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Via Regulations.gov

To: Department of Energy, Office of Energy Efficiency & Renewable Energy

Subject: Monetizing Emissions Reductions in the Technical Support Document for the Room Air Conditioners Request for Information (Docket no.: EERE-2014-BT-STD-0059)

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

These comments respond to the Department of Energy's ("DOE") recent request for information on the energy conservation standards for room air conditioners ("RFI").[2] In the RFI, DOE is requesting input on the "analytical framework, models, and tools that DOE is using to evaluate potential standards" for room air conditioners, including feedback on the draft technical support document.[3] Such analyses include a national impact analysis, emissions analysis, and monetization of emissions reduction benefits.[4] DOE also specifically asks for comments on market failures.[5]

In the technical support document, DOE departs from recent practice by proposing to focus on the domestic-only "interim" social cost of greenhouse gases estimates. Not only does DOE not provide a reasoned explanation for this methodological change, but a domestic-only value is also deeply flawed and inconsistent with federal guidance, and its use has been deemed by a federal court to be arbitrary and capricious. DOE should, as it has in the past, continue to monetize the full climate benefits of greenhouse gas emissions reductions, using the best available estimates, which were derived by the Interagency Working Group on the Social Cost of Greenhouse Gases ("IWG"). DOE should also factor these benefits into its choice of the maximum efficiency level that is economically justified, consistent with its statutory requirement to assess the national need to conserve energy under the Energy Policy and Conservation Act ("EPCA").[6]

I. Using the Global Estimate of the Social Cost of Greenhouse Gases Is Consistent with Standards of Rational Decisionmaking

DOE should use global estimates of the social costs of greenhouse gases for the proposal's national impact analysis and as a primary consideration in selecting the standards—not a domestic-only

1 Our organizations may separately and independently submit other comments on the RFI.
2 Dep't of Energy, Energy Conservation Program: Energy Conservation Standards for Room Air Conditioners, 85 Fed. Reg. 36,512 (June 17, 2020).
3 *Id.*
4 *Id.* at 36,513.
5 *Id*. at. 36516
6 42 U.S.C. § 6295(o)(2)(A).

social cost value, as it has in the draft technical support document.[7] Using the global estimate is not only consistent with standards of rational decisionmaking, and in line with existing federal guidance and case law, but is justified by DOE's mandate under the EPCA to advance U.S. welfare and ensure domestic energy conservation.[8]

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

The Administrative Procedure Act requires DOE to use the best available data and methodologies to account for the social cost of greenhouse gases. This mandate continues to remain in effect following the issuance of Executive Order 13,783. Indeed, agencies must continue to monetize the social cost of greenhouse gases using the best available science, as that order recognizes, and the IWG's 2016 estimates of the social cost of carbon reflect the best available data and methods.

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

> Normally, an agency rule would be arbitrary and capricious if the agency has relied on factors which Congress has not intended it to consider, *entirely failed to consider an important aspect of the problem*, offered an explanation for its decision that runs counter to the evidence before the agency, or is so implausible that it could not be ascribed to a difference in view of the product of agency expertise.[9]

Furthermore, the Court found that the standard requires agencies to "examine the relevant data and articulate . . . a rational connection between the facts found and the choice made."[10]

Two federal courts of appeals have already applied arbitrary and capricious review to require the use of the social cost of greenhouse gases in agency decision-making.[11] In *Center for Biological Diversity v. National Highway Traffic Safety Administration*, the U.S. Court of Appeals for the U.S. Court of Appeals for the Ninth Circuit ruled that, because the agency had monetized other uncertain costs and benefits of its vehicle fuel efficiency standard, its "decision not to monetize the benefit of carbon emissions reduction was arbitrary and capricious."[12] Specifically, it was arbitrary to "assign[ ] no value to *the most significant benefit* of more stringent [vehicle fuel efficiency] standards: reduction in carbon emissions."[13] When an agency bases a rulemaking on cost-benefit analysis, it is arbitrary to "put a thumb on the scale by undervaluing the benefits and overvaluing

7 Dep't of Energy, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Room Air Conditions 14-1 (June 2020) (hereinafter "2020 TSD").

8 *Zero Zone, Inc. v. U.S. Dep't of Energy,* 832 F.3d 654, 675 (7th Cir. 2016)..

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

10 *Id.*

11 A few courts have also applied arbitrary and capricious review to the use or non-use of the social cost of carbon in environmental impact statements under the National Environmental Policy Act. 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"—specifically, by applying the IWG's Social Cost of Carbon protocol. 52 F. Supp. 3d 1174, 1191 (D. Colo. 2014). The U.S. District Court of Oregon declined to follow suit in *League of Wilderness Defenders v. Connaughton*, but only because in that case the Forest Service had not conducted a quantitative analysis of either costs or benefits of climate change but rather addressed climate change qualitatively. No. 3:12-cv-02271-HZ, decided Dec. 9, 2014.

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

13 *Id.* at 1199.

the costs."[14] The court also approvingly cited a partial consensus among experts around an estimate of "$50 per ton of carbon (or $13.60 per ton CO2),"[15] which, in the year 2006 when the rule was issued, would have been consistent with estimates of a global social cost of carbon.[16]

Even more directly relevant to this rulemaking is the U.S. Court of Appeals for the Seventh Circuit's ruling in *Zero Zone Inc. v. Department of Energy*. There, the Seventh Circuit approved of the Department of Energy's use of the IWG's SCC estimates, holding that that "the expected reduction in environmental costs *needs* to be taken into account" in order for the Department "[t]o determine whether an energy conservation measure is appropriate under a cost-benefit analysis."[17] Furthermore, the court specifically rejected petitioner's challenge to the Department's use of a global (rather than domestic) social cost of carbon, holding that Department had reasonably identified carbon pollution as "a global externality" and appropriately concluded that, because "national energy conservation has global effects, . . . those global effects are an appropriate consideration when looking at a national policy."[18] The court also rejected industry petitioners' argument that EPCA prohibited consideration of global climate externalities, affirming as reasonable DOE's connection between global climate damages and national policy interests.[19]

And finally, and perhaps most germane of all, a recent ruling from the U.S. District Court for the Northern District of California struck down as arbitrary the Bureau of Land Management's ("BLM") repeal of the Waste Prevention Rule in part because the agency had abandoned the peer-reviewed, global estimates of the social cost of greenhouse gases in favor of flawed "interim" estimates that looked only at effects within the U.S. borders. In discussing the legal standard not to ignore important aspects of the rulemaking, the court reminded agencies that they lack discretion to ignore data that points in the opposite direction from its conclusions, and that agencies need more detailed justifications when they reverse prior positions.[20] As the Court explained, BLM did not meet these standards for numerous reasons.

For one, the court critiqued BLM for using a rushed methodology that was completed "without *any* public comment or peer review," noting that "a more comprehensive model [to measure domestic-only impacts] does not exist nor is there any indication that one was initiated."[21] The court further noted that "focusing solely on domestic effects has been soundly rejected by economists as improper and unsupported by science," explaining that the so-called "interim" model relied upon by BLM "ignores impacts on 8 million United States citizens living abroad, including thousands of United States military personnel; billions of dollars of physical assets owned by United States companies abroad; United States companies impacted by their trading partners and suppliers abroad; and global migration and geopolitical security."[22] And the court reminded BLM that executive orders, including Executive Orders 12,866 and 13,783, require consideration of "all" costs and benefits, based on the "best reasonably obtainable scientific, technical, economic, and other information," and concluded that "none of the regulatory rules or orders require exclusion of global impacts."[23] In fact, the court urged BLM to take better account of the fact that not only does

[14] *Id.* at 1198.
[15] 538 F.3d at 1199, 1201.
[16] *See* Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011-2015, 73 Fed. Reg. 24,352, 24,414 (May 2, 2008) (estimating that $14 per ton of carbon dioxide approximated global benefits).
[17] 832 F.3d 654, 677 (7th Cir. 2016).
[18] *Id.* at 679.
[19] *Id.* at 679.
[20] *California v. Bernhardt*, 2020 WL 4001480 (N.D. Cal. July 15, 2020), at *24–25.
[21] *Id.* at *25.
[22] *Id.* at *27.
[23] *Id.* at *26 (internal quotation marks omitted).

BLM admit that the domestic-only estimates are "underestimates," but that the global estimates are also likely underestimated.[24]

In short, agencies must monetize important greenhouse gas effects when their decisions are grounded in cost-benefit analysis.[25] An assessment of greenhouse gas impacts that looks only at impacts within the U.S. borders does not meet this standard.

b. *Federal Guidance Requires Consideration of Global Climate Damages*

Opponents of climate regulation have long challenged the global number in court and other forums, and often attempted to use the Office of Management and Budget's *Circular A-4* guidance on regulatory impact analysis as support[26]—as DOE does here.[27] Specifically, opponents have seized on *Circular A-4*'s instructions to "focus" on effects to "citizens and residents of the United States," while any significant effects occurring "beyond the borders of the United States . . . should be reported separately."[28]

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

> [Y]ou cannot conduct a good regulatory analysis according to a formula. Conducting high-quality analysis requires competent professional judgment. ***Different regulations may call for different emphases*** in the analysis, ***depending on the nature and complexity*** of the regulatory issues and the sensitivity of the benefit and cost estimates to the key assumptions.[29]

In fact, *Circular A-4* elsewhere assumes that agencies' analyses will not always be conducted from purely the perspective of the United States, as one of its instructions only applies "as long as the analysis is conducted from the United States perspective,"[30] suggesting that in some circumstances it is appropriate for the analysis to be global. For example, EPA and the Department of Transportation have adopted a global perspective on the analysis of potential monopsony benefits to U.S. consumers resulting from the reduced price of foreign oil imports following energy efficiency increases.[31]

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[24] *Id.* at *27.

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

[26] Ted Gayer & W. Kip Viscusi, *Determining the Proper Scope of Climate Change Policy Benefits in U.S. Regulatory Analyses: Domestic versus Global Approaches*, 10 REV. ENVTL. ECON. & POL'Y 245 (2016) (citing Circular A-4 to argue against a global perspective on the social cost of carbon); *see also, e.g.*, Petitioners Brief on Procedural and Record-Based Issues at 70, in *West Virginia v. EPA*, No. 15-1363, (D.C. Cir., filed Feb. 19, 2016) (challenging EPA's use of the global social cost of carbon).

[27] 2020 TSD at 14-1.

[28] Office of Mgmt. & Budget, Circular A-4 at 15 (2003). Note that Circular A-4 slightly conflates "accrue to citizens" with "borders of the United States": U.S. citizens have financial and other interests tied to effects beyond the borders of the United States.

[29] Circular A-4 at 3.

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

[31] *See* Howard & Schwartz, *supra* note 25, at 268-69.

Perhaps more than any other issue, a consideration of climate change requires precisely such a "different emphasis" from the default domestic-only assumption. To avoid a global "tragedy of the commons" that could irreparably damage all countries, including the United States, every nation should ideally set policy according to the global social cost of greenhouse gases.[32] Climate and clean air are global common resources, meaning they are freely available to all countries, but any one country's use—i.e., pollution—imposes harms on the polluting country as well as the rest of the world. Because greenhouse gas pollution does not stay within geographic borders but rather mixes in the atmosphere and affects climate worldwide, each ton emitted by the United States not only creates domestic harms, but also imposes large externalities on the rest of the world. Conversely, each ton of greenhouse gases abated in another country benefits the United States along with the rest of the world.

If all countries set their greenhouse emission levels based on only domestic costs and benefits, ignoring the large global externalities, the aggregate result would be substantially sub-optimal climate protections and significantly increased risks of severe harms to all nations, including the United States. Thus, basic economic principles demonstrate that the United States stands to benefit greatly if all countries apply global social cost of greenhouse gas values in their regulatory decisions and project reviews. Indeed, the United States stands to gain hundreds of billions or even trillions of dollars in direct benefits from efficient foreign action on climate change.[33]

Indeed, the impacts of greenhouse gas emissions on foreign nations results in an economic market failure known as an "externality." Here, DOE requests comments on market failures, which it defines as "situation[s] in which the market outcome does not maximize societal welfare,"[34] and thus impedes a standard from being economically justified as required under EPCA. One particular market failure is an externality, which "occurs when one party's actions impose uncompensated benefits or costs on another party."[35] And climate damages from the emissions of greenhouse gases is clearly one such market failure, as it causes uncompensated harm to individuals around the world. By disregarding this market failure, DOE fails to maximize societal welfare and thereby may be unable to justify future standards as "economically justified" as EPCA requires.[36]

Moreover, in order to ensure that other nations continue to use global social cost of greenhouse gas values, it is important that the United States itself do so.[37] 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.[38] For example, Canada and Mexico have explicitly borrowed the U.S. estimates of a global social cost of carbon to set their own fuel efficiency standards.[39] For the United States to depart from this collaborative dynamic by reverting to a domestic-only estimate would

[32] *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.").

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

[34] 85 Fed. Reg. at 36,516.

[35] Circular A-4 at 4.

[36] 42 U.S.C. § 6295(o)(2)(B)(i).

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

[38] *See* Howard & Schwartz, *supra* note 25, at Appendix B.

[39] *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).

undermine the country's long-term interests and could jeopardize emissions reductions underway in other countries, which are already benefiting the United States.

For these and other reasons, reliance on a domestic-only valuation is inappropriate. In the past, some agencies have, in addition to the global estimate, also disclosed a "highly speculative" estimate of the domestic-only effects of climate change. DOE has always included a chapter on a domestic-only value of carbon emissions in the economic analyses supporting its energy efficiency standards, though noting that a such domestic-only numbers are "approximate, provisional, and highly speculative."[40] Such an approach is consistent with *Circular A-4*'s suggestion that agencies may disclose domestic effects separately from global effects. However, as we have discussed, reliance on a domestic-only methodology would be inconsistent with both the inherent nature of climate change and the standards of *Circular A-4*. Consequently, under *Circular A-4*, DOE should use in its primary analysis the global social cost of carbon.

For more details on the justification for a global value of the social cost of greenhouse gases, including the applicable standards of rational decisionmaking, please see Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 Columbia J. Envtl. L. 203 (2017). Another strong defense of the global valuation as consistent with best economic practices appears in a letter published in *The Review of Environmental Economics and Policy*, co-authored by Nobel laureate Kenneth Arrow. As Arrow and his co-authors explained: "To solve the unprecedented global commons problem posed by climate change, all nations must internalize the global externalities of their emissions[.] . . . [O]therwise, collective abatement efforts will never achieve an efficient, stable climate outcome."[41]

c. Benefits and Costs that "Accrue to Citizens and Residents of the United States" Extend Far Beyond U.S. Borders

To follow *Circular A-4*'s instruction to analyze all significant effects that "accrue to [U.S.] citizens," agencies must look beyond "the borders of the United States" to a much broader range of climate effects. For one, because of our world's interconnected financial, political, health, security, and environmental systems, climate impacts occurring initially beyond the geographic borders of the United States cause significant costs that accrue to U.S. citizens and residents. Second, because U.S. climate policy impacts the climate policies of other nations, deregulatory actions such as this proposal have an indirect effect on foreign emissions and thus cause climate-related domestic impacts that are not accounted for in DOE's proposed methodology. And third, U.S. citizens have direct interests in climate-related impacts that will occur overseas, including those affecting citizens living abroad or harming international habitats or species that U.S. citizens value. EPA makes no effort to address this reality, rather saying the agency follows the guidance of *Circular A-4* by "focus[ing] on the direct impacts of climate change that are anticipated to occur within U.S. borders."[42] Below, we detail each of these three important aspects of climate damages for which the DOE's "domestic-only" valuation fails to account.

International Spillovers: First, DOE's valuation of the social cost of carbon ignores significant, indirect costs to trade, human health, and security likely to "spill over" to the United States as other

[40] DOE, 2016-12 Final Rule Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Air Compressors, 14-3 n. B.
[41] Richard Revesz, Kenneth Arrow et al., *The Social Cost of Carbon: A Global Imperative*, 11 REVIEW OF ENVTL. ECON. & POLICY 172 (2017).
[42] 2020 TSD at 14-1.

regions experience climate change damages.[43] As a federal court recently explained, this is "because emissions of most greenhouse gases contribute to damages around the world and the world's economies are now highly interconnected."[44] These spillover effects, "such as on trade and migration…must be considered in any attempt to estimate domestic impacts."[45] Due to its unique place among countries—both as the largest economy with trade- and investment-dependent links throughout the world, and as a military superpower—the United States is particularly vulnerable to effects that will spill over from other regions of the world. Spillover scenarios could entail a variety of serious costs to the United States as unchecked climate change devastates other countries. Correspondingly, mitigation or adaptation efforts that avoid climate damages to foreign countries will radiate benefits back to the United States as well.[46] While the current integrated assessment models ("IAMs") provide reliable but conservative estimates of global damages, they currently cannot calculate reliable region-specific estimates, in part because they do not model such spillovers.

As climate change disrupts the economies of other countries, decreased availability of imported inputs, intermediary goods, and consumption goods may cause supply shocks to the U.S. economy. Shocks to the supply of energy, technological, and agricultural goods could be especially damaging. For example, when Thailand—the world's second-largest producer of hard-drives—experienced flooding in 2011, U.S. consumers faced higher prices for many electronic goods, from computers to cameras.[47] A recent economic study explored how heat stress-induced reductions in productivity worldwide will ripple through the interconnected global supply network.[48] Similarly, the U.S. economy could experience demand shocks as climate-affected countries decrease their demand for U.S. goods. Financial markets may also suffer as foreign countries become less able to loan money to the United States and as the value of U.S. firms declines with shrinking foreign profits. As seen historically, economic disruptions in one country can cause financial crises that reverberate globally at a breakneck pace.[49]

The human dimension of climate spillovers includes migration and health effects. Water and food scarcity, flooding or extreme weather events, violent conflicts, economic collapses, and a number of other climate damages could precipitate mass migration to the United States from regions worldwide, especially, perhaps, from Latin America. For example, a 10% decline in crop yields could trigger the emigration of 2% of the entire Mexican population to other regions, mostly to the United States.[50] Such an influx could strain the U.S. economy and will likely lead to increased U.S. expenditures on migration prevention. Infectious disease could also spill across the U.S. borders, exacerbated by ecological collapses, the breakdown of public infrastructure in poorer nations,

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

[44] *California*, 2020 WL 4001480, at *23.

[45] *Id.* at *28.

[46] *See* Freeman & Guzman, *supra* note 43, at 1563-93.

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

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

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

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

declining resources available for prevention, shifting habitats for disease vectors, and mass migration.

Finally, climate change is predicted to exacerbate existing security threats—and possibly catalyze new security threats—to the United States.[51] Besides threats to U.S. military installations and operations at home and abroad from flooding, storms, extreme heat, and wildfires,[52] climate change is also a "source[] of conflict around the world" requiring U.S. response, according to a Department of Defense report issued last year.[53] This report corroborates a 2014 Department of Defense report declaring that climate effects "are threat multipliers that will aggravate stressors abroad such as poverty, environmental degradation, political instability, and social tensions—conditions that can enable terrorist activity and other forms of violence," and as a result "climate change may increase the frequency, scale, and complexity of future missions, including defense support to civil authorities, while at the same time undermining the capacity of our domestic installations to support training activities."[54] As an example of the climate-security-migration nexus, prolonged drought in Syria likely exacerbated the social and political tensions that erupted into an ongoing civil war,[55] which has triggered an international migration and humanitarian crisis.[56]

Because of these interconnections, attempts to artificially segregate a U.S.-only portion of climate damages will inevitably result in misleading underestimates. Some experts on the social cost of carbon have concluded that, given that integrated assessment models currently do not capture many of these key inter-regional costs, use of the global social cost of greenhouse gas estimates may be further justified as a proxy to capturing all spillover effects.[57] Though not all climate damages will spill back to affect the United States, many will, and together with other justifications, the likelihood of significant spillovers makes a global valuation the better, more transparent accounting of the full range of costs and benefits that matter to U.S. policymakers and the public.

Reciprocal Foreign Actions: Second, an indirect consequence of the United States using a global social cost of greenhouse gas to justify actions that protect against climate damages is that foreign countries take reciprocal actions that benefit the United States. Yet DOE arbitrarily fails to account for this likely significant impact. *Circular A-4* requires that the "same standards of information and

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

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

53 U.S. Dep't of Defense, Report on Effects of a Changing Climate to the Dep't of Defense 8 (Jan. 2019), *available at* https://media.defense.gov/2019/Jan/29/2002084200/-1/-1/1/CLIMATE-CHANGE-REPORT-2019.PDF. Recently-departed Secretary of Defense James Mattis has also explained that "[c]limate change is impacting stability in areas of the world where our troops are operating today." Andrew Revkin, *Trump's Defense Secretary Cites Climate Change as National Security Challenge*, ProPublica, Mar. 14, 2017.

54 U.S. Dep't of Defense, *Quadrennial Defense Review 2014* vi, 8 (2014).; see also U.S. Dep't of Defense, *Report to Congress: National Security Implications of Climate-Related Risks and a Changing Climate* (2015), *available at* http://archive.defense.gov/pubs/150724-congressional-report-on-national-implications-of-climate-change.pdf?source=govdelivery ("Global climate change will have wide-ranging implications for U.S. national security interests over the foreseeable future because it will aggravate existing problems—such as poverty, social tensions, environmental degradation, ineffectual leadership, and weak political institutions—that threaten domestic stability in a number of countries.")

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

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

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

analysis quality that apply to direct benefits and costs should be applied to ancillary benefits and countervailing risks."[58] Consequently, any attempt to estimate a domestic-only value of the social cost of greenhouse gas must include indirect effects from reciprocal foreign actions.

As detailed more in Howard & Schwartz (2017), because the world's climate is a single interconnected system, the United States benefits greatly when foreign countries consider the global externalities of their greenhouse gas pollution and cut emissions accordingly. Game theory predicts that one viable strategy for the United States to encourage other countries to think globally in setting their climate policies is for the United States to do the same, in a tit-for-tat, lead-by-example, or coalition-building dynamic. In fact, most other countries with climate policies already use a global social cost of carbon or set their carbon taxes or allowances at prices above their domestic-only costs, consistent with the global perspective used to date by U.S. agencies to value the cost of greenhouse gases. Both Republican and Democratic administrations have recognized that the analytical and regulatory choices of U.S. agencies can affect the actions of foreign countries, which in turn affect U.S. citizens.[59] This impact can be incredibly significant: According to one study, by 2030, direct U.S. benefits from global climate policies already in effect could reach over $2 trillion.[60] Any attempt to estimate a domestic-only value of the social cost of greenhouse gases must include such indirect effects from reciprocal foreign actions.[61]

Extraterritorial Interests: *Circular A-4* requires agencies to count all significant costs and benefits, and specifically explains the importance of including "non-use" values like "bequest and existence values". Yet by "ignoring these values" in calculating the social cost of carbon, contrary to *Circular A-4*'s explicit instructions, DOE "significantly understate[s] the … costs" of the proposed change in methodology.[62] Similarly, *Circular A-4* recognizes that U.S. citizens may have "altruism for the health and welfare of others," and instructs agencies that when "there is evidence of selective altruism, it needs to be considered specifically in both benefits and costs."[63] Many costs and benefits accrue to U.S. citizens from use values, non-use values, and altruism attached to climate effects occurring outside the U.S. borders, and DOE's valuation of the social cost of carbon fails to account for these significant effects.

A domestic-only estimate based on some rigid conception of geographic borders or U.S. share of world GDP will fail to capture all the climate-related costs and benefits that matter to U.S. citizens,[64] including significant U.S. ownership interests in foreign businesses, properties, and other assets, as

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58 Circular A-4 at 26.

59 Howard & Schwartz, *supra* note 25, at 232-37 (citing acknowledgement of this phenomenon by both the Bush administration and the Obama administration).

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

61 Kotchen shows that the optimally strategic social cost of greenhouse gas value will be strictly higher than the domestic value for all countries. Matthew J. Kotchen, *Which Social Cost of Carbon? A Theoretical Perspective* (NBER Working Paper, 2016). *See also* Comments from Robert Pindyck to BLM on the Social Cost of Methane in the Proposed Suspension of the Waste Prevention Rule (submitted Nov. 5, 2017) for a discussion of Kotchen (2016), and for a related discussion of why a domestic social cost of carbon is not in the United States' interest.

62 Circular A-4 at 22.

63 *Id.*

64 As the Northern District of California recently explained, the so-called "interim" Social Cost of Carbon "ignores impacts on 8 million United States citizens living abroad, including thousands of United States military personnel; billions of dollars of physical assets owned by United States companies abroad; United States companies impacted by their trading partners and suppliers abroad; and global migration and geopolitical security." Thus, the court held, reliance on this estimate in rulemaking unlawfully "fail[s] to consider . . . important aspect[s] of the problem" and "runs counter to the evidence before the agency." *California*, 2020 WL 4001480, at *23 (internal quotation marks omitted).

well as consumption abroad including tourism,[65] and even the 8.7 million Americans living abroad.[66]

The United States also has a willingness to pay—as well as a legal obligation—to protect the global commons of the oceans and Antarctica from climate damages. For example, the Madrid Protocol on Environmental Protection to the Antarctic Treaty commits the United States and other parties to the "comprehensive protection of the Antarctic environment," including "regular and effective monitoring" of "effects of activities carried on both within and outside the Antarctic Treaty area on the Antarctic environment."[67] The share of climate damages for which the United States is responsible is not limited to our geographic borders.

