long emphasized the importance of accounting for the potential of catastrophic climate change.[82] Catastrophic outcomes combine several overlapping concepts including unlucky states of the world (i.e., bad draws), deep uncertainty, and climate tipping points and elements.[83] 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.[84] 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.[85] Given the general opinion that bad surprises are likely to outweigh good surprises in the case of climate change,[86] modelers capture deep uncertainty by selecting probability distributions with a fat upper tail which reflects the greater likelihood of extreme events.[87] 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).[88]

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.[89] 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.[90] 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.[91]

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

[83] Kopp et al. (2016), *supra* note 82.

[84] *Id.*

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

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

[87] Weitzman (2011), *supra* note 85, 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."

[88] Weitzman, M. L. (2009). On modeling and interpreting the economics of catastrophic climate change. The Review of Economics and Statistics, 91(1), 1-19; Nordhaus (2009), *supra* note 85; Weitzman (2011), *supra* note 85.

[89] 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 82.

[90] *Id.*

[91] *Id.*; Kriegler, E., Hall, J. W., Held, H., Dawson, R., & Schellnhuber, H. J. (2009). Imprecise probability assessment of tipping points in the climate system. *Proceedings of the national Academy of Sciences*, *106*(13), 5041-5046; Diaz, D., & Keller, K. (2016). A potential disintegration of the West Antarctic Ice Sheet: Implications for economic analyses of climate policy. *The American Economic Review*, *106*(5), 607-611. See Table 1 of Kopp et al. (2016) *supra* note 82, for a full list of known tipping elements and points.

Social tipping points—including climate-induced migration and conflict—also exist. These various tipping points interact, such that triggering one tipping point may affect the probabilities of triggering other tipping points.[92] 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.[93] Accounting fully for these most pressing, and potentially most dramatic, uncertainties in the climate-economic system matter because humans are risk averse and tipping points—like many other aspects of climate change—are, by definition, irreversible.

How IAMs and the IWG Account for Uncertainty

Currently, IAMs (including all of those used by the IWG) capture uncertainty in two ways: deterministically and through uncertainty propagation. For the deterministic method, the modeler assumes away uncertainty (and thus the possibility of bad draws and fat tails) by setting parameters equal to their most likely (median) value. Using these values, the modeler calculates the median SCC value. Typically, the modeler conducts sensitivity analysis over key parameters—one at a time or jointly—to determine the robustness of the modeling results. This is the approach employed by Nordhaus in the preferred specification of the DICE model[94] 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.[95] Tol, Anthoff, and Hope employ this technique in FUND and PAGE—as did the IWG (2010, 2013, and 2016)—by specifying probability distributions for the climate and economic parameters in the models. These models are especially helpful for assessing the net effect of different parametric and stochastic uncertainties. For instance, both the costs of mitigation and the damage from climate change are uncertain. Higher costs would warrant less stringent climate policies, while higher damages lead to more stringent policy, so theoretically, the effect of these two factors on climate policy could be ambiguous. Uncertainty propagation in an IAM calibrated to empirically motivated distributions, however, shows that climate damage uncertainty outweighs the effect of cost uncertainty, leading to a stricter policy when uncertainty is taken into account than when it is ignored.[96] 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

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[92] Kriegler et al. (2009), *supra* note 91; Cai, Y., Lenton, T. M., & Lontzek, T. S. (2016). Risk of multiple interacting tipping points should encourage rapid CO2 emission reduction; Kopp et al. (2016) *supra* note 82.

[93] 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 82.

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

[95] In alternative calculation method, the modeler "performs optimization of polices for a large number of possible parameter combinations individually and estimates their probability weighted sum." Golub et al. *supra* note 77. 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.

[96] Tol (1999), *supra* note 76, 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."

(2016) 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.[97] 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.[98] 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.[99] 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.[100]

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.[101] 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

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[97] IWG (2010).