Similarly, U.S. citizens value natural resources and plant and animal lives abroad, even if they never use those resources or see those plants or animals. For example, the "existence value" of restoring the Prince William Sound after the 1989 Exxon Valdez oil tanker disaster—that is, the benefits derived by Americans who would never visit Alaska but nevertheless felt strongly about preserving the existence of this pristine environment—was estimated in the billions of dollars.[68] Though the methodologies for calculating existence value remain controversial,[69] U.S. citizens certainly have a non-zero willingness to pay to protect rainforests, charismatic megafauna like pandas, and other life and environments existing in foreign countries. U.S. citizens also have an altruistic willingness to pay to protect foreign citizens' health and welfare.[70] This altruism is "selective altruism," consistent with *Circular A-4*, because the United States is directly responsible for a huge amount of the historic emissions contributing to climate change.[71]

II. Using a Domestic-Only Social Cost of Greenhouse Gases Estimate Is Arbitrary and Capricious

DOE should not attempt to assess the impacts of future standards using on a domestic-only social cost of greenhouse gases, but rather should continue to focus on a global value. Not only is it inconsistent with *Circular A-4* and best economic practices to fail to estimate the global damages of U.S. greenhouse gas emissions in regulatory analyses, but existing methods for estimating a "domestic-only" value are unreliable, incomplete, and therefore inconsistent with *Circular A-4*. Indeed, in 2015, the Office of Management and Budget concluded, along with several other agencies, that "good methodologies for estimating domestic damages do not currently exist."[72] Moreover, a

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

66 Assoc. of Americans Resident Oversees, 8.7 million Americans (excluding military) live in 160-plus countries, available at https://www.aaro.org/about-aaro/8m-americans-abroad. Admittedly, 8.7 million is only 0.1% of the total population living outside the United States.

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

68 RICHARD REVESZ & MICHAEL LIVERMORE, RETAKING RATIONALITY 121 (2008).

69 *Id.* at 129.

70 *See* Arden Rowell, *Foreign Impacts and Climate Change*, 39 HARV. ENVT'L. L. REV. 371 (2015); Dana, *supra* note 65 (discussing U.S. charitable giving abroad and foreign aid, and how those metrics likely severely underestimate true U.S. willingness to pay to protect foreign welfare).

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

72 In November 2013, OMB requested public comments on the social cost of carbon. In 2015, OMB along with the rest of the Interagency Working Group issued a formal response to those comments. Interagency Working Group on the Social

domestic-only estimate misapplies models that were not built for the purpose of calculating regional damages, ignores recent literature on significant U.S. climate damages, and fails to reflect international spillovers to the United States, U.S. benefits from foreign reciprocal actions, and the extraterritorial interests of U.S. citizens including financial interests and altruism.

a. A federal court has ruled that use of the "interim" domestic-only social cost of greenhouse gases is arbitrary and capricious

In July 2020, the U.S. District Court for the Northern District of California ruled that the Bureau of Land Management's use of the "interim," domestic-only estimates for the social cost of greenhouse gases in its justification to rescind the 2016 Waste Prevention Rule was arbitrary and capricious.[73] The court found that not only did BLM "revers[e] [its] prior position" about the proper Social Cost of Carbon value without sufficient justification,[74] but also that the domestic-only social cost of greenhouse gases is methodologically flawed and inappropriate for use by federal agencies. The court noted that "focusing solely on domestic effects has been soundly rejected by economists as improper and unsupported by science."[75] And by omitting global effects, BLM's

> analysis ignores impacts on 8 million United States citizens living abroad, including thousands of United States military personnel; billions of dollars of physical assets owned by United States companies abroad; United States companies impacted by their trading partners and suppliers broad; and global migration and geopolitical security.[76]

In other words, even though BLM claimed that its "interim" estimates captured the effects accruing to the United States, the agency in fact overlooked the tremendous damages to U.S. interests resulting from climate impacts occurring from outside the country's geographical borders. In addition, the Northern District of California explained that by ignoring the National Academies' findings "that international effects can have significant spill-over effects in the United States, such as on trade and migration, which must be considered in any attempt to estimate domestic impacts," BLM casted aside the best available science.[77] Nor was the fact that President Trump rescinded the IWG's documents by Executive Order of legal relevance, since "[t]he Executive Order in and of itself has no legal impact on the consensus that IWG's estimates constitute the best available science about monetizing the impacts of greenhouse gas emissions."[78]

DOE is committing the same errors in its technical support document for room air conditioners as BLM did its justification for the rescission of the Waste Prevention Rule. Such obfuscation of global climate damages is inconsistent with the best available science and economics, and without providing "evidence of specialists' conflicting views or alternative scientific models" to support its change from its prior position (i.e. use of the IWG's social cost of carbon estimates),[79] reliance on the "interim" domestic-only social cost of greenhouse gases is arbitrary and capricious.

Cost of Carbon, *Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12,866* at 36 (July 2015).

[73] *California*, 2020 WL 4001480, at *28.
[74] *Id*. at *18.
[75] *Id.* at *27.
[76] *Id*.
[77] *Id*. at *28.
[78] *Id.* at *25.
[79] *Id*. at *27.

b. No current methodology for estimating a "domestic-only" value is consistent with practices for reasoned decisionmaking, as confirmed in a recent GAO report

The Office of Management and Budget, the National Academies of Sciences, the Government Accountability Office, and the economic literature all agree that existing methodologies for calculating a "domestic-only" value of the social cost of greenhouse gases are deeply flawed and result in severe and misleading underestimates.

In developing the social cost of carbon, the IWG did offer some such domestic estimates. Using the results of one economic model (FUND) as well as the U.S. share of global gross domestic product ("GDP"), the group generated an "approximate, provisional, and ***highly speculative***" range of 7–23% of the global social cost of carbon as an estimate of the purely direct climate effects to the United States.[80] Yet, as the IWG itself acknowledged, this range is almost certainly an underestimate because it ignores significant, indirect costs to trade, human health, and security that are likely to spill over into the United States as other regions experience climate change damages, among other effects.[81]

Neither the existing IAMs nor a share of global GDP are an appropriate basis for calculating a domestic-only estimate. The IAMs were never designed to calculate a domestic SCC, since a global SCC is the economically efficient value. FUND, like other IAMS, includes some simplifying assumptions: of relevance, FUND and the other IAMs are not able to capture the adverse effects that the impacts of climate change in other countries will have on the United States through trade linkages, national security, migration, and other forces.[82] This is why the IWG characterized the domestic-only estimate from FUND as a "highly speculative" underestimate. Similarly, a domestic-only estimate based on some rigid conception of geographic borders or U.S. share of world GDP will fail to capture all the climate-related costs and benefits that matter to U.S. citizens.[83] U.S. citizens have economic and other interests abroad that are not fully reflected in the U.S. share of global GDP. GDP is a "monetary value of final goods and services—that is, those that are bought by the final user—produced in a country in a given period of time."[84] GDP therefore does not reflect significant U.S. ownership interests in foreign businesses, properties, and other assets, as well as consumption abroad including tourism,[85] or even the 8 million Americans living abroad.[86]

At the same time, GDP is also over-inclusive, counting productive operations in the United States that are owned by foreigners. Gross National Income ("GNI"), by contrast, defines its scope not by

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80 Interagency Working Group on Social Cost of Carbon, Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis 11 (2010) (emphasis added).

81 *Id.* (explaining that the IAMs, like FUND, do "not account for how damages in other regions could affect the United States (e.g., global migration, economic and political destabilization").

82 *See, e.g.*, Dept. of Defense, *National Security Implications of Climate-Related Risks and a Changing Climate* (2015), *available at* http://archive.defense.gov/pubs/150724-congressional-report-on-national-implications-of-climate-change.pdf?source=govdelivery.

83 A domestic-only SCC would fail to "provide to the public and to OMB a careful and transparent analysis of the anticipated consequences of economically significant regulatory actions." Office of Information and Regulatory Affairs, *Regulatory Impact Analysis: A Primer* 2 (2011).

84 Tim Callen, *Gross Domestic Product: An Economy's All*, IMF, http://www.imf.org/external/pubs/ft/fandd/basics/gdp.htm (last updated Mar. 28, 2012).

85 "U.S. residents spend millions each year on foreign travel, including travel to places that are at substantial risk from climate change, such as European cities like Venice and tropical destinations like the Caribbean islands." Dana, *supra* note 65.

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

location but by ownership interests.[87] However, not only has GNI fallen out of favor as a metric used in international economic policy,[88] but using a domestic-only SCC based on GNI would make the SCC metrics incommensurable with other costs in regulatory impact analyses, since most regulatory costs are calculated by U.S. agencies regardless of whether they fall to U.S.-owned entities or to foreign-owned entities operating in the United States.[89] Furthermore, both GDP and GNI are dependent on what happens in other countries, due to trade and the international flow of capital. The artificial constraints of both metrics counsel against a rigid split based on either U.S. GDP or U.S. GNI.[90]

As a result, in 2015, OMB concluded, along with several other agencies, that "good methodologies for estimating domestic damages do not currently exist."[91] Similarly, the NAS recently concluded that current IAMs cannot accurately estimate the domestic social cost of greenhouse gases, and that estimates based on U.S. share of global GDP would be likewise insufficient.[92] William Nordhaus, the developer of the DICE model, cautioned earlier this year that "regional damage estimates are both incomplete and poorly understood," and "there is little agreement on the distribution of the SCC by region."[93] In short, any domestic-only estimate will be inaccurate, misleading, and out of step with the best available economic literature, in violation of *Circular A-4*'s standards for information quality.

Consistent with this longstanding consensus, in June 2020 the Government Accountability Office ("GAO") published a report critiquing the federal government's reliance on the "interim" social cost of carbon and its failure to implement the National Academies' recommendations on updating the social cost of carbon estimates.[94] GAO concluded that the integrated assessment models EPA used to derive its domestic-only social cost of carbon "were not premised or calibrated to provide estimates of the social cost of carbon based on domestic damages."[95] GAO further noted that the National Academies found that country-specific social costs of carbon estimates were "limited by existing methodologies, which focus primarily on global estimates and do not model all relevant interactions among regions."[96] Moreover, it explained, the National Academies concluded that "accurately estimating the damages from carbon dioxide emissions for the United States would involve more than examining the direct impacts of climate change that occur within U.S. physical

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

88 *Id*.

89 U.S. Office of Management and Budget & Secretariat General of the European Commission, *Review of Application of EU and US Regulatory Impact Assessment Guidelines on the Analysis of Impacts on International Trade and Development* 13 (2008).

90 Advanced Notice of Proposed Rulemaking on Regulating Greenhouse Gas Emissions Under the Clean Air Act, 73 Fed. Reg. 44,354, 44,415 (July 30, 2008) ("Furthermore, international effects of climate change may also affect domestic benefits directly and indirectly to the extent U.S. citizens value international impacts (e.g., for tourism reasons, concerns for the existence of ecosystems, and/or concern for others); U.S. international interests are affected (e.g., risks to U.S. national security, or the U.S. economy from potential disruptions in other nations).").

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

92 National Academies of Sciences, Engineering, and Medicine, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide 53 (2017) [hereinafter NAS Second Report].

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

94 GAO, Social Cost of Carbon: Identifying a Federal Entity to Address the National Academies' Recommendations Could Strengthen Regulatory Analysis, GAO-20-254 (June 2020) [Attached].

95 *Id.* at 29.

96 *Id.* at 26.

borders," as "U.S.-specific damages would need to consider how climate change and emissions reductions in other parts of the world could also affect the United States."[97]

GAO also concluded that "[t]he federal government has no plans to address the recommendations of the National Academies [] for updating the methodologies used to develop the federal estimates of the social cost of carbon," and "therefore, the federal government may not be well positioned to ensure agencies' future regulatory analyses are using the best available science until the agencies finalize federal estimates that consider the National Academies' implemented recommendations."[98]

Given the federal government's failure to act on the National Academies' recommendations to update the social cost of carbon estimates so that they *are* reflective of the best available science and economics, and given that the National Academies and many other organizations and economists aver that the IAMs are inappropriate for calculating domestic-only damages, DOE should not rely on so-called "interim" estimates.

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

Despite broad consensus that there are no existing methodologies that accurately project domestic climate damages, DOE attempts to derive a domestic estimate anyway using existing international damage estimates.[99] Specifically, DOE reports that it will use the IWG methodology to calculate a domestic-only SCC. Yet other agencies that have done so, like EPA, have used deeply flawed methodologies.

In particular, in its analysis justifying the repeal of the methane emissions standards from new sources, EPA reports that its domestic-only estimates are "calculated directly" from the models FUND and PAGE; for the model DICE, EPA simply assumes that U.S. damages are 10% of global damages.[100] EPA thus uses these models in ways they were never designed for—indeed, in ways their designers specifically cautioned against. EPA furthermore fails to assess the most up-to-date literature on U.S. damages and fails to take steps to reflect spillover effects, reciprocal benefits, or U.S. interests beyond our borders. EPA's methodology is deeply flawed.

The integrated assessment models used by the agency to calculate the social cost of greenhouse gases were designed to create global estimates and are best suited for those purposes. The models are limited in how accurately and fully they can estimate domestic values of the social cost of greenhouse gases. For example, the models make simplifying assumptions about the extent of heterogeneity in crucial parameters like relative prices and discount rates.[101] The models also simplify or ignore completely global spillovers from trade, migration, and other sources.[102] These types of spillovers will not, in many cases, affect the global estimate of climate change damages, but they will change (perhaps dramatically so) the domestic estimates. For example, trade effects will net to zero globally: A decrease in exports by one country must correspond to a decrease in imports

97 *Id*.
98 *Id.* at 29.
99 Transcript of Proceedings, In the Matter of: Room Air Conditioners Online Webinar 88 (Aug. 5, 2020), https://beta.regulations.gov/document/EERE-2014-BT-STD-0059-0018
100 EPA, Regulatory Impact Analysis for the Review and Reconsideration of the Oil and Natural Gas Sector: Emissions Standards for New, Reconstructed, and Modified Sources B-1 (Aug. 2020) [hereinafter "Methane RIA"].
101 Christian Gollier & James K. Hammitt, *The Long-Run Discount Rate Controversy*, 6 ANNU. REV. RESOUR. ECON. 273–295 (2014) at 287-289.
102 *See generally* Howard & Schwartz, *supra* note 25.

for another country.[103] Global estimates will also generally be more accurate than domestic estimates because aggregation of multiple values reduces the error of the overall estimate.[104]

An examination of the individual models used to calculate the "interim" domestic social cost of greenhouse gases—PAGE 2009, FUND 3.8, and DICE 2010[105]—highlights the current limitations to calculating of a domestic value of the social cost of greenhouse gases. For example, the only way that the PAGE model "calculate[s] directly" regional impacts is through its "regional scaling factors," which are "based on the length of each region's coastline relative to the [European Union]. Because of the long coastline in the EU, other regions are, on average, [deemed to be] less vulnerable than the EU for the same sea level and temperature increase."[106] In other words, PAGE calculates climate impacts occurring within U.S. borders by first estimating the climate damages that an additional ton of methane will cause in Europe, and then scaling down that value because the United States has a coastline that is three times shorter than Europe's.[107]

While relative coastline length may provide a reasonable scaling factor for certain climate damages, such as from coastal flooding, coastal storms, and other sea-level rise issues, it likely understates many other key climate damages—perhaps dramatically so—to the United States, where increases in mortality, agricultural losses, and other important climate effects will also occur in inland, warm areas of the country,[108] and will occur regardless of relative coastline length. Accordingly, EPA's methodology for calculating domestic climate damages from the PAGE model—one of just three models that the "interim" estimate incorporates—completely disregards significant damage categories.

The other two models on which the "interim" domestic social cost of greenhouse gases estimate relies similarly overlook substantial damage categories. The FUND model generally estimates domestic damages from climate change by scaling estimates according to gross domestic product or population. For instance, forestry damages are "mapped to the FUND regions assuming that the impact is uniform [relative] to GDP."[109] Similarly, domestic energy consumption changes are a function of gross domestic product, and the authors note that "heating demand is linear in the number of people" in a FUND region.[110] Scaling damages by gross domestic product and population will fail to capture important differences between countries like pre-existing climate, interconnectedness of trade relationships, climate change preparedness, and preferences.

These issues are readily apparent in the case of agricultural damage estimates in FUND. Agriculture is one of the most important sectors driving the relatively low damages in the FUND model. Yet, recent evidence on this sector that incorporates cutting-edge estimates of crop yield changes finds that the FUND model substantially understates the agricultural damages from climate change.[111]

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

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

105 Methane RIA, supra note 100, at B-1.

106 Interagency Working Group, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis 17 (2016).

107 According to the CIA's World Factbook, EU's coastline is over three times longer than the U.S. coastline. *Compare* https://www.cia.gov/library/publications/the-world-factbook/geos/ee.html, *with* https://www.cia.gov/library/publications/the-world-factbook/geos/us.html.

108 Solomon Hsiang et al., *Economic Damage from Climate Change in the United States*, 356 SCIENCE 1362–69 (2017).

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

110 *Id.* at 10.

111 Frances C. Moore et al., Economic Impacts of Climate Change on Agriculture: a Comparison of Process-Based and Statistical Yield Models, 12 Envtl. Research Letters (2017).

Particularly for domestic damages, new research shows that FUND dramatically understates the effect of warming on agricultural outcomes globally and for individual countries like the United States.[112] These higher damage estimates come from updates to the relationship between warming and crop yield but also from a more thorough modeling of international trade in agricultural products.

Finally, the author of DICE 2010 has explicitly warned against using a domestic-only value. In a recent article, William Nordhaus states, "The regional estimates [of the social cost of greenhouse gases] are poorly understood, often varying by a factor of 2 across the three models. Moreover, regional damage estimates are highly correlated with output shares." He later reiterates that "the regional damage estimates are both incomplete and poorly understood."[113] These statements reinforce the conclusion of OMB that "good methodologies for estimating domestic damages do not currently exist."[114]

In conclusion, if DOE follows the methodology of other agencies to calculate an interim social cost of greenhouse gases, its domestic only estimation ignores "important aspect[s] of the problem" and fails to articulate a rational connection between the data and the choice made, and is therefore arbitrary and capricious in violation of the Administrative Procedure Act.[115]

d. DOE Inconsistently Counts in Full the Portion of Cost that Will Accrue to Foreign Owners, While Ignoring Benefits from Global Climate Impacts

In addition to its failure to account for significant domestic costs, DOE also effectively treats costs and benefits inconsistently by counting considerable benefits that will accrue to foreign residents from the proposed change in methodology. Therefore, the agency has unlawfully "put a thumb on the scale" by counting certain purported foreign benefits while ignoring foreign costs.[116]

In rulemakings under EPCA, DOE conducts a manufacturer-impact analysis to assess the effect a proposed standard would have on companies that manufacture the appliance being assessed. The draft technical support document at issue here lists 31 manufacturers that a new air conditioner efficiency standard would affect.[117] The list includes a number of foreign-owned companies, such as the Matsushita Electric Corp.,[118] Samsung Electronics Co., Ltd.,[119] and LG Electronics Inc.[120] Additionally, as detailed below, the list includes numerous U.S.-based companies with substantial foreign ownership.

Yet nowhere in this proposal does DOE ever suggest that the agency will separate out cost effects to foreign interests, or relegate such effects to an appendix, in future rulemakings. Given the ownership of the corporations that produce room air conditioner equipment, however, a significant portion of the costs (or cost savings, in the case of a deregulatory rule) from energy-efficiency

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

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

[114] OMB 2015 Response to Comments, *supra* note 91.

[115] *State Farm*, 463 U.S. at 41-42 (applying the standards of review to deregulatory action and concluding that when "rescinding a rule" an agency "is obligated to supply a reasoned analysis for the change beyond that which may be required when an agency does not act in the first instance"); *see also* 5 U.S.C. § 706.

[116] *Ctr. for Biological Diversity*, 538 F.3d at 1198.

[117] 2020 TSD at 3-6, tbl. 3.6.1.

[118] Owned by Panasonic, based in Japan.

[119] Based in South Korea.

[120] A subsidiary of LG Corporation, which is based in South Korea.

standards will ultimately accrue to foreign owners and customers. Consequently, DOE's choice to ignore U.S. financial interests in global climate benefits is a starkly arbitrary and inconsistent treatment of costs and benefits.

Indeed, a significant portion of the effects of DOE's energy conservation program accrues to foreign entities. All industry compliance costs ultimately fall on the owners, employees, and customers of regulated and affected firms. At a minimum, many if not all regulated and affected firms that are public companies have significant foreign ownership of stock and corporate debt. As noted above, some of these companies are themselves foreign-based. For example, LG Electronics—a member of the Association of Home Appliance Manufacturers, which is represented on DOE's Appliance Standards and Rulemaking Federal Advisory Committee[121]—is a public company based in South Korea. In 2018, 35% of its parent company's shareholders were foreign investors and 34% were domestic.[122] While foreign-based investment banks and funds will have U.S. investors, U.S.-based funds that invest heavily in LG Corporation, like BlackRock,[123] will similarly have foreign investors.

Additionally, the major shareholders of many of the affected U.S.-based manufacturers, such as Whirlpool and the Home Depot Inc., are institutional investors with significant global portfolios.[124] Economy-wide, between 20-30% of U.S. stocks and 35% of U.S. corporate debt are held by foreigners,[125] with significant foreign direct investment in U.S. mining and fossil fuel extraction, in U.S. utilities, and in U.S. manufacturing.[126] A significant portion of the regulatory effects passing through publicly-traded regulated companies would ultimately be experienced by such foreign owners.

Furthermore, whether or not affected companies have foreign ownership, many will have direct or indirect foreign consumers, since a relatively few appliance manufacturers sell their goods worldwide.[127] Yet despite counting in full these effects to foreign owners and customers of U.S. firms, DOE ignores effects caused by climate change occurring outside U.S. borders. This inconsistent treatment of costs and benefits is patently arbitrary and capricious.

DOE has arbitrarily drawn different geographic lines around which costs and benefits it chooses to consider. DOE should consider all significant global harms for a global pollutant like greenhouse gases, instead of inconsistently treating the costs and benefits that accrue to foreign versus domestic entities.

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121 *See* Member Directory, Assoc. of Home Appliance Mfrs., *https://www.aham.org/AHAM/AuxCurrentMembers*.

122 Shareholder Composition, LG, https://www.lg.com/global/stock-bond-info-shareholder-composition.

123 Blackrock owned 12% of LG Electronics as of 2017. *S*ee BlackRock, Inc., Section 13G Filing (Jan. 11., 2017), *available at* https://www.sec.gov/Archives/edgar/data/1126956/000021545717000893/spire.inc.txt.

124 E.g. BlackRock, the Vanguard Group, and Fidelity.

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

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

127 E.g. On 56% of Whirlpool's net sales are in North America. See https://s22.q4cdn.com/226840148/files/doc_downloads/2020/04/Whirlpool-Investor-Overview-April-2020.pdf.

e. Using a global social cost of greenhouse gases estimate allow DOE to maximize net social welfare consistent with its obligations under EPCA

While reliance on the "interim" social cost of carbon would be arbitrary and capricious for any agency, this reliance is particularly troubling and unlawful under EPCA. Specifically, EPCA requires that amended or new standards adopted thereby be "economically justified," meaning that "the benefits of the standard exceed its burdens."[128] In making this cost-benefit assessment, EPCA is instructed to consider any "relevant" "factors" to "the greatest extent practicable," including the "need for national energy and water conservation."[129]

Without considering the full scope of climate damages resulting from greenhouse gas emissions—which the "interim" value that DOE proposes to use here fails to do, for all the reasons detailed above—the agency cannot make a rational assessment under EPCA that the "benefits" of any future "standard exceed its burdens." As detailed above, the "interim" social cost of greenhouse gases that DOE proposes to use here ignores many critical domestic effects resulting from such factors as international spillovers, reciprocal actions of foreign governments, and extraterritorial interests. Assigning "zero" value in a cost-benefit assessment to a "value of carbon emissions [that] is certainly not zero" is arbitrary and capricious, as the Ninth Circuit Court of Appeals has held.[130] While in that case the defendant agency failed to account for the value of any carbon emissions, an analysis that only considered a small fraction of the harm from carbon emissions, while harm outside U.S. borders was "nowhere accounted for in the agency's analysis," would be no less arbitrary.[131]

Whereas use of the "interim" method omits key factors that DOE must consider, the Seventh Circuit Court of Appeals held in *Zero Zone* that use of the global social cost of carbon in a cost-benefit analysis conducted under EPCA is a rational and reasonable means of measuring climate harm.[132] Accordingly, the use of the "interim" social cost estimates in a cost-benefit analysis fails to meaningfully capture the full range of climate harms and cannot rationally serve as a basis to conclude under EPCA that a regulatory proposal is cost-benefit justified, and DOE should continue to use the IWG's estimate.

f. DOE has very recently used the IWG's global estimates and fails to offer a reasoned explanation for its change in position regarding the social cost of carbon

In numerous rulemakings[133]—including since an 'interim' estimate became available, and as recently as January 2020—DOE has correctly centered its social cost of greenhouse gases estimates on global climate damages and acknowledged that the IWG estimates remain the best available estimates of the monetary damages of each additional ton of greenhouse gases.[134]

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[128] 42 U.S.C. § 6295(o)(2)(B)(i)..

[129] *Id.* § 6295(o)(2)(B)(i)(VI)–(VII).

[130] *Ctr. for Biological Diversity v. NHTSA*, 538 F.3d 1172, 1200 (9th Cir. 2008).

[131] *See id.*

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

[133] JANE A. LEGGETT, FEDERAL CITATIONS TO THE SOCIAL COST OF GREENHOUSE GASES, CONGRESSIONAL RESEARCH SERVICE (Mar. 2017).

[134] 85 Fed. Reg. 1565 ("Although uncertainties remain, the revised SCC values are based on the best available scientific information on the impacts of climate change. The current estimates of the SCC have been developed over many years, using the best science available, and with input from the public."

In energy conservation program rules for air compressors,[135] commercial packaged boilers,[136] portable air conditioners,[137] and uninterruptible power supplies,[138] all released on January 10, 2020, DOE used the IWG social cost of carbon estimates.[139] DOE used the range of social cost of carbon estimates of global damages, including the estimates calculated at 2.5-percent, 3-percent, and 5-percent discount rates, as well as the 95th percentile estimate.[140] In fact, in announcing the final standards, DOE explained: "The CO_2 reduction is a benefit that accrues globally. DOE maintains that consideration of global benefits is appropriate because of the global nature of the climate change problem."[141] The Department further stated that "preference is given to consideration of the global benefits of reducing CO_2 emissions,"[142] over domestic-only benefits of emissions reductions.

In those final rules, DOE placed a clear emphasis on global climate damages,[143] describing exactly why climate change requires a "different emphasis" than rulemakings with principally domestic impacts:[144]

> The climate change problem is highly unusual in at least two respects. First, it involves a global externality: Emissions of most greenhouse gases contribute to damages around the world even when they are emitted in the United States. Consequently, to address the global nature of the problem, the SCC must incorporate the full (global) damages caused by GHG emissions. Second, climate change presents a problem that the United States alone cannot solve. Even if the United States were to reduce its greenhouse gas emissions to zero, that step would be far from enough to avoid substantial climate change. Other countries would also need to take action to reduce emissions if significant changes in the global climate are to be avoided. … When these considerations are taken as a whole, the interagency group concluded that a global measure of the benefits from reducing U.S. emissions is preferable.[145]

The agency also explained that taking such a global perspective is in line with its statutory mandate under the EPCA to ensure that a standard is "economically justified." In doing so, DOE correctly identified the link between the need for national energy conservation and a focus on global climate change effects.

135 85 Fed. Reg. 1504 (Jan. 10, 2020).
136 85 Fed. Reg. 1592 (Jan. 10, 2020).
137 85 Fed. Reg. 1378 (Jan. 10, 2020).
138 85 Fed. Reg. 1447 (Jan. 10, 2020).
139 85 Fed. Reg. at 1506; *see also* 85 Fed. Reg. at 1649; 85 Fed. Reg. at 1381; 85 Fed. Reg. at 1477.
140 *See, e.g.,* 85 Fed. Reg. at 1507, tbl I.3 (Summary of Economic Benefits and Costs of Adopted Energy Conservation Standards for Air Compressors).
141 *Id*. at 1508.
142 *Id.* at 1564.
143 85 Fed. Reg. at 1504. Though DOE included a "speculative" domestic-only estimate in the Technical Support Document attached to that rulemaking, the same analysis says that "preference is given to consideration of the global benefits of reducing CO2 emissions" and that the "calculation for domestic values is approximate, provisional, and highly speculative." DOE, Technical Support Document: Energy Efficiency Program For Consumer Products and Commercial Industrial Equipment: Air Compressors at 14-3 & n. a (2016). Thus, the agency's clear focus was on a global estimate. *See also* 85 Fed. Reg. at 1652; 85 Fed. Reg. at 1425; 85 Fed. Reg. at 1480.
144 *See supra* note 32 and accompanying text.
145 85 Fed. Reg. 1566.

> DOE's approach is not in contradiction of the requirement to weigh the need for national energy conservation, as one of the main reasons for national energy conservation is to contribute to efforts to mitigate the effects of global climate change.[146]

In the January 2020 air compressors final rule, DOE also included an explanation of why the Department used the range of discount rates for the social costs of greenhouse gases. On the question of appropriate discount rates, DOE stated, "The central value, 3 percent, is consistent with estimates provided in the economics literature and OMB's *Circular A-4* guidance for the consumption rate of interest,"[147] and that "for purposes of capturing the uncertainties involved in regulatory impact analysis, the IWG emphasizes the importance of including all four sets of SC-CO2 values,"[148] which was reflected in DOE's analysis for this rule.[149] Using the range of discount rates and focusing on global damages is consistent with best practices and is consistent with *Circular A-4*, and the agency should continue to do so in this rulemaking as well. Previously, moreover, in a rulemaking for walk-in cooler and freezer systems released in July 2017, DOE similarly made use of the IWG ranges of social cost of carbon estimates,[150] and used a similar justification for considering global climate damages.[151]

In the draft Technical Support Document at issue here, DOE abruptly changes course and looks only at domestic effects in order to assess the social cost of carbon.[152] DOE's only justification is its reading of Executive Order 13,783,[153] which spawned the so-called "interim" domestic-only estimates[154] that have since been used by some agencies.[155] Despite having referenced a technical support document in multiple recent energy efficiency rules[156] that calls a domestic-only social cost of carbon values "approximate, provisional, and highly speculative,"[157] DOE now provides no rationale for its methodological change. In fact, the agency implies that it knows the "interim" estimates are flawed and not based on the best available science and economics.[158] Nor does DOE explain why Executive Order 13,783 is now suddenly dispositive when the agency has consistently used the global social cost of carbon since that Executive Order was issued in 2017.

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146 *Id.*

147 85 Fed. Reg. at 1566.

148 Id. at 1564; *see also* 85 Fed. Reg. at 1423; 85 Fed. Reg. at 1650

149 85 Fed. Reg. at 1564.

150 82 Fed. Reg. at 31,808.

151 Id. at 31,881.

152 2020 TSD at 14-1 ("Values used to represent the social cost of CO_2, methane and nitrous oxide will focus on the direct impacts of climate change that are anticipated to occur within U.S. borders.").

153 *Id.*

154 *See* Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources: Stay of Certain Requirements, 82 Fed. Reg. 51,788 (Nov. 8, 2017).

155 E.g. Waste Prevention, Production Subject to Royalties, and Resource Conservation; Delay and Suspension of Certain Requirements, 82 Fed. Reg. 46,458 (Oct. 5, 2017); Nat'l Highway Traffic Safety Admin. Final Regulatory Impact Statement: The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021 – 2026 Passenger Cars and Light Trucks (Mar. 2020).

156 DOE, 2016-12 Final Rule Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Air Compressors was included in the dockets for 85 Fed. Reg. 1504 (Jan. 10, 2020), 85 Fed. Reg. 1592 (Jan. 10, 2020), 85 Fed. Reg. 1378 (Jan. 10, 2020), 85 Fed. Reg. 1447 (Jan. 10, 2020).

157 DOE, 2016-12 Final Rule Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Air Compressors, 14-3 n. B.

158 2020 TSD at 14-1 ("Current domestic social cost estimates are interim values developed under E.O. 13783 for use in regulatory analyses until an improved estimate of the impacts of climate change on the U.S. can be developed based on the best available science and economics.").

When an agency departs from its prior policy, as DOE does here, it must offer a "reasoned explanation for its action."[159] However, DOE here fails "to identify or explain any changed circumstances, technology, or economic conditions that would justify" its use of the domestic-only SCC.[160] And, as explained further in Section IV, Executive Order 13,783 on its own does not compel the agency to depart from using a global estimate. As the Northern District of California recently explained:

> While the Executive branch holds the power to issue executive orders, an agency cannot flip-flop regulations on the whims of each new administration. The APA requires reasoning, deliberation, and process. These requirements exist, in part, because markets and industries rely on stable regulations. Here, BLM was not writing on a blank slate. It was required to provide a "reasoned explanation" for disregarding prior factual findings.[161]

Accordingly, DOE's sudden policy reversal does not meet the standards for rational decisionmaking and is an arbitrary exercise of discretion.

III. DOE Should Use Other Assumptions Made by the IWG

While DOE does not specify in this proposal how it plans to treat critical parameters in estimate climate damages such as the discount rate and the time horizon, other agencies that have recently applied the "interim" social cost estimates have made critical errors in these regards. Accordingly, we emphasize that DOE should continue to apply the IWG's recommendations on these fronts.

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

Because of the long lifespan of greenhouse gases and the long-term or irreversible consequences of climate change, the effects of today's emissions changes will stretch out over the next several centuries. The time horizon for an agency's analysis of climate effects, as well as the discount rate applied to future costs and benefits, determines how an agency treats future generations. Traditionally, federal agencies have focused on a central estimate of the social cost of greenhouse gases calculated at a 3% discount rate. Recent 'interim' estimates have given equal consideration to 7% discount rate, alleging that this is recommended by *Circular A-4*.[162] This is wrong.

A 7% rate for intergenerational climate effects is inconsistent with best economic practices, including under *Circular A-4*. In 2015, OMB explained that "Circular A-4 is a living document. . . . [T]he use of ***7 percent is <u>not</u> considered appropriate*** for intergenerational discounting. There is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself. "[163] While *Circular A-4* tells agencies generally to use a 7% discount rate in addition to lower rates for typical rules,[164] the guidance does not intend for default assumptions to produce analyses

159 *FCC v. Fox Television Stations, Inc.*, 556 U.S. 502, 515–16 (2009

160 *California*, 2020 WL 4001480, at *30 (explain that . BLM's revised estimate of compliance costs was arbitrary). recalculation.").

161 *Id.* at *16.

162 *See e.g.* EPA, Benefit and Cost Analysis for Revisions to the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category I-4 (2020).

163 OMB 2015 Response to Comments, *supra* note 91, at 36 (emphasis added).

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

inconsistent with best economic practices. *Circular A-4* clearly supports using lower rates to the exclusion of a 7% rate for the costs and benefits occurring over the extremely long, 300-year time horizon of climate effects.

A 7% Discount Rate Is Not "Sound and Defensible" or "Appropriate" for Climate Effects

Circular A-4 clearly requires agency analysts to do more than rigidly apply default assumptions: "You cannot conduct a good regulatory analysis according to a formula. Conducting high-quality analysis requires competent professional judgment."[165] As such, analysis must be "based on the best reasonably obtainable scientific, technical, and economic information available,"[166] and agencies must "*[u]se sound and defensible values* or procedures to monetize benefits and costs, and ensure that key analytical assumptions are defensible."[167] Rather than assume a 7% discount rate should be applied automatically to every analysis, *Circular A-4* requires agencies to justify the choice of discount rates for each analysis: "[S]tate in your report what assumptions were used, *such as . . . the discount rates* applied to future benefits and costs," and explain "clearly how you arrived at your estimates."[168] Based on *Circular A-4*'s criteria, there are numerous reasons why applying a 7% discount rate to climate effects that occur over a 300-year time horizon would be unjustifiable.

First, basing the discount rate on the **consumption rate of interest** is the correct framework for analysis of climate effects; a discount rate based on the private return to capital is inappropriate. *Circular A-4* does suggest that 7% should be a "default position" that reflects regulations that primarily displace capital investments; however, the Circular explains that "[w]hen regulation primarily and directly affects private consumption . . . *a lower discount rate is appropriate*."[169] The 7% discount rate is based on a private sector rate of return on capital, but private market participants typically have short time horizons. By contrast, climate change concerns the public well-being broadly. Rather than evaluating an optimal outcome from the narrow perspective of investors alone, economic theory requires analysts to make the optimal choices based on societal preferences and social discount rates. Moreover, because climate change is expected to largely affect large-scale consumption, as opposed to capital investment,[170] a 7% rate is inappropriate.

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[165] Circular A-4 at 3.
[166] *Id.* at 17.
[167] *Id.* at 27 (emphasis added).
[168] *Id.* at 3.
[169] *Id.* at 33.
[170] Maureen Cropper, *How Should Benefits and Costs Be Discounted in an Intergenerational Context?*, 183 RESOURCES 30, 33 (2013) ("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."); *see also* Richard G. Newell & William A. Pizer, Uncertain Discount Rates in Climate Policy Analysis, 32 ENERGY POL'Y 519, 521 (2004) ("Because climate policy decisions ultimately concern the future welfare of people—not firms—the consumption interest rate is more appropriate.").

In 2013, OMB called for public comments on the social cost of greenhouse gases. In its 2015 Response to Comment document,[171] OMB (together with the other agencies from the IWG) explained that

> [T]he consumption rate of interest is the correct concept to use . . . as the impacts of climate change are measured in consumption-equivalent units in the three IAMs used to estimate the SCC. This is consistent with OMB guidance in Circular A-4, which states that when a regulation is expected to primarily affect private consumption—for instance, via higher prices for goods and services—it is appropriate to use the consumption rate of interest to reflect how private individuals trade-off current and future consumption.[172]

The Council of Economic Advisers similarly interprets *Circular A-4* as requiring agencies to choose the appropriate discount rate based on the nature of the regulation: "[I]n Circular A-4 by the Office of Management and Budget (OMB) the appropriate discount rate to use in evaluating the net costs or benefits of a regulation depends on whether the regulation primarily and directly affects private consumption or private capital."[173] The NAS also explained that a consumption rate of interest is the appropriate basis for a discount rate for climate effects.[174] There is also strong consensus through the economic literature that a capital discount rate like 7% is inappropriate for climate change.[175] Finally, each of the three integrated assessment models upon which EPA bases its analysis—DICE, FUND, and PAGE—uses consumption discount rates; a capital discount rate is thus inconsistent with the underlying models. (See the technical appendix on discounting attached to these comments for more details.) For these reasons, 7% is an inappropriate choice of discount rate for the impacts of climate change.

Second, **uncertainty over the long time horizon** of climate effects should drive analysts to select a lower discount rate. As an example of when a 7% discount rate is appropriate, *Circular A-4* identifies an EPA rule with a 30-year timeframe of costs and benefits.[176] By contrast, greenhouse gas emissions generate effects stretching out across 300 years. As *Circular A-4* notes, "[p]rivate market rates provide a reliable reference for determining how society values time within a generation, but for extremely long time periods no comparable private rates exist."[177]

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

172 OMB 2015 Response to Comments, *supra* note 91, at 22.

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

174 NAS Second Report, *supra* note 92, at 28; *see also* Kenneth Arrow et al., Is There a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation?, 272 SCIENCE 221 (1996) (explaining that a consumption-based discount rate is appropriate for climate change).

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

176 Circular A-4 at 34; *see also* OMB 2015 Response to Comments, *supra* note 91, at 21 (noting that "most regulatory impact analysis is conducted over a time frame in the range of 20 to 50 years," and thus do not fully implicate "special ethical considerations [that] arise when comparing benefits and costs across generations").

177 Circular A-4 at 36.

Circular A-4 discusses how uncertainty over long time horizons drives the discount rate lower: "the longer the horizon for the analysis," the greater the "uncertainty about the appropriate value of the discount rate," which supports a lower rate.[178] *Circular A-4* cites the work of renowned economist Martin Weitzman and concludes that the "certainty-equivalent discount factor . . . corresponds to ***the minimum discount rate having any substantial positive probability***."[179] The National Academies of Sciences makes the same point about discount rates and uncertainty.[180] In fact, as discussed more below and in the technical appendix on discounting, uncertainty over the discount rate is best addressed by adopting a declining discount rate framework.

Third, a 7% discount rate **ignores catastrophic risks and the welfare of future generations**. As EPA shows in a recent cost-benefit analysis, the 7% rate truncates the long right-hand tail of social costs relative to the 3% rate's distribution.[181] The long right-hand tail represents the possibility of catastrophic damages. The 7% discount rate effectively assumes that present-day Americans are barely willing to pay anything at all to prevent medium- to long-term catastrophes. At the same time, the 7% distribution also misleadingly exaggerates the possibility of negative estimates of the social cost of greenhouse gases.[182] A negative social cost of carbon implies a discount rate so high that society is willing to sacrifice serious impacts to future generations for the sake of small, short-term benefits (such as slightly and temporarily improved fertilization for agriculture).

Fourth, a 7% discount rate would be inappropriate for climate change because it is based on **outdated data and diverges from the current economic consensus**. *Circular A-4* requires that assumptions—including discount rate choices—are "based on the best reasonably obtainable scientific, technical, and economic information available."[183] Yet *Circular A-4*'s own default assumption of a 7% discount rate was published 16 years ago and was based on data from decades ago.[184] *Circular A-4*'s guidance on discount rates is in need of an update, as the Council of Economic Advisers detailed recently after reviewing the best available economic data and theory:

> The discount rate guidance for Federal policies and projects was last revised in 2003. Since then a general reduction in interest rates along with a reduction in the forecast of long-run interest rates, warrants serious consideration for a reduction in the discount rates used for benefit-cost analysis.[185]

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178 *Id.*

179 *Id.*; *see also* CEA Issue Brief, *supra* note 173, at 9: "Weitzman (1998, 2001) showed theoretically and Newell and Pizer (2003) and Groom et al. (2007) confirm empirically that discount rate uncertainty can have a large effect on net present values. A main result from these studies is that if there is a persistent element to the uncertainty in the discount rate (e.g., the rate follows a random walk), then it will result in an effective (or certainty-equivalent) discount rate that declines over time. Consequently, lower discount rates tend to dominate over the very long term, regardless of whether the estimated investment effects are predominantly measured in private capital or consumption terms (see Weitzman 1998, 2001; Newell and Pizer 2003; Groom et al. 2005, 2007; Gollier 2008; Summers and Zeckhauser 2008; and Gollier and Weitzman 2010)."

180 NAS Second Report, *supra* note 92, at 27.

181 EPA, Benefit and Cost Analysis for Revisions to Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, at I-4 fig. I-1 (showing the 7% discount rate distribution).

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

183 Circular A-4 at 17.

184 The 7% rate was based on a 1992 report; the 3% rate was based on data from the 30 years preceding the publication of Circular A-4 in 2003. *Id.* at 33–34.

185 CEA Issue Brief, *supra* note 173, at 1; *see also id.* at 3 ("In general the evidence supports lowering these discount rates, with a plausible best guess based on the available information being that the lower discount rate should be at most 2 percent while the upper discount rate should also likely be reduced."); *id.* at 6 ("The Congressional Budget Office, the Blue Chip consensus forecasts, and the Administration forecasts all place the ten year treasury yield at less than 4 percent

In addition to recommending a value below 7% as the discount rate based on private capital returns, the Council of Economic Advisers further explains that, because long-term interest rates have fallen, a discount rate based on the consumption rate of interest "should be at most 2 percent."[186] The latest OMB updates to Circular A-94, the document on which *Circular A-4* based its discount rates,[187] also show that more up-to-date long-run discount rates are historically low. In the February 2018 update to Circular A-94's discount rates, the OMB found that the real, 30-year discount rate is 0.6 percent,[188] the lowest rate since the OMB began tracking the number.[189] Notably, the OMB also shows that the current real interest rate is negative for maturities less than 10 years.[190]

These low interest rates further confirm that applying a 7% rate to a context like climate change would be wildly out of step with the latest data and theory. Similarly, recent expert elicitations—a technique supported by *Circular A-4* for filling in gaps in knowledge[191]—indicate that a growing consensus among experts in climate economics for a discount rate between 2% and 3%; 5% represents the upper range of values recommended by experts, and few to no experts support discount rates greater than 5% being applied to the costs and benefits of climate change.[192] Based on current economic data and theory, the most appropriate discount rate for climate change is 3% or lower.

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

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

> Special ethical considerations arise when comparing benefits and costs across generations. . . It may not be appropriate for society to demonstrate a similar preference when deciding between the well-being of current and future generations. . . If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent.[193]

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in the future, while at the same time forecasting CPI inflation of 2.3 or 2.4 percent per year. The implied real ten year Treasury yield is thus below 2 percent in all these forecasts.").

186 *Id.* at 1.

187 Circular A-4 at 33.

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

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

190 Circular A-94 Appendix C, *supra* note 18888.

191 Circular A-4 at 41.

192 Peter Howard & Derek Sylvan, *The Economic Climate: Establishing Expert Consensus on the Economics of Climate Change,* INST. POLICY INTEGRITY WORKING PAPER 33–34 (2015) [hereinafter "Expert Consensus"]; M.A. Drupp, et al., *Discounting Disentangled: An Expert Survey on the Determinants of the Long-Term Social Discount Rate* (London School of Economics and Political Science Working Paper, May 2015) (finding consensus on social discount rates between 1-3%). Pindyck, in a survey of 534 experts on climate change, finds a mean discount rate of 2.9% in the climate change context and this rate drops to 2.6% when he omits individuals that lack confidence in their knowledge. Pindyck, R. S. (2016). *The social cost of carbon revisited* (No. w22807). National Bureau of Economic Research. Unlike Howard and Sylvan (2015), Pindyck (2016) combines economists and natural scientists in his survey, though the mean constant discount rate drops to 2.7% when including only economists. Again, this further supports the finding that the appropriate discount rate is between 2% and 3%.

193 Circular A-4 at 35-36.

Elsewhere in *Circular A-4*, OMB clarifies that sensitivity analysis should not result in a rigid application of all available assumptions regardless of plausibility. *Circular A-4* instructs agencies to depart from default assumptions when special issues "call for different emphases" depending on "the sensitivity of the benefit and cost estimates to the key assumptions."[194] More specifically:

> If benefit or cost estimates depend heavily on certain assumptions, you should make those assumptions explicit and carry out *sensitivity analyses using plausible alternative assumptions*. If the value of net benefits changes from positive to negative (or vice versa) or if the relative ranking of regulatory options changes with alternative plausible assumptions, you should conduct further analysis to determine ***which of the alternative assumptions is more appropriate***.[195]

In other words, if using a 7% discount rate would fundamentally change the agency's decision compared to using a 3% or lower discount rate, the agency must evaluate which assumption is most appropriate. Since OMB, the Council of Economic Advisers, the National Academies of Sciences, and the economic literature all conclude that a 7% rate is inappropriate for climate change, agencies should select a 3% or lower rate. EPA's selection of a 7% discount rate cannot be justified as "based on the best reasonably obtainable scientific, technical, and economic information available" and so is inconsistent with best practices for cost-benefit analysis under *Circular A-4*.[196] It would therefore be arbitrary for DOE to copy EPA's recent approach with respect to a 7% discount rate.

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

Circular A-4 contemplates the use of declining discount rates in its reference to the work of Weitzman.[197] As the Council of Economic Advisers explained earlier this year, Weitzman and others developed the foundation for a declining discount rate approach, wherein rates start relatively higher for near-term costs and benefits but steadily decline over time according to a predetermined schedule until, in the very long-term, very low rates dominate due to uncertainty.[198] The National Academies of Sciences' report also strongly endorses a declining discount rate approach.[199]

One possible schedule of declining discount rates was proposed by Weitzman.[200] It is derived from a broad survey of top economists and other climate experts and explicitly incorporates arguments around interest rate uncertainty. Work by Arrow *et al*, Cropper *et al*, and Gollier and Weitzman,

194 *Id.* at 3.
195 *Id.* at 42 (emphasis added).
196 *Id.* at 17.
197 Circular A-4, at page 36, cites to Weitzman's chapter in Portney & Weyant, eds. (1999); that chapter, at page 29, recommends a declining discount rate approach: "a sliding-scale social discounting strategy" with the rate at 3-4% through year 25; then around 2% until year 75; then around 1% until year 300; and then 0% after year 300.
198 CEA Issue Brief, *supra* note 173, at 9 ("[A]nother way to incorporate uncertainty when discounting the benefits and costs of policies and projects that accrue in the far future—applying discount rates that decline over time. This approach uses a higher discount rate initially, but then applies a graduated schedule of lower discount rates further out in time. The first argument is based on the application of the Ramsey framework in a stochastic setting (Gollier 2013), and the second is based on Weitzman's 'expected net present value' approach (Weitzman 1998, Gollier and Weitzman 2010). In light of these arguments, the governments of the United Kingdom and France apply declining discount rates to their official public project evaluations.").
199 NAS Second Report, *supra* note 92, at 166.
200 Martin L. Weitzman, *Gamma Discounting*, 91 AM. ECON. REV. 260, 270 (2001). Weitzman's schedule is as follows:

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

among others, similarly argue for a declining interest rate schedule and lay out the fundamental logic.[201] Another schedule of declining discount rates has been adopted by the United Kingdom.[202]

The technical appendix on discounting attached to these comments more thoroughly reviews the various schedules of declining discount rates available for agencies to select and explains why agencies not only can, but should adopt a declining discount framework to address uncertainty.