[98] Howard (2014), *supra* note 93. While both FUND and PAGE employ thin tailed distributions, the resulting distribution of the SCC is not always thin-tailed. In PAGE09, the ECS parameter is endogenous, such that the distribution of the ECS has a long tail following the IPCC (2007). *See* Chen, Z., Marquis, M., Averyt, K. B., Tignor, M., & Miller, H. L. (2007). Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. *Cambridge, UK and New York: Cambridge University Press, 996p*. Similarly, while Anthoff and Tol do not explicitly utilize fat-tail distributions, the distribution of net present welfare from a Monte Carlos simulation is fat tailed. Anthoff, D., & Tol, R. S. (2014). The Climate Framework for Uncertainty, Negotiation and Distribution (FUND): Technical description, Version 3.8. Available at www.fund-model.org. Explicitly modeling parameter distributions as fat tailed may further increase the SCC.

[99] Weitzman (2011), *supra* note 85; Kopp et al. (2016) *supra* note 82.

[100] Lemoine, D., & Traeger, C. P. (2016a). Ambiguous tipping points. *Journal of Economic Behavior & Organization*, *132*, 5-18; Lemoine & Rudik (2017), *supra* note 77. IAM modelers currently assume that society is equally averse to known unknown and known unknowns. Lemoine & Traeger, *id*.

[101] Nordhaus, W. D., & Boyer, J. (2000). Warning the World: Economic Models of Global Warming. MIT Press (MA); Nordhaus, W. D. (2008). A question of balance: Weighing the options on global warming policies. Yale University Press; Howard (2014), *supra* note 93; Kopp et al. (2016) *supra* note 82.

each time period.[102] 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.[103] Despite the obvious methodological basis for addressing tipping points, the latest versions of DICE[104] 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.[105]

The IWG approach also fails to include a risk premium—that is, the amount of money society would require in order to accept the uncertainty (i.e., variance) over the magnitude of warming and the resulting damages from climate change relative to mean damages (IWG, 2010; IWG, 2015)). The mean of a distribution, which is a measure of a distribution's central tendency, represents only one descriptor or "moment" of a distribution's shape. Each IAM parameter and the resulting SCC distributions have differing levels of variance (i.e., spread around the mean), skewness (i.e., a measure of asymmetry), and kurtosis (which, like skewness, is another descriptor of a distribution's tail) as well as means.[106] 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.[107] 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,[108] current IAM assumptions,[109] the NAS (2017) recommendations, nor with the IWG's own discussion (2010) of the possible values of the

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[102] Hope (2006) also calibrated a discontinuous damage function in PAGE-99 used by IWG (2010). Howard (2014), *supra* note 93.

[103] Kopp et al. (2016) *supra* note 82.

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

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

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

[107] 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.

[108] IWG, 2010, at fn 22; Cai et al., 2016, *supra* note 92, at 521.

[109] The developers of each of the three IAMs used by the IWG (2010; 2013; 2016) assume a risk aversion society. Nordhaus and Sztorc, 2013, *supra*; Anthoff, D., & Tol, R. S. (2010). The Climate Framework for Uncertainty, Negotiation and Distribution (FUND): Technical description, Version 3.5. Available at www.fund-model.org; Anthoff, D., & Tol, R. S. (2014). The Climate Framework for Uncertainty, Negotiation and Distribution (FUND): Technical description, Version 3.8. Available at www.fund-model.org; Hope, C. (2013). Critical issues for the calculation of the social cost of CO2: why the estimates from PAGE09 are higher than those from PAGE2002. *Climatic Change*, *117*(3), 531-543.

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).[110] Designing IAMs to properly account for the risk and ambiguity premiums from uncertain climate damages would increase the resulting SCC values they generate.

Even under the IWG's current assumption of risk neutrality, the mean SCC from uncertainty propagation excludes the (real) option value of preventing marginal CO_2 emissions.[111] 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.[112] If society exercises the option of emitting an additional unit of CO2 emissions today, "we will lose future flexibility that the [mitigation] option gave" leading to possible "regret and…a desire to 'undo'" the additional emission because it "constrains future behavior."[113] 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.[114] 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

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

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

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

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

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

[112] 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. Pindyck, R. S. (2007). Uncertainty in environmental economics. *Review of environmental economics and policy*, *1*(1), 45-65.

[113] Pindyck (2007).