A 300-Year Time Horizon Is Required

Related to the choice of discount rate, a 300-year time horizon for analysis of climate effects is required by best economic practices. In 2017, the National Academies of Sciences issued a report stressing the importance of a longer time horizon for calculating the social cost of greenhouse gases, finding 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."[203] 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."[204] 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. The National Academies of Science 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.[205]

IV. DOE Should Use the Interagency Working Group's 2016 Estimates of the Social Cost of Carbon, the Social Cost of Nitrous Oxide, and the Social Cost of Methane

In 2016, the IWG published updated central estimates for the social cost of greenhouse gases: about $52 per ton of carbon dioxide, $1,480 per ton of methane, and $18,500 per ton of nitrous oxide (in

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

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

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

203 NAS Second Report, *supra* note 92, at 78.

204 *Id.*

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

2019 dollars for year 2020 emissions).[206] Agencies must continue to use estimates of a similar or higher[207] value in their analyses and decisionmaking.

a. IWG's Methodology Is Rigorous, Transparent, and Based on the Best Available Data

Beginning in 2009, the IWG assembled experts from a dozen federal agencies and White House offices to "estimate the monetized damages associated with an incremental increase in carbon emissions in a given year" based on "a defensible set of input assumptions that are grounded in the existing scientific and economic literature."[208] IWG's methods combined three frequently used models built to predict the economic costs of the physical impacts of each additional ton of carbon.[209] The models together incorporate such damage categories as: agricultural and forestry impacts, coastal impacts due to sea level rise, impacts from extreme weather events, impacts to vulnerable market sectors, human health impacts including malaria and pollution, outdoor recreation impacts and other non-market amenities, impacts to human settlements and ecosystems, and some catastrophic impacts.[210] IWG ran these models using a baseline scenario including inputs and assumptions drawn from the peer-reviewed literature, and then ran the models again with an additional unit of carbon emissions to determine the increased economic damages.[211] IWG's social cost of carbon estimates were first issued in 2010 and have been updated several times to reflect the latest and best scientific and economic data.[212]

Following the development of estimates for carbon dioxide, the same basic methodology was used in 2016 to develop the social cost of methane and social cost of nitrous oxide—estimates that capture the distinct heating potential of methane and nitrous oxide emissions.[213] These additional metrics used the same economic models, the same treatment of uncertainty, and the same methodological assumptions that IWG applied to the social cost of carbon, and these new estimates underwent rigorous peer-review.[214]

IWG's methodology has been repeatedly endorsed by reviewers. In 2014, the U.S. Government Accountability Office concluded that IWG had followed a "consensus-based" approach, relied on peer-reviewed academic literature, disclosed relevant limitations, and adequately planned to

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[206] U.S. Interagency Working Group on the Social Cost of Greenhouse Gases, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (2016), *available at* https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf; *id.*, Addendum; *available at* https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/august_2016_sc_ch4_sc_n2o_addendum_final_8_26_16.pdf. Though these documents present cost values in 2007$, we have converted those values to 2019$ using the Bureau of Labor Statistics' consumer price index data, which is available at https://data.bls.gov/timeseries/CUUR0000SA0. As this data provides, 2007$ can be converted to 2019$ by multiplying by approximately 1.233.

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

[208] Interagency Working Group, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis (2010).

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

[210] *Id.* at 6–8.

[211] *Id.* at 24–25.

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

[213] *See* 2016 IWG Addendum at 2.

[214] *Id.* at 3.

incorporate new information through public comments and updated research.[215] In 2016 and 2017, the National Academies of Sciences, Engineering, and Medicine issued two reports that, while recommending future improvements to the methodology, supported the continued use of the existing IWG estimates.[216] And in 2016, the U.S. Court of Appeals for the Seventh Circuit held that the Department of Energy's reliance on IWG's social cost of carbon was reasonable.[217] It is, therefore, unsurprising that leading economists and climate policy experts have endorsed the IWG's values as the best available estimates.[218]

Furthermore, uncertainty over the values or range of values included in the IWG's social costs of greenhouse gases metric is not a reason to abandon the social cost of greenhouse gas methodologies;[219] 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.

Not only was justifying omitted climate damages due to uncertainty rejected by the Ninth Circuit in *Center for Biological Diversity*—"while . . . there is a range of values, the value of carbon emissions reduction is certainly not zero"[220]—but the range of values recommended by the IWG[221] and endorsed by the National Academies of Sciences[222] is rather manageable. In 2016, the IWG recommended values at discount rates from 2.5% to 5%, calculated as between $12 and $62 for year 2020 emissions.[223] Numerous federal agencies have had no difficulty either applying this range in their environmental impact statements or else focusing on the central estimate at a 3% discount rate.[224]

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

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

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

218 See, e.g., Richard Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 Science 655 (2017); Michael Greenstone et al., *Developing a Social Cost of Carbon for U.S. Regulatory Analysis: A Methodology and Interpretation*, 7 Rev. Envtl. Econ. & Pol'y 23, 42 (2013); Revesz, *Global Warming: Improve Economic Models of Climate Change*, *supra* note 207.

219 *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.").

220 538 F.3d at 1200.

221 *See* Interagency Working Group on the Social Cost of Greenhouse Gases, *Technical Update* (2016) (hereinafter 2016 TSD).

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

223 2016 TSD. The values given here are in 2007$. The IWG also recommended a 95th percentile value of $123.

224 BLM, *Envtl. Assessment—Waste Prevention, Prod. Subject to Royalties, and Res. Conservation* at 52 (2016); BLM, *Final Envtl. Assessment: Little Willow Creek Protective Oil and Gas Lease*, DOI-BLM-ID-B010-2014-0036-EA, at 82 (2015); Office of Surface Mining, *Final Envtl. Impact Statement—Four Corners Power Plant and Navajo Mine Energy Project* at 4.2-26 to 4.2-27 (2015) (explaining the social cost of greenhouse gases "provide[s] further context and enhance[s] the discussion of climate change impacts in the NEPA analysis."); U.S. Army Corps of Engineers, *Draft Envtl. Impact Statement for the Missouri River Recovery Mgmt. Project* at 3-335 (2016); U.S. Forest Serv., *Rulemaking for Colorado Roadless Areas: Supplemental Final Envtl. Impact Statement* at 120–23 (Nov. 2016) (using both the social cost of carbon and social cost of

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

In March 2017, President Trump disbanded the IWG and withdrew its technical support documents through Executive Order 13,783.[225] 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."[226] Consequently, while federal agencies no longer benefit from ongoing technical support from the IWG on using the social cost of greenhouse gases, by no means does the new Executive Order imply that agencies should not monetize potentially significant effects in their environmental impact statements.

The Executive Order does not prohibit agencies from relying on the same choice of models as the IWG, the same inputs and assumptions as the IWG, the same statistical methodologies as the IWG, or the same ultimate values as derived by the IWG. To the contrary, because the Executive Order requires consistency with *Circular A-4*, as agencies follow the Circular's standards for using the best available data and methodologies, they will necessarily choose similar data, methodologies, and estimates as the IWG, since the IWG's work continues to represent the best available estimates.[227] 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.

Indeed, as noted above, a federal court recently explained that "[t]he Executive Order in and of itself has no legal impact on the consensus that IWG's estimates constitute the best available science about monetizing the impacts of greenhouse gas emissions."[228] And notably, some agencies under the Trump administration, including DOE (as detailed above), have continued to use the IWG estimates even following the Executive Order. For example, in August 2017, the BOEM called the social cost of carbon "a useful measure" and applied it to analyze the consequences of offshore oil and gas drilling.[229]

Sincerely,

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methane relating to coal leases); NHTSA EIS, *Available at* http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/FINAL_EIS.pdf at 9-77.

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

226 *Id.* § 5(c).

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

228 *State of California v. Bernhardt*, 2020 WL 4001480, at *25.

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

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Appendices:

- Technical Appendix on Uncertainty
- Technical Appendix on Discounting

Attachments:

GAO, Social Cost of Carbon: Identifying a Federal Entity to Address the National Academies' Recommendations Could Strengthen Regulatory Analysis, GAO-20-254 (June 2020)

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.[1] Integrated assessment models (IAMs) currently used to calculate the social cost of carbon (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.[2] 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.[3] Rather than being a reason not to take action, uncertainty increases the SCC and should lead to more stringent policy to address climate change.[4]

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.[5] Stochastic uncertainty is persistent randomness in the economic-climate system, including various environmental phenomena such as volcanic eruptions and sun spots.[6] 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).[7]

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[1] 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.

[2] 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 Social Cost of Carbon, Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12,866 (2016).

[3] 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.

[4] *See* cites *supra* note 3.

[5] 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).

[6] 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 1; Golub et al. *supra* note 3.

A potential third type of uncertainty arises due to ethical or value judgements: normative uncertainty. Peterson (2006) *supra* note 1; 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 6.

[7] Peterson (2006), *supra* note 1; Pindyck (2007), *supra* note 3; Heal & Millner, *supra* note 6.

When modeling climate change uncertainty, scientists and economists have long emphasized the importance of accounting for the potential of catastrophic climate change.[8] Catastrophic outcomes combine several overlapping concepts including unlucky states of the world (i.e., bad draws), deep uncertainty, and climate tipping points and elements.[9] 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.[10] 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.[11] Given the general opinion that bad surprises are likely to outweigh good surprises in the case of climate change,[12] modelers capture deep uncertainty by selecting probability distributions with a fat upper tail which reflects the greater likelihood of extreme events.[13] 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).[14]

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.[15] 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.[16] 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.[17] Social tipping points—including climate-induced

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[8] 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.

[9] Kopp et al. (2016), *supra* note 8.

[10] *Id.*

[11] 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.

[12] 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.

[13] Weitzman (2011), *supra* note 11, 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."

[14] 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 11; Weitzman (2011), *supra* note 11.

[15] 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 8.

[16] *Id.*

[17] *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

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.[18] 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.[19] 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[20] 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.[21] 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.[22] 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

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policy. *The American Economic Review*, *106*(5), 607-611. See Table 1 of Kopp et al. (2016) *supra* note 8, for a full list of known tipping elements and points.

[18] Kriegler et al. (2009), *supra* note 17; 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 8.

[19] 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 8.

[20] 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

[21] 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 3. 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.

[22] Tol (1999), *supra* note 2, 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."

right skewed, fat tailed distribution to capture the potential of higher than expected warming). It also used scenario analysis: five different emissions growth scenarios and three discount rates. Second, the IWG (2016) 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.[23] 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 underestimates 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.[24] 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.[25] 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.[26]

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

[23] IWG (2010).

[24] Howard (2014), *supra* note 19. 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.

[25] Weitzman (2011), *supra* note 11; Kopp et al. (2016) *supra* note 8.

[26] Lemoine, D., & Traeger, C. P. (2016a). Ambiguous tipping points. *Journal of Economic Behavior & Organization*, *132*, 5-18; Lemoine & Rudik (2017), *supra* note 3. IAM modelers currently assume that society is equally averse to known unknown and known unknowns. Lemoine & Traeger, *supra* note 26.

(1994) survey of experts.[27] In PAGE09, Hope also explicitly models climate tipping points as a singular, discrete event (of a 5% to 25% loss in GDP) that has a probability (which grows as temperature increases) of occurring in each time period.[28] 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.[29] Despite the obvious methodological basis for addressing tipping points, the latest versions of DICE[30] 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.[31]

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.[32] 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.[33] 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

[27] 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 19; Kopp et al. (2016) *supra* note 8.

[28] Hope (2006) also calibrated a discontinuous damage function in PAGE-99 used by IWG (2010). Howard (2014), *supra* note 19.

[29] Kopp et al. (2016) *supra* note 8.

[30] 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.

[31] 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.

[32] 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).

[33] 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.

correspond with empirical evidence,[34] current IAM assumptions,[35] the NAS (2017) recommendations, nor with the IWG's own discussion (2010) of the possible values of the elasticity of the marginal utility of consumption. Evidence from behavioral experiments indicate that people and society are also averse to other attributes of parameter distributions – specifically to the thickness of the tails of distributions – leading to an additional ambiguity premium (Heal and Millner, 2014).[36] 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.[37] 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.[38] 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."[39] 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

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34 IWG 2010, *supra* note 23; Cai et al., 2016, *supra* note 18, at 521.

35 The developers of each of the three IAMs used by the IWG (2010; 2013; 2016) assume a risk aversion society. Nordhaus and Sztorc (2013), *supra* note 20; 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.

36 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.

37 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:

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

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.*

38 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 (2007), *supra* note 3. Uncertainty in environmental economics. *Review of environmental economics and policy*, *1*(1), 45-65.

39 Pindyck (2007), *supra* note 3.

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.[40] By nature of being optimization models (instead of policy models), these complex models focus on calculating the optimal tax and not the social cost of carbon, which differ in that the former is the present value of marginal damages on the optimal emissions path rather than on the BAU emissions path.[41] 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),[42] 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.[43] 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.[44]

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[40] Kann & Weyant, *supra* note 6; Pindyck (2007), *supra* note 3; Golub et al. (2014), *supra* note 3.

[41] 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.

[42] 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.

[43] Kann and Weyant (2000), *supra* note 6; Pindyck (2007), *supra* note 3; Golub et al. (2014), *supra* note 3.

[44] Kann and Weyant (2000), *supra* note 6; Pindyck (2007), *supra* note 3; Golub et al. (2014), *supra* note 3; Lemoine & Rudik (2017), *supra* note 3. Comparing the optimal tax to the mean SCC is made further difficult by the frequent use of DICE as the base from which most stochastic dynamic optimization models are built. As a consequence, deterministic model runs are frequently the base of comparison for these models. Lemoine & Rudik (2017), *supra* note 3.

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.[45] For SDP models, uncertainty tends to strengthen the optimal emissions path relative to the determinist case even without tipping points,[46] and these results are strengthened under realistic preference assumptions.[47] Given that there is no counter-balancing tipping abatement cost,[48] 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%[49] to 800%[50] 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.[51] Recent research has shown that accurate estimation of decisions under uncertainty crucially depends on distinguishing between risk and time preferences.[52] 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

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45 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 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. *See* Golub et al. (2014), *supra* note 3.

46 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. *See* Golub et al. (2014), *supra* note 3; Lemoine & Rudik (2017), *supra* note 3. 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.

47 Pindyck (2007), *supra* note 3; Golub et al. (2014), *supra* note 3; Lemoine & Rudik (2017), *supra* note 3.

48 Pindyck (2007), *supra* note 3.

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

50 Cai et al., 2016.

51 Cai et al., 2016; Lemoine & Rudik (2017), *supra* note 3. 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.

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

aversion.[53] 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.[54] Including more realistic preference assumptions in IAMs would further increase the SCC under uncertainty.

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

Conclusion: Uncertainty Raises the Social Cost of Greenhouse Gases

Overall, the message is clear: climate uncertainty is *never* a rationale for ignoring the SCC or shortening the time horizon of IAMs. Instead, our best estimates suggest that increased variability implies a higher SCC and a need for more stringent emission regulations.[55] Current omission of key features of the climate problem under uncertainty (the risk and climate premiums, option value, and fat tailed probability distributions) and incomplete modeling of tipping points imply that the SCC will further increase with the improved modeling of uncertainty in IAMs.

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53 Lemoine, D., & Traeger, C. P. (2016b). Economics of tipping the climate dominoes. *Nature Climate Change*.; Lemoine & Rudik (2017), *supra* note 3.

54 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 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.

55 Golub et al. (2014), *supra* note 3, states: "The most important general policy implication from the literature is that despite a wide variety of analytical approaches addressing different types of climate change uncertainty, none of those studies supports the argument that no action against climate change should be taken until uncertainty is resolved. On the contrary, uncertainty despite its resolution in the future is often found to favor a stricter policy." *See also* Comments from Robert Pindyck, to BLM, on the Social Cost of Methane in the Proposed Suspension of the Waste Prevention Rule (submitted Nov. 5, 2017) ("Specifically, my expert opinion about the uncertainty associated with Integrated Assessment Models (IAMs) was used to justify setting the SC-CH4 to zero until this uncertainty is resolved. That conclusion does not logically follow and I have rejected it in the past, and I reiterate my rejection of that view again here. While at this time we do not know the Social Cost of Carbon (SCC) or the Social Cost of Methane with precision, we do know that the correct values are well above zero…Because of my concerns about the IAMs used by the now-disbanded Interagency Working Group to compute the SCC and SC-CH4, I have undertaken two lines of research that do not rely on IAMs…[They lead] me to believe that the SCC is larger than the value estimated by the U.S. Government."

Technical Appendix: Discounting

The Underlying IAMs All Use a Consumption Discount Rate

Employing a consumption discount rate would also ensure that the U.S. government is consistent with the assumptions employed by the underlying IAM models: DICE, FUND, and PAGE. Each of these IAMs employs consumption discount rates calibrated using the standard Ramsey formula (Newell, 2017). In DICE-2010, the elasticity of the pure rate of time preference is 1.5 and an elasticity of the marginal utility of consumption (η) of 2.0. Together with its assumed per capita consumption growth path, the average discount rate over the next three hundred years is 2.4%.[1] However, more recent versions of DICE (DICE-2013R and DICE-2016) update η to 1.45; this implies an increase of the average discount rate over the timespan of the models to between 3.1% and 3.2% depending on the consumption growth path.[2] In FUND 3.8 and (the mode values in) PAGE09, both model parameters are equal to 1.0. Based on the assumed growth rate of the U.S. economy (without climate damages), the average U.S. discount rate in FUND 3.8 is 2.0% over the timespan of the model (without considering climate damages). Unlike FUND 3.8, PAGE09 specifies triangular distributions for both parameters with a pure rate of time preference of between 0.1 and 2 with a mean of 1.03 and an elasticity of the marginal utility of consumption of between 0.5 and 2 with a mean 1.17. Using the PAGE09's mode values (without accounting for climate damages), the average discount rate over the timespan of the models is approximately 3.3% with a range of 1.2% to 6.5%. Rounding up the annual growth rate over the last 50 years to approximately 2%,[3] the range of best estimates of the SDR implied in the short-run by these three models is approximately 3% (PAGE09's mode estimate and FUND 3.8) to 4.4% (DICE-2016), though the PAGE09 model alone implies a range of 1.1% to 6.0% with a central estimate of 3%. The range of potential consumption discount rates in these IAMs is relatively consistent with IWG (2010; 2013; 2016) in the short-run, though the discount rates of the IAMs employed by the IWG decline over time (due to declining growth rates over time) implying a potential upward bias to the IWG consumption discount rates.

A Declining Discount Rate is Justified to Address Discount Rate Uncertainty

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

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

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

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

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

discount rates.[5] Uncertainty about future discount rates could stem from a number of sources particularly salient in the context of climate change, including uncertainty about future economic growth, consumption, the consumption rate of interest, and preferences. Additionally, economic theory shows that if there is debate or disagreement over which discount rate to use, this should lead to the use of a declining discount rate (Weitzman, 2001; Heal & Millner, 2014). Though, the range of potential discount rates is limited by theory to potential consumption discount rates (see earlier discussion), which is certainly less than 7%.

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

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

Economists have recently highlighted two main motivations for using a declining discount rate, which we elaborate on in what follows. First, if the discount rate for a project is fixed but uncertain, then the certainty-equivalent discount rate will decline over time, meaning that benefits should be discounted using a declining rate.[6] Second, uncertainty about the growth rate of consumption or output also implies that a declining discount rate should be used, so long as shocks to consumption are positively correlated over time.[7] In addition to these two arguments, other motivations for declining discount rates have long been recognized. For instance, if the growth rate of consumption declines over time, the Ramsey rule[8] for discounting will lead to a declining discount rate.[9]

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

[6] This argument was first developed in Weitzman (1998) and Weitzman (2001).

[7] *See, e.g.,* Gollier (2009).

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

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

In the descriptive setting adopted by the IWG (2010), economists have demonstrated that calculating the expected net present value of a project is equivalent to discounting at a declining certainty equivalent discount rate when (1) discount rates are uncertain, and (2) discount rates are positively correlated (Arrow et al., 2014 at 157). Real consumption interest rates are uncertain given that there are no multi-generation assets to reflect long-term discount rates and the real returns to all assets—including government bonds—are risky due to inflation and default risk (Gollier & Hammitt, 2014). Furthermore, recent empirical work analyzing U.S. government bonds demonstrates that they are positively correlated over time; this empirical work has estimated several declining discount rate schedules that the IWG can use (Cropper et al., 2014; 2014; Arrow et al., 2013; Arrow et al., 2014; Jouini and Napp, 2014; Freeman et al. 2015).

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

If the normative approach to discounting is used in the future (i.e., the current approach of IAMs), economists have demonstrated that an extended Ramsey rule[10] implies a declining discount rate when (1) the growth rate of per capita consumption is stochastic,[11] and (2) consumption shocks are positively correlated over time (or their mean or variances are uncertain) (Arrow et al., 2013; Arrow et al., 2014; Gollier & Hammitt, 2014; Cropper et al., 2014).[12] While a constant adjustment downwards (known as the precautionary effect[13]) can be theoretically correct when growth rates are independent and identically distributed (Cropper et al., 2014), empirical evidence supports the two above assumptions for the United States, thus implying a declining discount rate (Cropper et

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

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

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

[13] The precautionary effect measures aversion to future "wiggles" in consumption (i.e., preference for consumption smoothing) (Traeger, 2014).

al., 2014; Arrow et al., 2014; IPCC, 2014).[14] We should further expect this positive correlation to strengthen over time due to the negative impact of climate change on consumption, as climate change causes an uncertain permanent reduction in consumption (Gollier, 2009).[15]

Several papers have estimated declining discount rate schedules for specific values of the pure rate of time preference and elasticity of marginal utility of consumption (e.g., Arrow et al., 2014), though recent work demonstrates that the precautionary effect increases and discount rates decrease further when catastrophic economic risks (such as the Great Depression and the 2008 housing crisis) are modeled (Gollier & Hammitt, 2014; Arrow et al., 2014). It should be noted that this decline in discount rates due to uncertainty in the global growth path is in addition to that resulting from a declining central growth path over time (Nordhaus, 2014; Marten, 2015).[16]

Additionally, a related literature has developed over the last decade demonstrating that normative uncertainty (i.e., heterogeneity) over the pure rate of time preference (δ)—a measure of impatience—also leads to a declining social discount rate (Arrow et al., 2014; Cropper et al., 2014; Freeman and Groom, 2016). Despite individuals differing in their pure rate of time preference (Gollier and Zeckhauser, 2005), an equilibrium (consumption) discount exists in the economy. In the context of IAMs, modelers aggregate social preferences (often measured using surveyed experts) by calibrating the preferences of a representative agent to this equilibrium (Millner and Heal, 2015; Freeman and Groom, 2016). The literature generally finds a declining social discount rate due to a declining collective pure rate of time preference (Gollier and Zeckhauser, 2005; Jouini et al., 2010; Jouini and Napp, 2014; Freeman and Groom, 2016).[17] The heterogeneity of preferences and the uncertainty surrounding economic growth hold simultaneously (Jouini et al., 2010; Jouini and Napp, 2014), leading to potentially two sources of declining discount rates in the normative context.

Declining Rates are Actionable and Time-Consistent

There are multiple declining discount rate schedules from which the U.S. government can choose, of which several are provided in Arrow et al. (2014) and Cropper et al. (2014). One possible declining interest rate schedule for consideration by the IWG is the one proposed by Weitzman (2001).[18] It is derived from a broad survey of top economists in context of climate change, and explicitly

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

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

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

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

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

incorporates arguments around interest rate uncertainty.[19] Other declining discount rate schedule include Newell and Pizer (2003); Groom et al. (2007); Freeman et al. (2015). Many leading economists support the United States government adopting a declining discount rate schedule (Arrow et al., 2014; Cropper et al., 2014). Moreover, the United States would not be alone in using a declining discount rate. It is standard practice for the United Kingdom and French governments, among others (Gollier & Hammitt, 2014; Cropper et al., 2014). The U.K. schedule explicitly subtracts out an estimated time preference.[20] France's schedule is roughly similar to the United Kingdom's. Importantly, all of these discount rate schedules yield lower present values than the constant 2.5% discount rate employed by IWG (2010), suggesting that even the lowest discount rate evaluated by the IWG is too high.[21] The consensus of leading economists is that a declining discount rate schedule should be used, harmonious with the approach of other countries like the United Kingdom. Adopting such a schedule would likely increase the SCC substantially from the administration's 3% estimate, potentially up to two to three fold (Arrow et al., 2013; Arrow et al., 2014; Freeman et al., 2015).

A declining discount rate motived by discount rate or growth rate uncertainty avoids the time inconsistency problem that can arise if a declining pure rate of time preference (δ) is used. *Circular A-4* cautions that "[u]sing the same discount rate across generations has the advantage of preventing time-inconsistency problems."[22] A time inconsistent decision is one where a decision maker changes his or her plan over time, solely because time has passed. For instance, consider a decision maker choosing whether to make an investment that involves an up-front payment followed by future benefits. A time consistent decision maker would invest in the project if it had a positive net-present value, and that decision would be the same whether it was made 10 years before investment or 1 year before investment. A time inconsistent decision maker might change his or her mind as the date of the investment arrived, despite no new information becoming available. Consider a decision maker who has a declining pure rate of time preference (δ) trying to decide whether to invest in a project that has large up-front costs followed by future benefits. Ten years prior to the date of investment, the decision maker will believe that this project is a relatively unattractive investment because both the benefits and costs would be discounted at a low rate. Closer to the date of investment, however, the costs would be relatively highly discounted, possibly leading to a reversal of the individual's decision. Again, the discount rate schedule is time consistent as long as δ is constant.

The arguments provided here for using a declining consumption discount rate are not subject to this time inconsistency critique. First, time inconsistency occurs if the decision maker has a declining pure rate of time preference, not due to a decreasing discount rate term structure.[23]

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

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

21 Using the IWG's 2010 SCC model, Johnson and Hope (2012) find that the U.K. and Weitzman schedules yield SCCs of $55 and $175 per ton of CO_2, respectively, compared to $35 at a 2.5% discount rate. Because the 2.5% discount rate was included by the IWG (2010) to proxy for a declining discount rate, this result indicates that constant discount rate equivalents may be insufficient to address declining discount rates.

22 *Circular A-4* at 35.

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

Second, uncertainty about growth or the discount rate avoids time inconsistency because uncertainty is only resolved in the future, after investment decisions have already been made. As the NAS (2017) notes, "One objection frequently made to the use of a declining discount rate is that it may lead to problems of time inconsistency….This apparent inconsistency is not in fact inconsistent….At present, no one knows what the distribution of future growth rates…will be; it may be different or the same as the distribution in 2015. Even if it turns out to be the same as the distribution in 2015, that realization is new information that was not available in 2015."[24]

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

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

There is a strong consensus among economists that it is theoretically correct to use consumption discount rates in the intergenerational setting of climate change, such as in the calculation of the SCC. Similarly, there is a strong consensus that a capital discount rate is inappropriate according to "good economics" (Newell, 2017).[25] This consensus holds across panels of experts on the social cost of carbon (NAS, 2017); surveys of experts on climate change and discount rates (Weitzman, 2001; Drupp et al., 2015; Howard and Sylvan, 2015; and Pindyck, 2016); the three most commonly cited IAMs employed in calculating the federal SCC; and the government's own analysis (IWG, 2010; CEA, 2017). For more analysis of this issue, see the discussion in the main body our Comments on the inappropriateness of using a discount rate premised on the return to capital in intergenerational settings.

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[24] National Academies of Sciences, Engineering, and Medicine, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide 182 (2017).

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

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United States Government Accountability Office
Report to Congressional Requesters

June 2020

SOCIAL COST OF CARBON

Identifying a Federal Entity to Address the National Academies' Recommendations Could Strengthen Regulatory Analysis

GAO-20-254

GAO Highlights

Highlights of GAO-20-254, a report to congressional requesters

June 2020

SOCIAL COST OF CARBON

Identifying a Federal Entity to Address the National Academies' Recommendations Could Strengthen Regulatory Analysis

Why GAO Did This Study

To address climate change, some countries develop monetary estimates to assess the costs and benefits of government actions to reduce greenhouse gas emissions, including carbon dioxide. In the United States, in 2009, OMB convened an interagency working group to estimate the social cost of carbon—the dollar value of the effects of an incremental increase in carbon dioxide emissions in a given year—for assessing regulatory costs and benefits. In 2017, the National Academies recommended updates to the methods used to develop the estimates. Later that year, Executive Order 13783 disbanded the working group, withdrew its guidance, and directed agencies to ensure that, to the extent permitted by law, estimates are consistent with Circular A-4, OMB's general guidance for regulatory analysis. GAO was asked to review approaches for developing and using the estimates.

This report examines, among other objectives: (1) how the federal government's current estimates compare to its prior estimates and (2) how the federal government plans to address the recommendations of the National Academies. GAO reviewed executive orders, OMB guidance, and regulatory impact analyses and interviewed OMB, EPA, NHTSA, and BLM officials and staff who had conducted such analyses.

What GAO Recommends

GAO recommends that OMB identify a federal entity responsible for addressing the National Academies' recommendations. OMB did not comment on the recommendation.

View GAO-20-254. For more information, contact J. Alfredo Gómez at (202) 512-3841 or gomezj@gao.gov.

What GAO Found

According to documents reviewed and interviews with officials from the Environmental Protection Agency (EPA), Bureau of Land Management (BLM), and National Highway Traffic Safety Administration (NHTSA), the federal government's current social cost of carbon estimates used in conducting regulatory impact analyses are lower than its prior estimates. Although both the prior and current estimates were calculated using the same economic models, two key assumptions used to calculate the current estimates were changed: using (1) domestic rather than global climate change damages (see table) and (2) different discount rates (3 and 7 percent rather than 2.5, 3, and 5 percent). As a result, the current federal estimates, based on domestic climate damages, are about 7 times lower than the prior federal estimates that were based on global damages (when both prior and current estimates are expressed in 2018 U.S. dollars and calculated using a 3 percent discount rate).

Prior and Current Federal Estimates of the Social Cost of Carbon, per Metric Ton, at a 3 Percent Discount Rate in 2018 U.S. Dollars

Year of emissions	Prior estimates (based on global climate change damages)	Current estimates (based on domestic climate change damages)
2020	$50	$7
2030	$60	$8
2040	$72	$9
2050	$82	$11

Source: GAO analysis of data from the Interagency Working Group on Social Cost of Greenhouse Gases, EPA, and the United States Gross Domestic Product Price Index from the U.S. Department of Commerce, Bureau of Economic Analysis. | GAO-20-254

The federal government has no plans to address the recommendations of the National Academies of Sciences, Engineering, and Medicine for updating the methodologies used to develop the federal estimates of the social cost of carbon. In a January 2017 report, the National Academies made recommendations for updating the methodologies used to estimate the social cost of carbon to ensure federal estimates reflect the best available science. The Office of Management and Budget (OMB) in Circular A-4 provided guidance to federal agencies on how to conduct regulatory analyses, and in 2017 Executive Order 13783 directed agencies to use that guidance when estimating the social cost of carbon; both direct agencies to use the best available science. OMB staff GAO interviewed said the agency does not have specific plans for implementing the recommendations and that no federal agency has responsibility for addressing them. OMB staff told GAO that nonfederal entities are leading research efforts that are responsive to the recommendations, but no federal entity has responsibility for monitoring developments in scientific research or ensuring updated federal estimates consider such developments. However, OMB continues to play a leading role in the federal government's use of the social cost of carbon by having responsibility for the guidance in Circular A-4, which Executive Order 13783 directs agencies to be consistent with in developing their social cost of carbon estimates. By identifying a federal entity to be responsible for addressing the National Academies' recommendations, OMB would have better assurance that agencies use the best available science in their regulatory impact analyses.

Contents

Tables

Figure

Abbreviations

BLM	Bureau of Land Management
EPA	Environmental Protection Agency
FUND	Climate Framework for Uncertainty, Negotiation, and Distribution (model)
GDP	gross domestic product
IWG	Interagency Working Group on Social Cost of Carbon
NEPA	National Environmental Policy Act
NHTSA	National Highway Traffic Safety Administration
OECD	Organisation for Economic Co-operation and Development
OMB	Office of Management and Budget
USGCRP	U.S. Global Change Research Program

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June 23, 2020

Congressional Requesters

The U.S. Global Change Research Program (USGCRP) concluded in its November 2018 Fourth National Climate Assessment that addressing the potential impacts of climate change is a global challenge.[1] Many countries have been deliberating on how to reduce carbon dioxide and other greenhouse gas emissions that, according to USGCRP, are increasing in concentrations and thereby driving changes in the earth's climate by trapping heat in the atmosphere and preventing it from returning to space.[2] According to the Environmental Protection Agency (EPA), these gases remain in the atmosphere long enough to become "well mixed," meaning that the amount measured in the atmosphere is roughly the same all over the world, regardless of the source of the emissions, and therefore contribute to damages around the world independent of the country in which they are emitted.[3] In examining possible approaches to address these emissions, some countries are weighing the potential costs of taking actions to reduce emissions against their expected benefits by including monetary estimates of the effects of carbon dioxide and other greenhouse gas emissions in cost-benefit analyses. Developing these monetary estimates and using them to assess the costs and benefits of taking government actions to reduce greenhouse gas emissions involves a complex mix of economic analysis, climate modeling, and science.

[1]D.R. Reidmiller, C.W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B. C. Stewart (eds.), *2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* (Washington, DC: U.S. Global Change Research Program, November 2018). USGCRP coordinates and integrates the activities of 13 federal agencies that research changes in the global environment and their implications for society. Under the Global Change Research Act of 1990, USGCRP is to periodically prepare a scientific assessment—known as the National Climate Assessment—which is an important resource for understanding and communicating climate change science and impacts in the United States. Pub. L. No. 101-606, § 103, 104 Stat. 3096, 3098 (1990). The Office of Science and Technology Policy within the Executive Office of the President oversees USGCRP.

[2]Greenhouse gases include carbon dioxide, methane, nitrous oxide, and synthetic chemicals such as fluorinated gases.

[3]Environmental Protection Agency, *Overview of Greenhouse Gases*, accessed June 17, 2020, https://www.epa.gov/ghgemissions/overview-greenhouse-gases.

In the United States, the federal government has used the social cost of carbon as its approach for developing monetary estimates for greenhouse gas emissions.[4] The social cost of carbon represents the long-term net economic damages associated with an incremental increase in carbon dioxide or other greenhouse gas emissions in a given year (typically measured in dollars per metric ton). According to EPA, the estimates represent the monetary value of a wide range of anticipated climate impacts resulting from carbon dioxide and other greenhouse gas emissions, such as net changes in agricultural productivity and human health, property damage from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning.[5] For the purposes of this report, we use the phrase "social cost of carbon" to refer generally to the social costs of carbon dioxide, methane, or nitrous oxide emissions.

Under a 1993 executive order and Office of Management and Budget (OMB) guidance, federal agencies are to examine the economic effects of proposed regulatory actions to assess whether the benefits of a proposed regulation justify its costs.[6] In conducting their regulatory impact analyses, agencies generally began incorporating estimates of the social cost of carbon after a federal appellate court decision in 2008.[7] In 2009, OMB and the Council of Economic Advisers convened the Interagency Working Group on Social Cost of Carbon (IWG) to develop government-wide

[4]In economic theory, social costs are private costs borne by individuals directly involved in a transaction together with the external costs borne by third parties not directly involved in the transaction.

[5]Environmental Protection Agency, Office of Air Quality Planning and Standards, *Regulatory Impact Analysis for the Repeal of the Clean Power Plan, and the Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units* (Research Triangle Park, NC: June 2019). Estimates of the social cost of carbon depend on the data and the models used to calculate them.

[6]Executive Order 12866, issued in 1993, directs federal agencies to assess the quantifiable and qualitative costs and benefits of proposed regulations and select the regulatory alternative that maximizes net benefits (unless a statute requires otherwise). Exec. Order No. 12866, 58 Fed. Reg. 51,735 (Sept. 30, 1993). OMB issued Circular A-4 in 2003 to provide guidance to federal agencies on how to conduct regulatory analyses as directed by Executive Order 12866. OMB, Circular A-4: Regulatory Analysis (Sept. 17, 2003). Agencies submit proposed regulations and associated regulatory impact analyses to OMB for formal review. OMB assists the President in, among other things, meeting policy, budget, management, and regulatory objectives. The Council of Economic Advisors is tasked with providing objective economic advice to the President.

[7]*See* Ctr. For Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1203 (9th Cir. 2008).

estimates of the social cost of carbon for federal agencies to use in conducting regulatory impact analyses for rulemaking. The IWG finalized its estimates for the social cost of carbon in 2010 and included them in a Technical Support Document that also provided guidance for agencies on using the estimates.[8] The IWG issued updates to the Technical Support Document that included revised estimates of the social cost of carbon in 2013, minor technical corrections in 2015, and enhanced discussion of uncertainties around the estimates in 2016.[9] The IWG was comprised of representatives of many federal agencies, including, among others, EPA and the Departments of Energy and Transportation, which used its estimates in analyzing dozens of proposed and final regulations.[10]

In January 2017, in response to a request from the IWG, the National Academies of Sciences, Engineering, and Medicine issued a report that included recommendations for updating the underlying methods used by the IWG to develop its estimates of the social cost of carbon.[11] In March 2017, Executive Order 13783, to promote energy independence and

[8]Interagency Working Group on Social Cost of Carbon, United States Government, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866* (Washington, D.C.: February 2010).

[9]Interagency Working Group on Social Cost of Carbon, United States Government, *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866* (Washington, D.C.: May 2013). This document was reissued with minor technical corrections in November 2013 and July 2015. Interagency Working Group on Social Cost of Greenhouse Gases, United States Government, *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866* (Washington, D.C.: August 2016). Prior to 2016, the IWG's estimates were of the social cost of carbon dioxide. In 2016, the IWG included initial estimates of the social costs of methane and nitrous oxide in an addendum to the Technical Support Document. See 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* (Washington, D.C.: August 2016).

[10]In July 2014, we reported that the IWG's participating offices and agencies were the Council of Economic Advisers; Council on Environmental Quality; Departments of Agriculture, Commerce, Energy, Transportation, and the Treasury; Domestic Policy Council; Environmental Protection Agency; National Economic Council; Office of Management and Budget; and Office of Science and Technology Policy. See GAO, *Regulatory Impact Analysis: Development of Social Cost of Carbon Estimates*, GAO-14-663 (Washington, D.C: July 24, 2014).

[11]National Academies of Sciences, Engineering, and Medicine, *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide* (Washington, D.C: January 2017).

economic growth, stated, among other things, a policy that necessary and appropriate environmental regulations comply with the law, are of greater benefit than cost, when permissible, achieve environmental improvements for the American people, and are developed through transparent processes employing the best available peer-reviewed science and economics.[12] The executive order stated that, to ensure sound regulatory decision-making, it is essential that agencies use estimates of costs and benefits in their regulatory analyses that are based on the best available science and economics. The executive order disbanded the IWG and withdrew its Technical Support Document guidance and social cost of carbon estimates "as no longer representative of governmental policy," changing how federal estimates for the social cost of carbon would be developed going forward. As we reported in March 2019, beginning in 2017 with Executive Order 13783, the administration revoked policies that had identified addressing climate change as a priority.[13]

Numerous studies have concluded that climate change poses significant risks to environmental and economic systems.[14] Based on the significant fiscal exposure that a changing climate poses to the federal government, in February 2013, we added *Limiting the Federal Government's Fiscal Exposure by Better Managing Climate Change Risks* to our list of federal areas at high risk for waste, fraud, abuse, and mismanagement or most in need of transformation.[15] Limiting the federal government's fiscal exposure to climate change risks presents a challenge no matter the outcome of domestic and international efforts to reduce emissions, in part, because greenhouse gases already in the atmosphere will continue

[12]Exec. Order No. 13783, 82 Fed. Reg. 16,093 (Mar. 28, 2017).

[13]For example, we reported that Executive Order 13783 revoked certain executive actions, such as the Climate Action Plan, that we previously found had demonstrated leadership support for reducing aspects of fiscal exposure to climate change and federal technical assistance so that decision makers at all levels of government can make more informed choices about how to manage climate change risks. See GAO, *High-Risk Series: Substantial Efforts Needed to Achieve Greater Progress on High-Risk Areas,* GAO-19-157SP (Washington, D.C.: March 2019).

[14]See, for example, USGCRP, *Fourth National Climate Assessment* (2018) and the series of work by the National Academies on climate change, including National Research Council, *Advancing the Science of Climate Change* (Washington, DC: 2010).

[15]GAO-19-157SP.

altering the climate system for many decades, according to USGCRP and the National Academies.[16]

You asked us to review how the federal government, U.S. states, and foreign countries have developed and used estimates of the social cost of carbon. This report examines: (1) how the federal government's current estimates of the social cost of carbon compare to prior estimates and how selected federal agencies have used the current estimates in recent rulemakings; (2) how the federal government plans to address the National Academies' recommendations; (3) how selected U.S. states have developed and used estimates of the social cost of carbon, or other valuation methods; and (4) how selected foreign countries have developed and used estimates of the social cost of carbon, or other valuation methods.

To examine how the federal government's current estimates of the social cost of carbon compare to prior estimates and how selected federal agencies have used the current estimates in recent rulemakings, we reviewed documents on how federal agencies estimated the social cost of carbon for use in regulatory cost-benefit analyses, both before and after agencies updated their estimates in response to Executive Order 13783.[17] The agencies we selected to review were EPA, the Department of the Interior's Bureau of Land Management (BLM), and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) based on their recent rulemakings using the current federal

[16]USGCRP, *Fourth National Climate Assessment* (2018). National Academy of Sciences and The Royal Society, *Climate Change Evidence & Causes: An overview from the Royal Society and the US National Academy of Sciences* (2014).

[17]This report does not address the use of the social cost of carbon in federal environmental impact statements under the National Environmental Policy Act (NEPA). In August 2016, the Council on Environmental Quality issued final guidance for federal departments and agencies on consideration of greenhouse gas emissions and the effects of climate change in their NEPA reviews. This guidance, among other things, noted that the federal social cost of carbon provided a harmonized, interagency metric that can give decision makers and the public useful information for their NEPA reviews. In March 2017, Executive Order 13783 called for the Council for Environmental Quality to rescind its guidance, and in April 2017 the Council withdrew the guidance. See 82 Fed. Reg. 16576 (Apr. 5, 2017). In June 2019, the Council on Environmental Quality published draft guidance to assist federal agencies in their consideration of greenhouse gas emissions in NEPA analysis and documentation. The guidance provides that agencies need not weigh the effects of the various alternatives in NEPA in a monetary cost-benefit analysis using any monetized social cost of carbon estimates or other similar metrics. 84 Fed. Reg. 30097, 30098-99 (June 26, 2019).

estimates of the social cost of carbon.[18] We interviewed agency officials to learn about the guidance, assumptions, and methods they used to develop their current estimates. We also reviewed federal direction and guidance on how agencies are to assess costs and benefits in regulatory analysis, including Executive Order 12866 and OMB Circular A-4.[19] We interviewed OMB staff, including staff from the Office of Information and Regulatory Affairs, about the agency's guidance, such as Circular A-4, and their role in reviewing agency regulations.[20]

To examine how the federal government plans to address the National Academies' recommendations for updating estimates of the social cost of carbon, we reviewed documents on how the federal agencies we included in our review had considered the recommendations and the agencies' plans for addressing them. We interviewed officials from the agencies to understand their plans to address the recommendations, including their plans to collaborate with other federal agencies and offices. We also reviewed federal direction and guidance to agencies to use the best reasonably obtainable science and economics when assessing costs and benefits in regulatory analysis, including Executive Order 12866 and OMB Circular A-4.

To examine how selected U.S. states have developed and used estimates of the social cost of carbon, or other valuation methods, we sought to identify states using estimates based on both the current and prior federal estimates, or other valuation methods. Through a literature review and interviews with knowledgeable parties, we did not identify any U.S. states using the current federal estimates or other valuation methods. We identified nine U.S. states that called for using the prior federal estimates in state decision-making; we selected a nonprobability

[18]Through a search of the *Federal Register*, we found that EPA, BLM, and NHTSA had all issued rulemakings from March 2017 to January 2019 that used the federal government's current estimates of the social cost of carbon issued after Executive Order 13783. We did not include the Department of Energy (DOE) in our review as we did not identify any DOE rulemakings using the federal government's current estimates of the social cost of carbon issued after Executive Order 13783. For a more complete discussion of our scope and methodology, see appendix I.

[19]Exec. Order No. 12866, 58 Fed. Reg. 51,735 (Sept. 30, 1993). OMB, Circular A-4: Regulatory Analysis (Sept. 17, 2003).

[20]OMB's Office of Information of Regulatory Affairs is the federal government's central authority for the review of executive branch regulations, approval of information collections, establishment of statistical practices, and coordination of federal privacy policy.

sample of four of these states—California, Minnesota, Nevada, and New York—that we found to be most relevant to our purposes based on the frequency by which they appeared in the literature we reviewed and the information we received in interviews we conducted with knowledgeable stakeholders.[21] Findings from these selected U.S. states cannot be generalized to all 50 U.S. states but present illustrative examples of how states have accounted for the effects of carbon dioxide or other greenhouse gases, in monetary terms, in their decision-making. We then reviewed documents and interviewed state officials to learn how the selected state governments developed and used the estimates in regulatory and project cost-benefit analyses. We also selected a nonprobability sample of U.S. states—Montana and Texas—that had submitted written comments on aspects of the prior federal estimates for rulemaking and raised issues with using them. According to officials, neither state had developed nor used estimates of the social cost of carbon at the time of our review. We reviewed documents and interviewed officials from Montana and Texas.

To examine how selected foreign countries have developed and used estimates of the social cost of carbon, or other valuation methods, we selected a nonprobability sample of countries—Canada, France, Germany, and the United Kingdom—that are using monetary estimates for greenhouse gas emissions in decision-making and that we found to be most relevant to our purposes based on the frequency by which they appeared in the literature we searched and the information we received in interviews we conducted with knowledgeable stakeholders. We reviewed documents on how the national governments of the selected countries have estimated monetary estimates for carbon dioxide and other greenhouse gas emissions for use in regulatory and project cost-benefit analysis. We also interviewed government officials from every selected country on the topic of addressing greenhouse gas emissions in governmental cost-benefit analysis to gather information on how their governments developed and use the monetary estimates in regulatory and project cost-benefit analysis and other decision-making. Findings from this nonprobability sample of selected countries cannot be generalized to all countries worldwide but provide illustrative examples of the ways countries are developing and using estimates of the social cost

[21]Through our review of literature and interviews with knowledgeable stakeholders, we may not have identified all U.S. states calling for the use of the prior federal social cost of carbon estimates in state decision-making. As a result, the nine U.S. states we identified should not be considered a complete list of states relying on the prior federal estimates.

of carbon or other valuation methods. Appendix I contains more detailed information on the objectives, scope, and methodology of our review.

We conducted this performance audit from May 2018 to June 2020, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Executive Order 12866, issued in 1993, directs federal agencies to assess the potential benefits and costs of significant regulatory actions, including those that may have an annual effect on the economy of $100 million or more.[22] Under the executive order, for significant regulatory actions, agencies must also assess the potential benefits and costs of reasonably feasible alternatives and explain why the planned regulation is preferable to the identified alternatives. For each significant regulatory action, an agency is to develop the proposed regulation and an associated regulatory impact analysis and submit them both to OMB for formal review. After OMB concludes its review, the agency is to publish the proposed regulation in the Federal Register for public comment. The agency is then to issue a document summarizing its consideration of public comments and, if appropriate, modify the proposed regulation in response to the comments. This phase of regulatory development may also include further internal and external review. The agency is to submit the final regulatory impact analysis and regulation to OMB for review before it publishes the final regulation in the *Federal Register*.

In 2003, OMB issued Circular A-4 to provide guidance to federal agencies on how to conduct regulatory analyses as directed by Executive Order

[22]Exec. Order No. 12866, 58 Fed. Reg. 51,735 (Sept. 30, 1993). Significant regulatory actions consist of several categories of rules. In addition to regulatory actions that may have an annual effect on the economy of $100 million or more, they include those that are likely to result in a rule that may adversely affect in a material way the economy; a sector of the economy; productivity; competition; jobs; the environment; public health or safety; or state, local, or tribal governments or communities. Other significant regulatory actions include those that are likely to result in a rule that may create a serious inconsistency or otherwise interfere with an action taken or planned by another agency; materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of recipients thereof; or raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in Executive Order 12866.