[114] Kann & Weyant, *supra*; Pindyck (2007), *supra*; Golub et al. (2014), *supra*.

damages on the optimal emissions path rather than on the BAU emissions path.[115] 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),[116] 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.[117] Recent computational advancements in SDP are helping overcome the need for strong simplifying assumptions in this literature for purpose of tractability. Traditionally, these simplifications led to unrealistically fast rates of learning – leading to incorrect outcomes – and difficulty in comparing results across papers (due to differing uncertain parameters, models of learning, and model types). Even so, newer methods still only allow for a handful of uncertain parameters compared to the hundreds of uncertain parameters in FUND and PAGE. Despite these limitations, the literature supports the above finding that the SCC, if anything, increases under uncertainty.[118]

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.[119] For SDP models, uncertainty

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

[116] 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.

[117] Kann and Weyant, 2000, *supra*; Pindyck, 2007, *supra*; Golub et al., 2014, *supra*.

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

[119] The real options literature tends to find an increase in the optimal emissions path under uncertainty relative to the deterministic case (Pindyck, 2007), though the opposite is true when modelers account for the possibility of large damages (i.e., tipping point or black swan events) even with a risk-neutral society (Pindyck, 2007; Golub et al., 2014). Solving finite horizon models employing non-recursive methods, modelers find that the results differ depending on the model of learning – the

tends to strengthen the optimal emissions path relative to the determinist case even without tipping points,[120] and these results are strengthened under realistic preference assumptions.[121] Given that there is no counter-balancing tipping abatement cost,[122] 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%[123] to 800%[124] 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.[125] Recent research has shown that accurate estimation of decisions under uncertainty crucially depends on distinguishing between risk and time preferences.[126] 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.[127] 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.[128] Including more realistic preference assumptions in IAMs would further increase the SCC under uncertainty.

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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).

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

[121] Pindyck, 2007; Golub et al., 2017; Lemoine and Rudik, 2017

[122] Pindyck, 2007

[123] Lemoine, D., & Traeger, C. P. (2016b). Economics of tipping the climate dominoes. *Nature Climate Change*.

[124] Cai et al., 2016

[125] Cai et al., 2016; Lemoine and Rudik, 2017. The standard utility function adopted in IAMs with constant relative risk version implies that the elasticity of substitution equals the inversion of relative risk aversion. As a consequence, the society's preferences for the intra-generational distribution of consumption, the intergenerational distribution of consumption, and risk aversion hold a fixed relationship. For purposes of stochastic dynamic programming, this is problematic because this assumption conflates intertemporal consumption smoothing and risk aversion. Botzen, W. W., & van den Bergh, J. C. (2014). Specifications of social welfare in economic studies of climate policy: overview of criteria and related policy insights. *Environmental and Resource Economics*, *58*(1), 1-33. By adopting the Epstein-Zinn utility function which separates these two parameters, modelers can calibrate them according to empirical evidence. For example, Cai et al. (2016) replace the DICE risk aversion of 1.45 and elasticity parameter of 1/1.45 with values of 3.066 and 1.5, respectively.

[126] James Andreoni & Charles Sprenger, *Risk Preferences Are Not Time Preferences*, 102 Am. Econ. Rev. 3357–3376 (2012).

[127] Lemoine, D., & Traeger, C. P. (2016b). Economics of tipping the climate dominoes. *Nature Climate Change*.; Lemoine and Rudik, 2017

[128] Typically, IAMs assume constant relative prices of consumption goods. Gerlagh, R., and B.C.C. Van der Zwaan. 2002. "Long-term substitutability between environmental and man-made goods." *Journal of Environmental Economics and Management 44*(2):329-345; Sterner, T., and U.M. Persson. 2008. "An Even Sterner Review: Introducing Relative Prices into the

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.[129] 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.

Discounting Debate." *Review of Environmental Economics and Policy 2*(1):61-76. By replacing the standard isoelastic utility function in IAMs with a nested CES utility function following Sterner and Persson (2008), Cai et al. (2015) find that even a relatively small tipping point (i.e., a 5% loss) can substantially increase the SCC in the stochastic dynamic setting. Cai, Y., Judd, K. L., Lenton, T. M., Lontzek, T. S., & Narita, D. (2015). Environmental tipping points significantly affect the cost− benefit assessment of climate policies. *Proceedings of the National Academy of Sciences*, *112*(15), 4606-4611.

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