12866.[23] Circular A-4 states that it is designed to assist agencies by defining "good regulatory analysis" and standardizing the way benefits and costs of federal regulations are measured and reported. In particular, the guidance provides for systematic evaluation of quantitative benefits and costs, including their monetization when possible, and qualitative benefits and costs (when quantification is not feasible).[24] The circular states that the analysis is to be "based on the best reasonably obtainable scientific, technical, and economic information available." Circular A-4 also provides guidance on selecting discount rates to adjust the estimated benefits and costs for differences in timing—that is, to determine how much future benefits and costs are worth today.[25] According to Circular A-4, a regulatory impact analysis should include an evaluation of the benefits and costs of the proposed action and any reasonable alternatives, as well as a description of assumptions and uncertainty. It acknowledges that agencies cannot analyze all regulations according to a formula, and that different regulations may call for different emphases in the analysis. Executive Order 13563, which reaffirmed and supplemented Executive Order 12866, generally directs federal agencies to conduct regulatory impact analyses based on the best available science.[26] It also directs agencies "to use the best available techniques to quantify present and future benefits and costs as accurately as possible."[27]

[23]OMB, *Circular A-4: Regulatory Analysis* (Sept. 17, 2003).

[24]Monetization is the process of estimating the dollar value of benefits and costs.

[25]When the benefits and costs of a regulation will occur in the future, agencies are to determine the present value of future benefits and costs by applying an appropriate discount rate—the rate used to convert benefits and costs occurring in different time periods to a common present value. The discount rate adjusts future values based on the observation that people usually prefer receiving an amount of money today rather than receiving the same amount in the future.

[26]Exec. Order No. 13563, 76 Fed. Reg. 3821 (Jan. 18, 2011).

[27]Executive Order 13563 and related implementing guidance direct agencies to ensure the objectivity of any scientific and technological information and processes used to support the agency's regulatory actions and that such information should be subject to well-established scientific processes, including peer review where appropriate. For the implementing guidance, see Executive Office of the President, *Memorandum for the Heads of Executive Departments and Agencies 3-9-09, Subject: Scientific Integrity* (Washington, D.C.: March 9, 2009).

Economic Modeling to Determine the Social Cost of Carbon

To develop estimates of the social cost of carbon, analysts use economic models known as "integrated assessment models."[28] With these models, according to the National Academies, analysts define a baseline of current and future carbon dioxide emissions by projecting future economic growth, population, and technological change.[29] Then, a small increase in carbon dioxide emissions (typically, a 1 metric ton increase) is added to the baseline emissions projections of the models. The models then translate the emissions increase into an increase in atmospheric carbon dioxide concentrations, which results in an increase in global average temperature. The models then translate the temperature change into physical impacts and monetized damages—that is, damages expressed in dollars.

According to a 2017 National Academies report, because most of the warming caused by carbon dioxide emissions persists for well over a millennium, changes in carbon dioxide emissions today may affect economic outcomes for centuries to come.[30] To create a social cost of

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[28]Integrated assessment models integrate climate and economic data into a single modeling framework for estimating future economic effects resulting from climate change. In general, these models translate carbon dioxide emissions scenarios into changes in greenhouse gas concentrations in the atmosphere, greenhouse gas concentrations in the atmosphere into temperature changes, and temperature changes into net economic effects (i.e., damages and benefits).

[29]According to the Organisation for Economic Co-operation and Development, the monetary estimates for the social cost of carbon can be based on at least two different assumptions on the greenhouse gas emissions trajectory. One assumption that can be made to determine the emissions trajectory is that global policies are adopted to reduce emissions at the socially optimal level from an economic perspective—that is, where the marginal damages equal the marginal costs of avoiding the damage. This approach attempts to use a cost-benefit approach to maximize net benefits by equalizing the marginal benefits and costs, which would involve using marginal climate damages estimates and marginal abatement cost estimates. Marginal abatement costs are the additional cost incurred to reduce an additional metric ton of greenhouse gas emissions. Under this assumption, the emissions trajectory and monetary value for greenhouse gas emissions would be determined by where the marginal climate damages equal marginal abatement costs to reduce emissions. Another possible assumption on the emissions trajectory, used by the United States government, is that the emissions trajectory is based on a business-as-usual trajectory, which means emissions are forecasted based on the existing emissions trend with no additional policies to reduce emissions in the future. Under this approach, the social cost of carbon value provides a measure of marginal climate damages at business-as-usual emissions levels. See Organisation for Economic Co-operation and Development, Stephen Smith and Nils Axel Braathen, *Monetary Carbon Values in Policy Appraisal: An Overview of Current Practice and Key Issues* (Paris, OECD Environment Working Papers, No. 92, 2015).

[30]National Academies, *Valuing Climate Damages* (2017).

carbon estimate for emissions occurring in a given year, models use discounting to convert the projected monetized climate damages into a present value. This process involves reducing the damages in each future year by a percentage known as the discount rate. Therefore, applying a higher discount rate reduces future values to a greater degree than applying a lower discount rate. According to the National Academies, the present value of damages reflects society's willingness to trade value in the future for value today.[31]

Federal Efforts to Estimate the Social Cost of Carbon in Regulatory Analysis

Federal agencies began including estimates of the social cost of carbon in regulatory impact analyses following a 2008 decision for NHTSA to do so by the U.S. Court of Appeals for the Ninth Circuit.[32] Afterward, EPA and the Departments of Energy and Transportation incorporated a variety of individually developed estimates of the social cost of carbon into their regulatory analyses. These estimates were derived from academic literature and ranged, in general, from $0 to $159 (in 2006, 2007, or 2008 dollars) per metric ton of carbon dioxide emitted in 2007. These estimates also varied in whether they reflected domestic or global measures of the social cost of carbon.

In early 2009, in part to improve consistency in agencies' use of social cost of carbon estimates in regulatory impact analyses, OMB's Office of Information and Regulatory Affairs and the Council of Economic Advisers convened the IWG. The IWG then developed interim government-wide social cost of carbon estimates based on an average of selected estimates published in academic literature.[33] In October 2009, the IWG reassembled to decide how its final social cost of carbon estimates would be developed. Once the IWG reached agreement, EPA officials, as participants in the IWG, calculated the estimates using integrated assessment models, and the IWG issued these estimates and its

[31]National Academies, *Valuing Climate Damages* (2017).

[32]Specifically, the Ninth Circuit held that NHTSA, in its 2006 final rule on certain fuel economy standards, had acted arbitrarily and capriciously by failing to monetize the value of carbon emissions reduction and directed NHTSA to include such a monetized value in an updated regulatory impact analysis for the regulation. Ctr. For Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1203 (9th Cir. 2008). The Ninth Circuit issued the 2008 opinion after vacating and withdrawing its prior opinion, 508 F.3d 508, issued on Nov. 15, 2007.

[33]GAO-14-663.

decisions in the 2010 Technical Support Document.[34] The IWG provided revised estimates and decisions in a 2013 update to the Technical Support Document. In 2015 and 2016, the IWG again updated the Technical Support Document—providing minor technical corrections and issuing the first estimates of the social cost of the greenhouse gases methane and nitrous oxide in 2016.[35]

As we reported in 2014, the federal government used the estimates from the Technical Support Document and its updates in dozens of proposed and final regulations.[36] For example, in 2014 the Department of Energy issued a final regulation establishing energy conservation standards for certain commercial refrigeration equipment—that is, walk-in coolers and freezers.[37] In assessing the likely costs and benefits of the regulation in a regulatory impact analysis, the department considered the potential global benefits resulting from reductions in carbon dioxide emissions that would occur as a result of the new standards. To put the reductions in carbon dioxide in monetary terms, the department used social cost of carbon estimates from the 2013 update to the Technical Support Document. To do so, the department developed a stream of annual damages by multiplying the carbon dioxide emissions reductions projected for each year by the social cost of carbon estimates for that year, thereby expressing the avoided damages in monetary terms. To calculate a present value of the avoided damages, the department discounted the stream of annual damages with the discount rate for the specific social cost of carbon estimate it used.

The IWG requested that the National Academies evaluate its approach to estimating the social cost of carbon. In 2016, the National Academies released an interim report that evaluated whether there was a need for a

[34]EPA calculated the estimates of the social cost of carbon and other greenhouse gases using three integrated assessment models: (1) the Dynamic Integrated Climate and Economy (DICE) model, (2) the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) model, and (3) the Policy Analysis of the Greenhouse Gas Effect (PAGE) model.

[35]The IWG's models run through 2300, which require assumptions about gross domestic product (GDP), population, and greenhouse gas emission trajectories after 2100—the last year for which these data are available from the IWG's chosen sources.

[36]GAO-14-663.

[37]Energy Conservation Program: Energy Conservation Standards for Walk-In Coolers and Freezers, 79 Fed. Reg. 32,050 (Jun. 3, 2014) (codified as amended at 10 C.F.R. pt. 431 subpt. R).

near-term update to the social cost of carbon and concluded that a near-term update was not warranted.[38] In January 2017, the National Academies issued a final report that included several recommendations to the IWG for improving the scientific basis, characterization of uncertainty, and transparency of the IWG's estimation framework.[39] In March 2017, Executive Order 13783 disbanded the IWG and withdrew its Technical Support Document and updates, including its social cost of carbon estimates, as "no longer representative of governmental policy," and directed that agencies ensure, to the extent permitted by law, that any monetary estimates for carbon dioxide and other greenhouse gases be consistent with OMB Circular A-4.[40] As a participant in the IWG, EPA's National Center for Environmental Economics had used the integrated assessment models to calculate the prior federal estimates and therefore was positioned to develop estimates under the executive order, according to EPA officials and OMB staff. As a result, EPA developed the current federal estimates.[41]

Two Broad Approaches for Developing Monetary Estimates for Greenhouse Gas Emissions

In addition to the federal government, the governments of some U.S. states and foreign countries use monetary estimates for greenhouse gas emissions to help develop regulations and other policies. Two broad approaches for developing monetary estimates for greenhouse gas emissions are used by governments in decision-making:[42]

- **Social cost of carbon (i.e., damage costs) approach.** The social cost of carbon, also known as a damage costs approach, provides

[38]National Academy of Sciences, Engineering, and Medicine, *Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on Near-Term Update* (Washington, D.C.: National Academies Press, 2016). The National Academies' 2016 report concluded that updating a key parameter on climate sensitivity would likely not alone significantly improve the IWG's estimates of the social cost of carbon and therefore a near-term update was not warranted.

[39]National Academies, *Valuing Climate Damages* (2017).

[40]82 Fed. Reg. 16,093, 16,095 (Mar. 31, 2017).

[41]EPA developed its current estimates of the social cost of carbon and other greenhouse gases using the three integrated assessment models that had been used to calculate the federal government's prior estimates: (1) the 2010 version of the Dynamic Integrated Climate and Economy (DICE) model, (2) the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) model version 3.8, and (3) the 2009 version of the Policy Analysis of the Greenhouse Gas Effect (PAGE) model.

[42]Instead of developing monetary estimates, in some cases, governments use current and projected market prices of greenhouse gas allowances within an emissions trading system to assign a monetary estimate to greenhouse gases for use in decision-making.

monetary estimates for greenhouse gas emissions based on the economic damages caused by emitting an additional unit of carbon dioxide or other greenhouse gas (customarily in metric tons).

- **Target-consistent approach.** The target-consistent approach provides monetary estimates for greenhouse gas emissions based on the marginal abatement cost for achieving a given emissions reduction target—that is, the cost of abating the last metric ton of carbon dioxide needed to meet a particular emissions target at least cost to society.

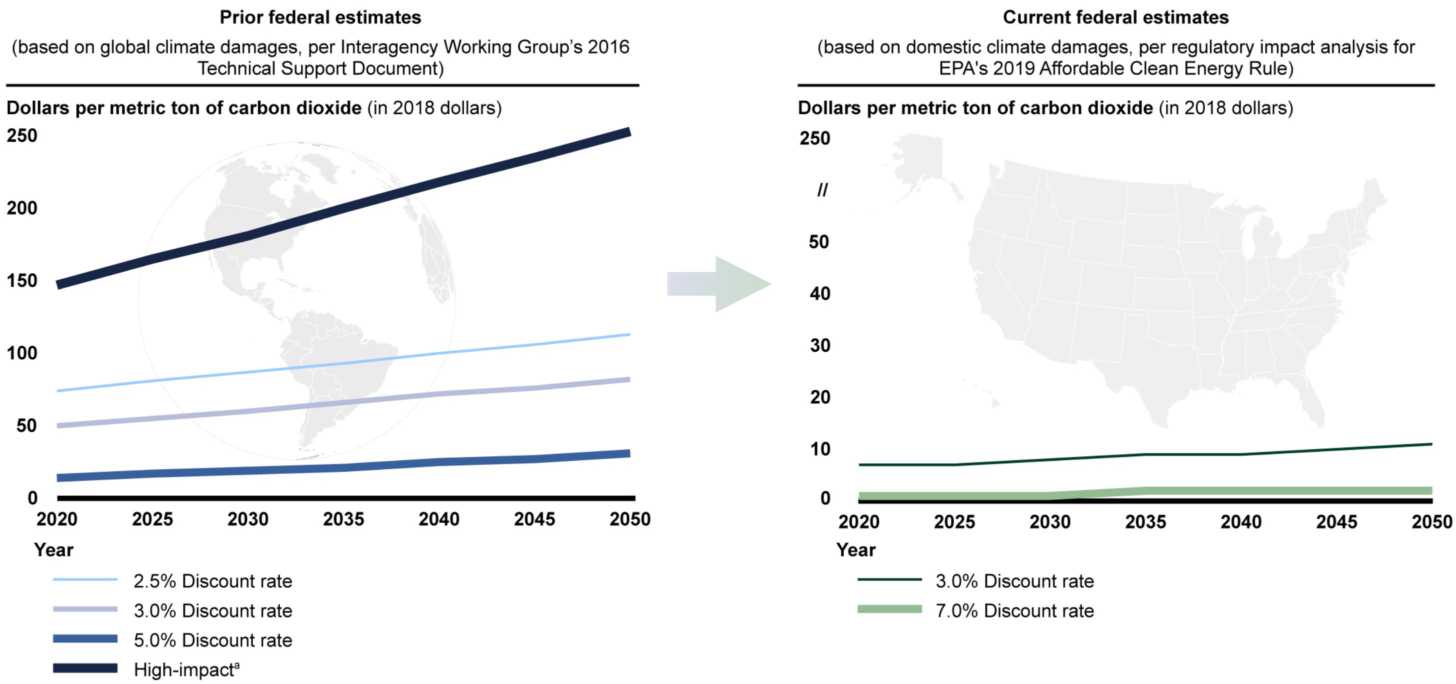
Current Federal Estimates of the Social Cost of Carbon Are Lower Than Prior Estimates because of Changes to Two Key Assumptions

The federal government's current estimates of the social cost of carbon are lower than its prior estimates due to changes in two key assumptions used to calculate them—specifically, a narrower geographic scope of climate damages and different discount rates. According to documents we reviewed and officials we interviewed, the changes in the key assumptions are the result of changes in guidance agencies are to follow, which affected how the agencies have considered costs and benefits in recent rulemakings. The three selected federal agencies used social cost of carbon estimates based on the current key assumptions in considering costs and benefits in recent rulemakings.

Current Federal Estimates of the Social Cost of Carbon Are Lower Than Prior Estimates Due to Changed Assumptions on Scope of Climate Damages and Discount Rates

The federal government's current estimates of the social cost of carbon are lower than prior estimates because, according to documents we reviewed and EPA officials and OMB staff we interviewed, they are based on two key changed assumptions: that the estimates are to (1) include domestic rather than global damages from climate change and (2) be calculated using a higher range of discount rates—3 to 7 percent—rather than 2.5 to 5 percent used for the prior estimates, which results in lower present values. See figure 1, which compares the prior and current federal estimates of the social cost of carbon dioxide. EPA had responsibility for calculating the prior federal estimates and has also developed the current federal estimates.

Figure 1: Prior and Current Federal Estimates of the Social Cost of Carbon Dioxide in 2018 U.S. Dollars, 2020-2050



Source: GAO analysis of data from Interagency Working Group on Social Cost of Greenhouse Gases (IWG) and Environmental Protection Agency (EPA). | GAO-20-254

Notes: Values are adjusted for inflation and expressed in 2018 U.S. dollars using the United States Gross Domestic Product Price Index from the U.S. Department of Commerce, Bureau of Economic Analysis. The prior federal estimates were developed by the Interagency Working Group on Social Cost of Carbon (and calculated by EPA, as a member of the working group, using economic models maintained by the agency) and published in a 2016 update to its Technical Support Document. The current estimates were developed in response to Executive Order 13783 of March 2017 and used in regulatory impact analyses for several recent rulemakings, including EPA's Affordable Clean Energy Rule of 2019.

[a]The prior federal high-impact estimates were meant to represent higher-than-expected impacts from temperature changes (i.e., low-probability but high-impact damages "further out in the tails of the [social cost of carbon] distributions"). The high-impact estimates are the result of averaging the damages in the 95th percentile (i.e., higher than 95 percent of the damage results) across all three of the integrated assessment models, which are then discounted at the "central" 3 percent rate. The appendix of the 2016 update to the Technical Support Document provides additional high-impact estimates, on a model-by-model basis, discounted at the 2.5 percent and 5 percent discount rates.

The federal government's prior estimates of the social cost of carbon were based on the global climate damages from emissions, according to the technical documents we reviewed. For each emissions year, the IWG developed four estimates of the social cost of carbon that were based on global climate damages.[43] Three of the estimates were the average values from the integrated assessment models discounted at rates of 2.5, 3, and 5 percent respectively, and the fourth estimate was a high-impact estimate (that also used a 3 percent discount rate).[44] Although the estimate calculated using a 3 percent discount rate was considered the primary (i.e., central) value, for the purposes of capturing the uncertainties involved in regulatory impact analysis, the IWG in its Technical Support Documents issued from 2010 to 2016 emphasized the importance of agencies including all four estimates in their regulatory impact analyses. According to those documents, the IWG's choice of discount rates was meant to address, among other things, that there is uncertainty in how interest rates may change over time and the fact that climate damages resulting from greenhouse gas emissions will span across generations.

By comparison, at the same discount rate, the federal government's current estimates are significantly lower than the prior estimates because they are based on domestic rather than global damages. This difference can be seen when comparing the current and prior estimates calculated at the same 3 percent discount rate (see table 1). For example, for the social cost of carbon dioxide, EPA's current estimates that are based on domestic climate damages are about 7 times lower than the prior federal estimates that were based on global damages. To see more information on the current estimates that EPA developed for the social cost of carbon dioxide, as well as the social cost of methane, see appendix II.

[43]As explained previously, as a member of the IWG, EPA had responsibility for maintaining the economic models that were used to calculate the estimates.

[44]The high-impact estimate is meant to represent higher-than-expected impacts from temperature changes (i.e., low-probability but high-impact damages "further out in the tails of the [social cost of carbon] distributions"). The high-impact estimate is the result of averaging the damages in the 95th percentile—that is higher than 95 percent of the damage results for each model—across all three of the integrated assessment models, which is then discounted at a 3 percent rate.

Table 1: Prior and Current Federal Estimates of the Social Cost of Carbon Dioxide per Metric Ton at a 3 Percent Discount Rate in 2018 U.S. Dollars, 2020-2050

Year of emissions	Prior estimates (based on global climate damages)[a]	Current estimates (based on domestic climate damages)[b]
2020	$50	$7
2030	$60	$8
2040	$72	$9
2050	$82	$11

Sources: GAO analysis of data from Interagency Working Group on Social Cost of Greenhouse Gases and Environmental Protection Agency (EPA). | GAO-20-254

Notes: The prior and current federal estimates of the social cost of carbon dioxide were originally reported in 2007 and 2016 U.S. dollars, respectively. We adjusted values for inflation and expressed in 2018 U.S. dollars using the United States Gross Domestic Product Price Index from the U.S. Department of Commerce, Bureau of Economic Analysis.

[a]The prior federal estimates were originally reported in 2007 dollars in the Interagency Working Group's 2016 Technical Support Document.

[b]The current federal estimates were originally reported in 2016 dollars in the regulatory impact analysis for EPA's 2019 Affordable Clean Energy Rule.

A Change in the Guidance Used to Develop the Estimates Changed Two Key Assumptions Underlying Federal Estimates of the Social Cost of Carbon

The change in guidance used to develop the current social cost of carbon estimates under Executive Order 13783 resulted in a change in two key assumptions for calculating those estimates—from global to domestic climate damages and from a lower to a higher range of discount rates—according to documents we reviewed and EPA officials and OMB staff we interviewed. The prior federal estimates used the guidance found in the IWG's technical support documents, which concluded that the social cost of carbon should be based on the global climate damages of emissions. In its technical support documents, the IWG explained that this conclusion was based on its findings that the problem of climate change: (1) involves a global negative externality—that is, emissions of most greenhouse gases, such as carbon dioxide, contribute to damages around the world even when they are emitted in the United States and (2) is a problem that the United States alone cannot solve.[45] The IWG found that developing a domestic social cost of carbon would be greatly complicated by the relatively few region- or country-specific estimates that could be found in the academic literature. In addition, the IWG's guidance called for agencies to use a range of discount rates to calculate the social cost of carbon. Specifically, the IWG's technical support documents called for using estimates based on discount rates of 2.5, 3, and 5 percent (and a

[45]OMB defines an externality as a situation when one party's actions impose uncompensated benefits or costs on another party.

fourth high-impact estimate based on a 3 percent discount rate), as explained above.

For the current estimates, Executive Order 13783 directs agencies, when conducting regulatory impact analyses, to ensure, to the extent permitted by law, that their estimates of the social cost of carbon are consistent with OMB Circular A-4's guidance on regulatory cost-benefit analysis. The executive order provides that, effective immediately, when monetizing the value of changes in greenhouse gas emissions resulting from regulations, including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates, agencies shall ensure, to the extent permitted by law, that any such estimates are consistent with the guidance contained in Circular A-4.[46] Moreover, according to EPA in the regulatory impact analysis for the 2019 Affordable Clean Energy Rule, the two analytical considerations highlighted in Executive Order 13783 are the geographic scope of greenhouse gas impacts (i.e., domestic or global climate damages) and appropriate discount rates. EPA officials stated that Executive Order 13783 was the impetus for developing its current estimates of the social cost of carbon and that the executive order directed the agency to adhere closely to the guidance in Circular A-4, which the agency did, according to agency officials, by basing the estimates on domestic climate damages and using the discount rates of 3 and 7 percent specified in OMB's guidance.

OMB Circular A-4 states that it was designed to assist federal agencies in conducting regulatory analyses and standardize the way agencies measure and report the expected costs and benefits of federal regulations.[47] Circular A-4 also states that the scope of federal regulatory impact analyses should focus on domestic impacts—that is, the costs and benefits of a proposed regulation that accrue to U.S. citizens and residents. However, Circular A-4 also states that further analysis may be

[46]The Executive Order notes that OMB Circular A-4 of September 17, 2003 (Regulatory Analysis) was issued after peer review and public comment and has been widely accepted for more than a decade as embodying the best practices for conducting regulatory cost-benefit analysis. Id. at 16,096.

[47]Unlike the Technical Support Documents issued from 2010 through 2016 that focused specifically on determining estimates of the social cost of carbon, OMB Circular A-4, issued in 2003, provides general guidance on how agencies are to present costs and benefits in regulatory impact analysis and is not specific to valuing greenhouse gas emissions.

necessary in some cases. Where agencies choose to evaluate a regulation that is likely to have effects beyond the borders of the United States, Circular A-4 states that agencies should report these effects separately and that the timeframe for analysis should cover a period long enough to encompass all the important benefits and costs likely to result from the rule.[48] OMB staff told us that there is broad latitude in Circular A-4 to include the international (i.e., global) effects of a proposed regulation, in addition to the main presentation of domestic costs and benefits, to provide information to decision makers and the public.[49]

Concerning discount rates, when federal agencies use discounting to express the present value of a regulation's projected costs and benefits, OMB Circular A-4 states that the agencies should use 3 and 7 percent discount rates—which are to represent the social rate of time preference for consumers and the opportunity cost of capital, respectively.[50] OMB Circular A-4 also states that special ethical considerations arise when

[48]With respect to the effects of regulations beyond U.S. borders, the IWG acknowledged that its approach to developing estimates for the social cost of carbon differed from the general approach to regulatory analysis in OMB Circular A-4. In 2014, we examined how EPA had used economic analyses in its decision-making during the rulemaking process and the extent to which the agency adhered to OMB's guidance in Circular A-4, including with respect to the IWG's social cost of carbon estimates. We recommended, among other things, that OMB clarify the relationship between the IWG's Technical Support Documents and OMB's Circular A-4. Given that the IWG was disbanded by Executive Order 13783 in March 2017 and its social cost of carbon estimates were withdrawn, we closed this recommendation as not implemented. See GAO, *Environmental Regulation: EPA Should Improve Adherence to Guidance for Selected Elements of Regulatory Impact Analyses*, GAO-14-519 (Washington, D.C.: July 18, 2014).

[49]The IWG 2010 Technical Support Document states that under "OMB guidance contained in Circular A-4, analysis of economically significant proposed and final regulations from the domestic perspective is required, while analysis from the international perspective is optional." However, the IWG concluded that a modified approach was needed because of the global nature of climate change and therefore a global measure of the benefits from reducing U.S. emissions was more appropriate.

[50]According to OMB Circular A-4, the social rate of time preference is the rate at which society discounts future consumption flows to their present value. For example, Circular A-4 states that if one takes the rate that the average saver uses to discount future consumption as a measure of the social rate of time preference, then the real rate of return on long-term government debt may provide a fair approximation—which over the last 30 years (at the time of publication in 2003) averaged around 3 percent in real terms on a pre-tax basis. Also from Circular A-4, the opportunity cost of capital is to reflect the returns to real estate and small business capital as well as corporate capital and is the appropriate discount rate whenever the main effect of a regulation is to displace or alter the use of capital in the private sector. OMB Circular A-4 states that the 7 percent rate is an estimate of the average before-tax rate of return to private capital in the U.S. economy.

comparing expected benefits and costs of a regulation that span across generations. Circular A-4 explains that future citizens who are affected by the choices of society cannot take part in making them and today's society must act with some consideration of their interest. To address this, Circular A-4 states that for rules that will have important intergenerational benefits or costs, agencies might consider a sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent. Such analyses examine how the results of the regulatory impact analysis vary with plausible changes to key assumptions and inputs that were separate from the main presentations of costs and benefits.[51]

Three Selected Federal Agencies Used the Current Key Assumptions in Considering Costs and Benefits in Recent Rulemakings

Following the issuance of Executive Order 13783 in March 2017, EPA developed the current federal estimates of the social cost of carbon using the same models it had used to calculate the prior federal estimates. EPA used the estimates in its regulatory impact analyses for, among others, the 2019 rulemaking that repealed the Clean Power Plan and replaced it with the Affordable Clean Energy Rule.[52]

BLM and NHTSA relied on EPA's current estimates of the social cost of carbon in their recent rulemakings.[53] For example, for its 2018 final regulation rescinding and revising certain requirements of the 2016 Waste Prevention Rule, BLM relied on the current estimates of the social cost of

[51]When explaining its choice to use a range of discount rates lower than those specified in OMB Circular A-4, the IWG stated that the guidance provides agencies with the flexibility to consider intergenerational costs or benefits in a sensitivity analysis using lower discount rates. OMB staff we interviewed confirmed this view. The staff said Circular A-4 provides agencies with the flexibility to tailor their cost-benefit analyses to the specific circumstances of the proposed regulations that are under consideration, including the scope of damages and selection of discount rates. OMB staff said this flexibility extends to including discount rates other than 3 and 7 percent—as long as the agencies explain the analytical basis for their choices.

[52]Environmental Protection Agency, *Regulatory Impact Analysis for the Repeal of the Clean Power Plan, and the Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units*, EPA-452/R-19-003 (Washington, D.C.: June 2019). For the final rule, *see* Repeal of the Clean Power Plan; Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units; Revisions to Emission Guidelines Implementing Regulations, 84 Fed. Reg. 32,520 (July 8, 2019).

[53]BLM is responsible for managing federal public lands for a variety of uses such as energy development, livestock grazing, recreation, and timber harvesting while ensuring natural, cultural, and historic resources are maintained for present and future use. NHTSA enforces vehicle performance standards to ensure motor vehicle safety and works to reduce deaths, injuries, and economic losses from motor vehicle crashes.

carbon that EPA provided.[54] According to BLM's regulatory impact analysis for the final regulation, changes in carbon dioxide emissions were expected to be minimal, so its regulatory impact analysis focused primarily on the impacts of changes in methane emissions. BLM officials told us that during the interagency review process, EPA provided the current social cost of methane estimates that BLM used in the rulemaking. In addition, for the Safer Affordable Fuel-Efficient Vehicles Rule proposed in 2018, NHTSA used EPA's current social cost of carbon dioxide estimates for its regulatory impact analysis.[55]

Agencies also presented supplemental sensitivity analyses, as suggested by OMB's guidance. OMB Circular A-4 states that it is usually necessary for agencies to provide a sensitivity analysis to reveal whether, and to what extent, the results of their regulatory impact analyses are sensitive to plausible changes in the main assumptions and numeric inputs. Both EPA and NHTSA conducted such supplemental sensitivity analyses with respect to the social cost of carbon in their regulatory impact analyses, although these analyses were not the basis for the proposed regulations, according to the regulatory impact analyses we reviewed and the agency officials we interviewed. As mentioned previously, Circular A-4 states that where agencies choose to evaluate regulations that are likely to have effects beyond the borders of the United States, those effects should be reported separately and that the timeframe for the agencies' analyses should cover a period long enough to encompass all the important

[54]Bureau of Land Management, *Regulatory Impact Analysis for the Final Rule to Rescind or Revise Certain Requirements of the 2016 Waste Prevention Rule* (Washington, D.C.: Aug. 31, 2018). For the final rule, *see* Waste Prevention, Production Subject to Royalties, and Resource Conservation; Rescission or Revision of Certain Requirements, 83 Fed. Reg. 49,184 (Sept. 28, 2018).

[55]NHTSA's regulatory impact analysis for the proposed Safer Affordable Fuel-Efficient Vehicles Rule included estimates of the social cost of carbon dioxide in its central analysis. NHTSA also included monetary estimates for methane and nitrous oxide in separate sensitivity analyses, where the estimates were calculated using warming potential conversion factors applied to the social cost of carbon. They were not calculated using the IWG's social cost methodology, although NHTSA stated that it would consider using this approach in its analysis supporting the final rule. See EPA and NHTSA, *Preliminary Regulatory Impact Analysis: The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021 – 2026 Passenger Cars and Light Trucks* (Washington, D.C.: July 2018, updated Oct. 16, 2018). For the proposed rule, *see* The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks, 83 Fed. Reg. 42,986 (Aug. 24, 2018). As we discuss later, NHTSA finalized the Safer Affordable Fuel-Efficient Vehicles Rule after we provided a draft of this report for the agency's review and comments, but we did not include the final rule in the scope of this review.

benefits and costs likely to result from the rule. In sensitivity analyses, EPA showed what the costs and benefits of its regulation could be using a social cost of carbon based on global, instead of domestic, climate damages (using discount rates of both 3 and 7 percent).[56] Additionally, EPA showed costs and benefits reflecting that climate damages span generations by using a discount rate of 2.5 percent (for both domestic and global estimates).[57] In a sensitivity analysis for its proposed regulation, NHTSA used a social cost of carbon based on domestic damages and a 2.5 percent discount rate to account for the intergenerational nature of climate damages. NHTSA also used a social cost of carbon based on domestic damages and a 7 percent discount rate to represent a low estimation of climate damages. Unlike EPA, NHTSA did not use a social

[56]The social cost of carbon estimates based on global climate damages that EPA used in its sensitivity analyses were comparable to the prior federal social cost of carbon estimates developed by the IWG (also based on global climate damages), when using the same discount rates. For example, at a 3 percent discount rate, EPA's social cost of carbon dioxide based on global damages that it used in its sensitivity analysis for emissions occurring over the years 2025 to 2035 ranged from $55 to $66 per metric ton (in 2018 dollars). The IWG's social cost of carbon dioxide, per its 2016 update to its Technical Support Document, for emissions occurring over the years 2025 to 2035 ranged from $55 to $66 per metric ton (in 2018 dollars).

[57]EPA used the same approach to its supplemental sensitivity analysis for the social cost of methane in its regulatory impact analysis for a 2018 proposed rule on the oil and natural gas sectors. See Environmental Protection Agency, *Regulatory Impact Analysis for the Proposed Reconsideration of the Oil and Natural Gas Sector Emission Standards for New, Reconstructed, and Modified Sources,* EPA-452/R-18-001 (Washington, D.C.: September 2018). For the proposed rule, see *Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources Reconsideration*, 83 Fed. Reg. 52056 (Oct. 15, 2018).

cost of carbon based on global damages in its sensitivity analyses.[58] Also, BLM did not include a changed social cost of methane in its sensitivity analyses.[59] OMB staff told us that differences between how the agencies accounted for the social cost of carbon in their sensitivity analyses were not, as a general matter, inconsistent with the guidance in Circular A-4.

[58]After we provided a draft of this report to NHTSA for its review and comment, the agency issued the final Safer Affordable Fuel-Efficient Vehicles Rule in April 2020. Because the final rule was issued after January 2019 (the end date for our search for rulemakings using the current federal estimates of the social cost of carbon), we did not include the final rule in our scope of this review. In its regulatory impact analysis for the final rule, NHTSA used estimates of the social cost of carbon dioxide based on domestic damages and a 3 percent discount rate in its central analysis. In a sensitivity analysis for the final rule, NHTSA used social cost of carbon dioxide estimates based on domestic damages and a 2.5 percent discount rate to account for the intergenerational nature of climate damages; NHTSA also used a social cost of carbon dioxide based on domestic damages and a 7 percent discount rate to represent a low estimation of climate damages. Unlike the regulatory impact analysis for its proposed rule, NHTSA used social cost of carbon estimates based on global damages and discount rates of 3 and 7 percent rates in additional sensitivity analyses. Furthermore, in its regulatory impact analysis for the final rule NHTSA included additional sensitivity analyses using estimates of the social costs of methane and nitrous oxide based on domestic climate damages and a 3 percent discount rate (as developed by EPA for use in regulatory analyses conducted under the guidelines specified in Executive Order 13783 and OMB Circular A–4).

[59]NHTSA and BLM both reported that Executive Order 13783 withdrew the federal government's previous estimates that were based on global damages and drove the agencies' decisions to use EPA's more recent interim estimates (which were based on domestic climate damages). BLM officials stated that the regulatory impact analysis for its 2018 final regulation included a table comparing the value of methane reductions achieved under the 2018 final regulation (derived using social cost of methane estimates based on domestic climate damages) to the value of methane reductions from the 2016 final regulation (derived using a social cost of methane based on global climate damages). The officials stated that, since the 2018 final regulation rescinded the prior provisions affecting methane emissions, the practical effect of presenting this information is the same as disclosing the final regulation's impacts using social cost of methane estimates based on global climate damages.

The Federal Government Has No Plans to Address the National Academies' Recommendations for Updating the Social Cost of Carbon

The federal government has no plans to address the National Academies' short- and long-term recommendations for updating the methodologies used by federal agencies to develop their estimates of the social cost of carbon. OMB staff said the agency is monitoring developments in research in this area but said it has no plans for implementing the National Academies' recommendations.

The National Academies Made Short- and Long-term Recommendations for Updating the Methodologies Used to Estimate the Social Cost of Carbon

In a January 2017 report, the National Academies made several short- and long-term recommendations for comprehensively updating the methodologies used by federal agencies to estimate the social cost of carbon. The task of the National Academies report was to ensure that the federal government's social cost of carbon estimates reflect the best available science. The report makes short-term recommendations for improvements to the methodologies used to develop the federal estimates, as well as longer-term recommendations for more comprehensive updates.[60] In a press release on its recommendations, the National Academies stated that the federal government should use a new framework that would strengthen the scientific basis, provide greater transparency, and improve characterization of the uncertainties of its social cost of carbon estimates. The recommendations state that they were aimed at addressing the limitations of the existing methodologies used to estimate the social cost of carbon. For example, the National Academies stated that the estimates used by federal agencies had been based on integrated assessment models that did not use the latest research.

According to the National Academies, its recommendations are to improve estimates of the social cost of carbon within the federal regulatory context. Although they were addressed to the now-disbanded IWG, the National Academies' recommendations remain relevant because, as the National Academies stated, they are for comprehensively

[60]The recommendations were directed to the IWG because it had requested that National Academies evaluate its approach for estimating the social cost of carbon. As stated in the National Academies' 2017 report, "the task was to ensure that the [social cost of carbon] estimates reflect the best available science, focusing on issues related to the choice of models and damage functions, climate science modeling assumptions, socioeconomic and emissions scenarios, presentation of uncertainty, and discounting." See National Academies of Sciences, *Valuing Climate Damages* (2017).

updating the methodologies that were used to develop both the prior and current federal estimates. Furthermore, OMB staff said they recognized that the National Academies' recommendations are general calls for improvements to the underlying methodologies used to estimate the social cost of carbon.

Among its short-term recommendations (i.e., to be achieved in 2 to 3 years), the National Academies recommended a new framework where the main analytical steps used to develop the federal estimates (which are now contained in each integrated assessment model) would be "unbundled" into four separate "modules."[61] With separate modules, as academic and scientific disciplines underpinning them became more sophisticated, each module could be updated. The National Academies stated the four modules would address the following:

- **socioeconomics,** to project population and the value of the goods and services produced in the United States (i.e., gross domestic product) that in turn drives projections of carbon dioxide and other greenhouse gas emissions;
- **climate,** to take greenhouse gas emissions projections from the socioeconomics module and estimate their effects on temperature and other physical variables;
- **damages,** to translate the results of the climate module (e.g., changes in temperature and sea level) into estimates of physical impacts and monetized damages over time; and
- **discounting,** to convert the future stream of monetized damages estimates from the damages module into a single present value.

Among its discussion of the short-term recommendations, the National Academies stated that existing OMB guidance (i.e., Circular A-4) does not fully address the issue of discounting over long time periods. The National Academies reported that, in an intergenerational context, OMB

[61]The methodology to develop the federal estimates of the social cost of carbon used three distinct integrated assessment models to estimate the economic consequences of carbon dioxide emissions. First, in each model, a baseline of carbon dioxide emissions was defined along with projections of underlying socioeconomic factors—global economic growth and population—decades into the future. Then, a small increase in carbon dioxide emissions was added to the baseline for each of the three models, which was translated into an increase in atmospheric carbon dioxide and a resulting increase in global mean temperature. These results were used to estimate potential net damages in dollars, using discounting to convert future damages into present dollars. The final IWG analysis averaged the results from the three models. EPA used the same methodology in developing the current estimates under Executive Order 13783.

recognizes that addressing these issues leads to the use of generally lower discount rates. Instead of using fixed discount rates, as suggested by OMB Circular A-4 (i.e., 3 and 7 percent) and used for the current federal estimates and by the IWG's approach (i.e., 2.5, 3, and 5 percent) for the prior federal estimates, the National Academies recommended that the new discounting module should incorporate the relationship between economic growth and discounting when calculating the discount rates—a step that would help account for uncertainty surrounding such rates over long time periods. As a result, the National Academies recommended incorporating variable discount rates that better reflect the relationship between economic growth over time and discounting.[62] The National Academies stated doing so would help address the inherent uncertainty surrounding long-term discount rates.

Among its long-term recommendations (i.e., to be achieved in 5 or more years), the National Academies recommended that the damages module be updated so that it disaggregates climate damages by geographic region and economic sector—and in doing so include (1) interactions and spillover effects among regions and sectors and (2) feedback to the other three modules. The National Academies concluded that estimating a country-specific social cost of carbon for the United States was "feasible in principle" but limited by existing methodologies, which focus primarily on global estimates and do not model all relevant interactions among regions. The National Academies stated that accurately estimating the damages from carbon dioxide emissions for the United States would involve more than examining the direct impacts of climate change that occur within U.S. physical borders. According to the National Academies, more complete estimates of U.S.-specific damages would need to consider how climate change and emissions reductions in other parts of the world could also affect the United States—for example, through (1) increased migration because of economic or political destabilization and (2) reciprocal actions by other countries in response to U.S. emission reductions.

[62]To incorporate variable discount rates that better reflect the relationship between economic growth and discounting, the National Academies recommended using what is called the Ramsey formula to determine the discount rates it uses to estimate the social cost of carbon. The Ramsey formula returns a discount rate that equals the pure rate of time preference plus the product of the value of an additional dollar as society grows wealthier and the growth rate of per capita consumption.

OMB Is Monitoring Research, but neither OMB nor Other Agencies Have Responsibility for or Plans to Implement the National Academies' Recommendations

OMB staff (including staff from the Office of Information and Regulatory Affairs) we interviewed said the agency does not have specific plans for implementing the National Academies' recommendations and that no federal agency has responsibility for addressing the recommendations. OMB staff said that many of the recommendations for improving the modeling and estimates were meant for the long term—that is, to be achieved in 5 years or more—and since the recommendations were issued in 2017, there is still time to address them. OMB staff told us the agency supports the National Academies' recommendation that the estimates be updated every 5 years and that a 5-year timeframe is a reasonable trade-off between policy needs and the frequency of technical updates in the research.

However, the staff said the agency is monitoring developments in research in this area. According to OMB staff, two nonfederal entities, specifically Resources for the Future and the University of Chicago's Climate Impact Lab, are leading research efforts that are responsive to the National Academies' recommendations, so the agency is following their work.[63]

According to a senior official with Resources for the Future's Social Cost of Carbon Initiative, the organization has taken the lead in coordinating action on updating the social cost of carbon estimates and conducting additional research to implement the National Academies' recommendations. The senior official said that Resources for the Future is currently building and maintaining the academic and research communities that are working to improve the social cost of carbon for use by the federal government. The Social Cost of Carbon Initiative, a multiyear, multidisciplinary research initiative to address the National Academies' recommendations for updating the methodologies used to estimate the social cost of carbon, will be using one of two updated simplified climate models to model the temperature changes and other earth system responses under different emissions trajectories. Both

[63]Resources for the Future is a nonpartisan, nonprofit research institution that has a mission of improving environmental, energy, and natural resource policies through economic research. Part of the institution's work, for example, involves building a new open source computing platform where researchers can access and contribute research that feeds into improved social cost of carbon estimates. The University of Chicago's Climate Impact Lab is a collaborative project of 30 climate scientists, economists, and other experts from some of the nation's leading research institutions working to, among other things, combine local climate projections with historical observations to yield highly localized pictures of future climate impacts that can help inform social cost of carbon estimates. OMB staff also expressed interest in learning of other groups actively involved in updating the methods used for estimating the social cost of carbon.

models are responsive to the recommendations of the National Academies for updating the climate models used in social cost of carbon estimates, according to Resources for the Future.

In line with the National Academies' recommendations, the Climate Impact Lab stated that it is working to leverage recent advances in science and economics to develop empirically derived estimates of the social cost of carbon. The Director of the Climate Impact Lab stated that the National Academies' recommendations were aimed at helping the process for estimating the social cost of carbon to draw more easily on a wide range of expertise in a range of scientific disciplines. To this end, the Director stated that the Climate Impact Lab is building a comprehensive body of research quantifying the impacts of climate change by economic sectors and communities around the world.

OMB continues to play a leading role in the federal government's use of the social cost of carbon, as one of the entities that convened the IWG and also as having responsibility for OMB's guidance in Circular A-4, which Executive Order 13783 directs agencies to follow in developing their estimates. The Circular states that the analysis is to be "based on the best reasonably obtainable scientific, technical, and economic information available." Executive Order 13783 states that to ensure sound regulatory decision-making, it is essential that agencies use estimates of costs and benefits in their regulatory analyses that are based on the best available science and economics. Also, as we found in May 2011, OMB provides high-level policy direction for federal climate change programs and activities and leads formal and informal interagency initiatives on related issues.[64] Furthermore, OMB staff told us that one of the agency's major roles is overseeing a centralized review process for regulations under Executive Order 12866. OMB staff said they look to ensure consistency with Executive Order 12866, Circular A-4, and the principles of other executive orders, such as Executive Order 13783, in agencies' regulatory impact analyses.

For its current estimates, EPA calculated domestic climate damages by taking values for the United States from two of the three integrated assessment models and estimating domestic damages for the United

[64]GAO, *Climate Change: Improvements Needed to Clarify National Priorities and Better Align Them with Federal Funding Decisions,* GAO-11-317 (Washington, D.C.: May 20, 2011).

States for the third model.[65] EPA reported that the agency estimated an approximation of domestic damages based on the integrated assessment models that were available, and EPA officials said the models did not include second-order effects that would be important for accurately estimating a social cost of carbon based on domestic climate damages. According to the National Academies, the integrated assessment models were not premised or calibrated to provide estimates of the social cost of carbon based on domestic damages, and more research would be required to update the models to do so. The National Academies stated it is important to consider what constitutes a domestic impact in the case of a global pollutant that could have international implications that affect the United States.

EPA stated that the agency's current estimates of the social cost of carbon are interim until more comprehensive estimates can be developed that consider the National Academies' recommendations and thus help ensure they reflect the best available science.[66] The rulemakings we reviewed used the current federal estimates, which were based on EPA's interim estimates; therefore, the federal government may not be well positioned to ensure agencies' future regulatory analyses are using the best available science until the agencies finalize federal estimates that consider the National Academies' implemented recommendations. OMB staff said that no federal agency has responsibility for addressing the recommendations, monitoring developments in scientific research, or ensuring that updated federal estimates consider such developments. By identifying a federal entity or entities to be responsible for addressing the National Academies' recommendations for updating the methodologies used to estimate the federal social cost of carbon, including monitoring scientific research and ensuring that updates to the estimates consider such research, OMB would have better assurance that agencies use the best available science in the social cost of carbon estimates they use in their regulatory impact analyses.

[65]According to EPA, the third model only calculates global estimates, and therefore, EPA approximated U.S. damages as 10 percent of the third model's estimates. See EPA, *Regulatory Impact Analysis for Repeal of the Clean Power Plan* (2019).

[66]EPA, *Regulatory Impact Analysis for Repeal of the Clean Power Plan* (2019).

Selected U.S. States Have Developed and Used Estimates of the Social Cost of Carbon That Are Largely Based on the Federal Government's Prior Estimates

Four selected U.S. states—California, Minnesota, Nevada, and New York—have developed and used estimates of the social cost of carbon that are largely based on the federal government's prior estimates, and the states use their estimates to regulate utilities and make other state policy decisions. According to state documents and officials, these estimates generally incorporate two key assumptions underlying the federal government's prior estimates: that (1) U.S. greenhouse gas emissions contribute to damages around the world and (2) relatively low discount rates are appropriate to calculate their social costs. We did not find states using estimates based on other approaches, including the federal government's current estimates.[67]

California

Two California state agencies have developed social cost of carbon estimates for analyzing policy and regulating utilities by adopting some of the prior federal estimates, according to documents we reviewed and officials we interviewed. The California Air Resources Board, the primary agency responsible for regulating sources of air pollution, developed estimates of the social cost of carbon (i.e., social cost estimates for both carbon dioxide and methane) in 2017 by adopting three of the four prior federal estimates for each emissions year, according to the documents we reviewed. According to the documents, the board adopted the prior federal estimates that were based on discount rates of 2.5, 3, and 5 percent (see table 2).[68]

The board used these estimates to assess policy options in California's 2017 statewide plan for addressing climate change, which establishes the policy path for the state to reach its 2030 emissions target.[69] For each policy option in the plan, such as a statewide emissions trading system, the board estimated the monetary benefits of avoided emissions by using the social cost of carbon. California's plan states that although the prior federal estimates had been withdrawn as no longer representative of federal governmental policy, it did not alter their scientific integrity. The plan states that the prior federal estimates continue to reflect the best available science for estimating the socio-economic impacts of carbon

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[67]See appendix III for information from two selected U.S. states that have raised issues about the use of the federal government's prior estimates.

[68]The board did not adopt the high-impact prior federal estimates.

[69]California Air Resources Board, *California's 2017 Climate Change Scoping Plan* (November 2017).

dioxide emissions and other greenhouse gases. Furthermore, an official told us the board adopted and used the prior federal estimates because they were generally accepted among practitioners.

Table 2: Social Cost of Carbon Estimates Developed by the California Air Resources Board per Metric Ton of Carbon Dioxide in 2018 U.S. Dollars, 2020-2030

Year of emissions	5 percent discount rate	3 percent discount rate	2.5 percent discount rate
2020	$14	$50	$74
2025	$17	$55	$81
2030	$19	$60	$87

Source: GAO analysis of data from California Air Resources Board, California's 2017 Climate Change Scoping Plan. | GAO-20-254

Note: The California Air Resources Board adopted prior federal estimates of the social cost of carbon dioxide as published in the Interagency Working Group on Social Cost of Carbon's 2015 update to the Technical Support Document. The values are adjusted for inflation and expressed in 2018 U.S. dollars using the United States Gross Domestic Product Price Index from the U.S. Department of Commerce, Bureau of Economic Analysis.

The California Public Utilities Commission, the state's utility and essential service regulator, adopted the prior federal estimates that were based on a 3 percent discount rate. The commission also adopted the prior federal high-impact estimates, which were to represent low-probability but higher-impact effects from temperature changes (see table 3). A commission official told us that staff consulted with the California Air Resources Board about the most appropriate estimates to use and ultimately selected the prior federal estimates because the board had reviewed them and considered them to be reliable.

Table 3: Social Cost of Carbon Estimates Developed by the California Public Utilities Commission per Metric Ton of Carbon Dioxide in 2018 U.S. Dollars, 2020-2030

Year of emissions	3 percent discount rate	High impact estimate[a]
2020	$50	$147
2025	$55	$165
2030	$60	$181

Source: GAO analysis of data from California Public Utilities Commission, Decision Adopting Cost-Effectiveness Analysis Framework Policies for all Distributed Energy Resources. | GAO-20-254

Note: The California Public Utilities Commission adopted prior federal estimates of the social cost of carbon dioxide as published in the Interagency Working Group on Social Cost of Carbon's 2015 update to the Technical Support Document. Values are adjusted for inflation and expressed in 2018 U.S. dollars using the United States Gross Domestic Product Price Index from the U.S. Department of Commerce, Bureau of Economic Analysis.

[a]The high-impact estimates are meant to represent low-probability but high-impact damages from climate change and are the result of averaging the damages in the 95th percentile—that is higher

than 95 percent of the damage results for each model—across all three of the integrated assessment models and then applying a 3 percent discount rate.

A 2019 decision by the commission adopting a set of polices to establish a cost-effectiveness framework for distributed energy resources provided, among other things, that the commission will use social cost of carbon estimates on a trial basis for potential use in integrated resource planning.[70] An official told us the commission is testing in a trial whether a societal cost test, which would include using estimates of the social cost of carbon to account for avoided emissions, is useful in assessing whether distributed energy resources will help meet California's carbon reduction objectives. During the trial period, which ends in December 2020, the official said the commission would be using the test for informational purposes and not as a factor in whether to approve a resource plan.

State officials from both the board and commission told us that using a social cost of carbon that accounts for global, rather than domestic, climate damages is most appropriate because carbon dioxide is a global pollutant—that is, carbon dioxide emissions from one country cause damages that are felt across the globe. Furthermore, board officials said they did not use the 7 percent discount rate recommended by OMB Circular A-4 to estimate the social cost of carbon for two reasons: (1) the 7 percent discount rate is intended to reflect returns on capital and is not applicable to the effects of greenhouse gas emissions and (2) that using such a high discount rate too greatly diminishes the benefits of actions taken now to prevent damages that future generations will otherwise experience.

Minnesota

In 2018, Minnesota's utility regulator, the Minnesota Public Utility Commission, developed estimates of the social cost of carbon for utility resource planning based on the prior federal estimates but with modifications, including shortening the time period for projected climate

[70]Public Utilities Commission of the State of California, *Decision Adopting Cost-Effectiveness Analysis Framework Policies for All Distributed Energy Resources*, Rulemaking 14-10-003 (May 16, 2019). A utility resource plan consists of a set of options to meet the service needs of utility customers over a forecast period. According to the Federal Energy Regulatory Commission, distributed energy resources are typically small and geographically dispersed generation resources such as solar or combined heat and power.

damages (see table 4).[71] The commission requires utilities to use its estimates of the social cost of carbon in their resource plans to account for the cost of carbon dioxide emissions.[72] According to a Minnesota state official we interviewed, the commission is most likely to select the resource plan that provides the greatest net benefit for the state in the greatest number of planning scenarios.

The commission stated that to address some of the inherent uncertainties in estimating the long-term damage costs of carbon emissions, it elected to adopt a broader rather than a narrower range of social cost of carbon estimates—that is, by adopting low as well as high estimates for each emissions year. To develop its low estimates, the commission used a 5 percent discount rate like the prior federal estimates but shortened the time period for projected damages to the year 2100 because, in the commission's view, projected damages after that point had greater uncertainty as they were extrapolated mathematically and not fully modelled.[73] This step lowered the commission's estimates relative to the prior federal estimates on which they were based. To develop a set of high estimates, the commission used a 3 percent discount rate and projected damages through the year 2300 (the same as the prior federal estimates).[74]

[71]The Minnesota Public Utilities Commission presents its estimates in its order establishing environmental cost values. Minnesota Public Utilities Commission, *Order Updating Environmental Cost Values*, Docket E-999/CI-14-643 (Jan. 3, 2018).

[72]Minnesota Public Utilities Commission, *Order Updating Environmental Cost Values* (Jan. 3, 2018).

[73]The Minnesota Public Utility Commission based its estimates on the federal government's prior estimates published in 2015. See Interagency Working Group on Social Cost of Carbon, United States Government, *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (Washington, D.C.: July 2015). The prior federal estimates were modeled on damages projected through 2300 but, as discussed earlier, required assumptions about key inputs after the year 2100.

[74]The Minnesota Public Utility Commission developed estimates of the social cost of carbon dioxide. An official stated that the commission does not require the use of social costs of other greenhouse gases—such as, methane or nitrous oxide—in utility resource planning. This is because, according to the commission's order, carbon dioxide represents 99 percent of greenhouse gas emissions, and therefore, an accurate estimate of its environmental cost will account for almost all greenhouse gas costs.

Table 4: Social Cost of Carbon Estimates Developed by the Minnesota Public Utilities Commission per Short Ton of Carbon Dioxide in 2018 U.S. Dollars, 2020-2050

Year of emissions	Low estimate[a]	High estimate[b]
2020	$10	$45
2030	$12	$54
2040	$14	$64
2050	$16	$73

Source: GAO analysis of data from Minnesota Public Utilities Commission, Order Updating Environmental Cost Values (2018). | GAO-20-254

Note: The Minnesota Public Utilities Commission based its estimates on the prior federal estimates of the social cost of carbon dioxide as published in the Interagency Working Group on Social Cost of Carbon's 2015 update to the Technical Support Document, but with modifications. A short ton is a measure equal to 2,000 pounds, whereas metric tons (which are the units used for the prior federal estimates) equal 1,000 kilograms or approximately 2,204.6 pounds. The estimate values are adjusted for inflation and expressed in 2018 U.S. dollars using the United States Gross Domestic Product Price Index from the U.S. Department of Commerce, Bureau of Economic Analysis.

[a]Based on climate damages projected through calendar year 2100 and discounted at a 5 percent rate.

[b]Based on climate damages projected through calendar year 2300 and discounted at a 3 percent rate.

The commission adopted modified versions of the prior federal estimates to balance the recommendations of state agencies that called for directly adopting the prior federal estimates with the recommendations of an administrative law judge who called for more extensive modifications, according to the order we reviewed. To develop its estimates, the commission requested that two state agencies—the Minnesota Pollution Control Agency and Minnesota Department of Commerce—convene a stakeholder group to provide recommendations on how the commission should investigate the issue of the environmental costs of generating electricity. In response, among other things, in 2014 the agencies recommended that the commission adopt the federal government's estimates of the social cost of carbon as the environmental costs of carbon dioxide. Officials from the agencies told us that they advised the commission to adopt the prior federal estimates of the social cost of carbon because the estimates represented the best available science. Both agencies concluded that using estimates based on global damages was most appropriate because carbon dioxide is a pollutant that causes negative effects that are not limited to the country where it is emitted, according to the agencies' report to the commission we reviewed and our discussions with agency officials.[75] Both agencies also advocated using discount rates of 5 percent and lower as were used for the prior federal estimates. An agency official we interviewed explained that using a higher discount rate—such as 7 percent as suggested by OMB—was inappropriately high for valuing the effects of actions taken today on future generations.

In 2015 and 2016, an administrative law judge presided over evidentiary hearings at the request of the commission to address whether the prior federal social cost of carbon was reasonable and the best available measure to determine the environmental cost of carbon dioxide emissions under Minnesota law, and, if not, what measure was better supported by the evidence. Based on evidence and testimony presented by environmental and economic experts, as well as advocates representing environmental and business concerns, the judge found that the federal government's prior estimates generally provided a practicable basis for quantifying a range of environmental costs associated with carbon dioxide emissions, although the judge noted several shortcomings.[76] The Minnesota Public Utilities Commission concurred with the judge that the prior federal cost of carbon provided the best framework from which to establish a range of environmental costs associated with carbon dioxide emissions for purposes of Minnesota law, although it declined to adopt several of the judge's specific recommendations.[77]

Nevada

In 2018, Nevada's state utility regulator identified the prior federal estimates as an example that utilities may use to meet state requirements

[75]Minnesota Department of Commerce and Minnesota Pollution Control Agency, *Comments of the Minnesota Department of Commerce, Division of Energy Resources and the Minnesota Pollution Control Agency* (Docket No. E999/CI-00-1636, Jun. 10, 2014).

[76]For example, the judge found that the federal damage estimates beyond calendar year 2100 had greater uncertainty and recommended that the Commission decline to consider carbon dioxide costs accruing after the year 2200 when calculating the social cost of carbon dioxide.

[77]State of Minnesota, Office of Administrative Hearings, *For the Public Utilities Commission: In the Matter of the Further Investigation into Environmental and Socioeconomic Costs Under Minnesota Statutes Section 216B.2422, Subdivision 3, Findings of Fact, Conclusions, and Recommendations: Carbon Dioxide Value* (OAH 80-2500-31888, MPUC E-999/CI-14-643: Jan. 2018). Specifically, the Commission declined to use the 2.5% discount rate used by the federal Interagency Working Group. It also declined to adopt a range of values based on damage estimates calculated through the year 2200 as recommended by the judge, and instead adopted a range of costs that included one estimate calculated through 2100 and another calculated through 2300.

to account for the environmental costs of carbon dioxide emissions when submitting energy resource plans for consideration, according to an order we reviewed and officials we interviewed.[78] State law requires the Nevada Public Utility Commission to give preference to energy providers that, among other things, reduce customer exposure to the price volatility of fossil fuels and the potential costs of carbon.[79] The commission held public workshops from October 2017 to July 2018 to determine the best method to meet this requirement and, based on the results of the workshops, subsequently amended its regulations to require the use of a social cost of carbon based on global climate costs (i.e., damages) and the best available science and economics in utility resource plans.[80] Officials said the regulations do not specify the social cost of carbon estimates that utilities must use in their proposed resource plans, but the regulations identified the federal government's prior estimates as an example of estimates calculated using the best available science and economics that could fulfill the commission's requirement.[81] According to Nevada officials, the regulations provide utilities the flexibility to use estimates other than the prior federal estimates to represent the environmental cost of carbon dioxide emissions, as long as the utilities justify why the estimates they use are representative of the best available science and economics.

New York

Officials with three New York state agencies told us they use social cost of carbon estimates that the state utility regulator, the New York State Public Service Commission, developed by adopting some of the prior federal estimates. A 2016 New York State Public Service Commission order outlines a cost-benefit analysis framework for evaluating proposals to help implement the state's clean energy strategy, including a requirement to account for carbon dioxide emissions by using the prior

[78]Public Utilities Commission of Nevada, Investigation and rulemaking to implement Senate Bill 65 (2017), Docket 17-07020 (August 2018).

[79]Nev. Rev. Stat. § 704.746(5)(e).

[80]Nev. Admin. Code § 704.937.

[81]Specifically, the regulations pointed to the federal government's prior estimates published in 2016. See Interagency Working Group on Social Cost of Greenhouse Gases, United States Government, *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866* (Washington, D.C.: August 2016).

federal estimates of the social cost of carbon.[82] The order adopted the prior federal estimates of the social cost of carbon that were based on a 3 percent discount rate (see table 5).

Table 5: Social Cost of Carbon Estimates Developed by New York State Agencies per Metric Ton of Carbon Dioxide in 2018 U.S. Dollars, 2020-2050

Year of emissions	3 percent discount rate
2020	$52
2030	$62
2040	$73
2050	$86

Source: GAO analysis of data from New York Public Services Commission, Order Establishing the Benefit Cost Analysis Framework. | GAO-20-254

Note: New York state agencies adopted prior federal estimates of the social cost of carbon dioxide as published in the Interagency Working Group on Social Cost of Carbon's 2013 update to the Technical Support Document. Values are adjusted for inflation and expressed in 2018 U.S. dollars using the United States Gross Domestic Product Price Index from the U.S. Department of Commerce, Bureau of Economic Analysis.

The commission uses the social cost of carbon estimates for conducting regulatory activities and implementing programs, according to officials we interviewed. For example, the commission uses the estimates to help calculate the credits it provides to clean energy generators, such as community solar generators, as incentives to participate in clean energy programs.[83] Commission officials told us they use the prior federal estimates that were based on a 3 percent discount rate.[84]

The New York State Energy Research and Development Authority follows the commission's framework and uses the social cost of carbon estimates to conduct studies that inform state energy policy and program

[82]State of New York Public Service Commission, Order Establishing the Benefit Cost Analysis Framework, Case 14-M-0101 (Jan. 21, 2016), Appendix C. State of New York Public Service Commission, *Benefit Cost Analysis Framework.*

[83]Clean energy credits, according to Public Service Commission officials, are the higher of the social cost of carbon or the marginal abatement cost.

[84]New York state agencies use social cost of carbon estimates discounted at 3 percent as presented by the IWG in 2013. Interagency Working Group on Social Cost of Carbon, United States Government, *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866* (Washington, D.C.: May 2013).

investment decisions.[85] According to authority officials, they conduct studies, such as an analysis performed for New York's 2018 Offshore Wind Master Plan, using the estimates to determine if energy policies will benefit the state and consider whether energy resources under consideration are technologically and economically feasible.[86] Additionally, officials from New York's environmental regulator, the Department of Environmental Conservation, said they use the estimates when accounting for avoided emissions in internal policy analyses.

New York officials we spoke with said they chose to use a social cost of carbon that accounts for global, rather than domestic, climate damages because carbon dioxide is a global pollutant. Officials said using a social cost of carbon based on only domestic damages ignores the fundamental externality problem of greenhouse gas emissions—that is, carbon dioxide emissions cause warming and resulting damages worldwide. Officials said if countries only consider the domestic damages of their carbon dioxide emissions then they would undervalue the potential benefits of emissions reductions policies, thereby dissuading needed action. Furthermore, agency officials said they chose to use a social cost of carbon based on a 3 percent discount rate, as opposed to the 7 percent discount rate recommended by OMB Circular A-4, because using a lower rate is more appropriate for assessing the long-term externality costs of carbon dioxide emissions.

[85]The New York State Energy Research and Development Authority's mission is to develop a more reliable and affordable energy system in New York and promote energy efficiency and renewable energy resources.

[86]New York State Energy Research and Development Authority, *New York State Offshore Wind Master Plan: Charting a Course to 2,400 Megawatts of Offshore Wind Energy* (January 2018).

Selected Countries Have Developed and Used Monetary Estimates for Emissions Based on the Social Cost of Carbon and Target-Consistent Approaches

Of the four selected countries in our review, two have developed and used monetary estimates for greenhouse gas emissions based on the social cost of carbon (i.e., damage costs) approach, and the two other selected countries based their estimates on the target-consistent approach. Canada has adopted and used some of the prior U.S. federal estimates of the social cost of carbon, and Germany has developed and used its own estimates of the social cost of carbon.[87] In contrast, France and the United Kingdom have developed and used estimates based on the target-consistent approach, which involves estimates that are based on the projected least costly pathway for meeting national emissions targets.[88]

Canada and Germany Have Developed and Used Monetary Estimates for Greenhouse Gas Emissions Based on the Social Cost of Carbon Approach

Canada and Germany both developed monetary estimates for greenhouse gas emissions using the social cost of carbon approach. Canadian and German officials said they chose to develop estimates using the social cost of carbon approach because it allows emissions to be measured in terms of their impacts on society, which according to these officials, is how externalities are typically included in government cost-benefit analyses. To develop its estimates, Canada adopted some of the prior U.S. federal estimates of the social cost of carbon.[89] Specifically, for each emissions year Canada adopted two of the four prior U.S. estimates. As its primary estimates, Canada adopted those calculated using a 3 percent discount rate and, for use in sensitivity analysis, Canada adopted the U.S. high-impact estimates that represent lower-probability but high-impact damages (see table 6).

[87]For the purposes of this report, when we refer to these countries by name, we mean their central or federal governments. Also in this report, we refer to the German government approach as the social cost of carbon for purposes of consistency, but in a key German technical document it is referred to as a damage costs approach.

[88]The French government generally uses the term “cost-effectiveness approach” instead of target-consistent approach, and “cost-benefit approach” instead of the social cost of carbon approach. In this report, for consistency, we refer to both the French and UK approaches as the target-consistent approach.

[89]As stated in its technical document, Canada adopted some of the prior U.S. federal estimates of the social cost of carbon (as published by the IWG in 2015 and converted by Canada to 2012 Canadian dollars). See Environment and Climate Change Canada, *Technical Update to Environment and Climate Change Canada’s Social Cost of Greenhouse Gas Estimates* (Gatineau, Quebec: March 2016).

Table 6: Social Cost of Carbon Estimates Developed by Canada per Metric Ton of Carbon Dioxide in 2018 U.S. Dollars, 2020-2050

Year of emissions	Primary estimates (based on 3% discount rate)	High-impact estimates (based on 3% discount rate)[a]
2020	$38	$159
2030	$45	$197
2050	$62	$267

Source: GAO analysis of data from Environment and Climate Change Canada. | GAO-20-254

Note: Official estimates for Canada were adjusted for inflation by converting from 2012 to 2018 Canadian dollars using the gross domestic product (GDP) deflator for Canada from the Organisation for Economic Co-operation and Development retrieved from FRED (Federal Reserve Bank of St. Louis). The estimates were then converted to U.S. dollars using daily representative exchange rates from the International Monetary Fund averaged over calendar year 2018.

[a]Canada's high-impact estimates are used for sensitivity analysis and, as adopted from the U.S. Interagency Working Group on Social Cost of Carbon, represent the 95th percentile of the estimates discounted at a 3 percent rate. These estimates represent higher-than-expected damages from temperature changes—that is, low-probability but high-impact damages.

Germany developed two social cost of carbon estimates for each emissions year, a primary estimate and a high-impact estimate for use in sensitivity analysis, that were produced using a single integrated assessment model (see table 7).[90]

[90]Germany adopted climate damages estimates produced using the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) integrated assessment model. See David Anthoff, *Report on marginal external damage costs inventory of greenhouse gas emissions* (Hamburg: Hamburg University, 2007). The German estimates also reflect climate damages that are weighted based on a region's relative wealth—that is, a method known as equity weighting—according to German officials because climate damages that happen in a region with relatively less wealth (measured in gross domestic product per capita) will have a greater negative impact on the region than in a richer region.

Table 7: Social Cost of Carbon Estimates Developed by Germany per Metric Ton of Carbon Dioxide in 2018 U.S. Dollars, 2016-2050

Year of emissions	Primary estimates	High-impact estimates[a]
2016	$218	$776
2030	$248	$812
2050	$291	$885

Source: GAO analysis of data from Germany's Federal Environment Agency (UBA). | GAO-20-254

Note: Official values for Germany were adjusted for inflation by converting from 2016 to 2018 euros using the gross domestic product (GDP) deflator for Germany from the Organisation for Economic Co-operation and Development retrieved from FRED (Federal Reserve Bank of St. Louis). The values were then converted to U.S. dollars using daily representative exchange rates from the International Monetary Fund averaged over calendar year 2018. The German Federal Environment Agency provided values for only 2016, 2030, and 2050; the agency recommended that agencies interpolate linearly between years for which no values are indicated.

[a]Germany's high-impact values are used for sensitivity analysis and represent the projected damages from emissions using an effective discount rate that is based on a pure rate of time preference with a value of zero percent. The effective discount rate is determined inside the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) model using a Ramsey-like formula that incorporates the pure rate of time preference, the marginal utility of income, and GDP growth rates.

Canadian and German officials we interviewed said they chose to develop estimates based on global climate damages because greenhouse gas emissions cause damages worldwide regardless of where they are originally emitted. According to Canadian and German documents we reviewed and officials we interviewed, if all countries only accounted for the domestic damages caused by their emissions, then not all relevant climate damages would be accounted for globally because each country would be ignoring the damages its emissions cause in other countries, which could limit the potential for global action to mitigate climate change.

Canada and Germany differed in their choices of discount rates, but both countries chose discount rates that took into account the long-term nature of climate damages from greenhouse gas emissions, according to documents we reviewed and officials we interviewed. Canadian officials said they adopted the prior U.S. federal estimates that were discounted at a 3 percent rate because their national guidance calls for using such low discount rates in circumstances where impacts occur over a long time horizon or where environmental and human health are involved.[91]

[91]See Treasury Board of Canada Secretariat. *Canadian Cost-Benefit Analysis Guide: Regulatory Proposals* (2007).

Alternatively, Germany chose to use discount rates that are not constant and instead change over time based on the level of projected economic growth, according to German officials.[92] Specifically, Germany's discount rate for its primary estimates starts near 3 percent in 2006 and declines to 2 percent by 2250. For its high-impact estimates, Germany's discount rate starts near 2 percent and declines to 1 percent by 2250.[93] Canadian and German officials said they chose their respective discount rates because climate change will cause environmental impacts and damages over a long time span.[94]

Canada and Germany differed in how they developed monetary estimates for other greenhouse gases. Canada adopted the prior U.S. federal estimates of the social cost of nitrous oxide and the social cost of methane.[95] In contrast, according to documents we reviewed and officials we interviewed, Germany calculates monetary estimates for nitrous oxide and methane emissions by multiplying the United Nation's

[92]This is reflected in the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) model's Ramsey-based discounting formula. Specifically the discount rate based on the Ramsey formula incorporates the pure rate of time preference (i.e., the rate of discount of future welfare), the marginal utility of income (i.e., the change in the value of money as society gets wealthier), and the projected growth in gross domestic product per capita. In this setup, the FUND model assumes that the gross domestic product per capita growth rate declines over time, which causes the overall discount rate to go down over time in the FUND model's projections.

[93]One component of the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) model's Ramsey formula is the pure rate of time preference between future and current consumption that is ascribed to society. German officials said they chose a 1 percent pure rate of time preference for its central estimates and 0 percent for its estimates for sensitivity analysis.

[94]Canadian and German officials said that because climate damages occur over a long time span, using a higher discount rate—such as 7 percent to represent the opportunity cost of capital as specified by OMB—would significantly diminish how future damages are valued. According to Canadian officials, using a discount rate higher than 3 percent would not necessarily be appropriate for discounting climate damages.

[95]As stated in its technical document, Canada adopted some of the prior U.S. federal estimates of the social cost of nitrous oxide and social cost of methane (as published by the IWG in 2016 and converted by Canada to 2012 Canadian dollars). See Environment and Climate Change Canada, *Technical Update to Environment and Climate Change Canada's Social Cost of Greenhouse Gas Estimates* (Gatineau, Quebec: March 2016).

Intergovernmental Panel on Climate Change's Global Warming Potential factor for each gas by its monetary estimates for carbon dioxide.[96]

According to documents we reviewed and officials we interviewed, Canada and Germany both use their monetary estimates for greenhouse gas emissions in cost-benefit analysis of policies, regulations, or projects, including those meant to help achieve emissions reduction goals tied to their respective national climate change strategies. The Canadian national government uses its monetary estimates for greenhouse gas emissions in cost-benefit analyses to evaluate all federal regulations affecting such emissions, including regulations that are meant to help implement the Canadian national climate change strategy, according to officials.[97] For example, the Canadian national government has used its monetary estimates in regulatory impact analyses for regulations creating emissions standards for coal-fired electricity producers. Germany's Umweltbundesamt (the German Environment Agency, or UBA), the country's main federal environmental protection agency, has used its monetary estimates for greenhouse gas emissions to evaluate policies developed to meet its 2030 contribution to Germany's Climate Action Plan of 2016, which set a national goal of reaching carbon neutrality by 2050, according to German officials.[98] For more information on Canada and Germany's approaches, see appendixes IV and V, respectively.

[96]See Dr. Astrid Matthey and Dr. Björn Bünger, Umweltbundesamt (German Environment Agency), *Methodological Convention 3.0 for the Assessment of Environmental Costs* (Dessau-Rosslau: September 2018). The Global Warming Potential factor was developed to allow comparisons of the global warming potential of different gases. Specifically, it is a measure of how much energy the emissions of one metric ton of a gas will absorb over a given period of time, relative to the emissions of one metric ton of carbon dioxide.

[97]Canada's national climate change strategy, the Pan-Canadian Framework on Clean Growth and Climate Change of 2016, guides Canada's efforts to reduce greenhouse gas emissions and sets an emissions target of a 30 percent reduction from 2005 levels by 2030. See Environment and Climate Change Canada, *Pan-Canadian Framework on Clean Growth and Climate Change: Canada's plan to address climate change and grow the economy* (Gatineau, Quebec: 2016).

[98]Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, *Climate Action Plan 2050: Principles and goals of the German government's climate policy* (Berlin, Germany: November 2016).

France and the United Kingdom Have Developed and Used Monetary Estimates for Greenhouse Gas Emissions Based on the Target-Consistent Approach

France and the United Kingdom have both developed and used monetary estimates for greenhouse gas emissions based on the target-consistent approach (see table 8). Officials in both France and the United Kingdom said their monetary estimates represent the minimum costs of reducing greenhouse gas emissions to meet their respective national emissions reduction targets.

Table 8: Monetary Estimates for Greenhouse Gases Based on the Target-Consistent Approach Developed by France and the United Kingdom per Metric Ton of Carbon Dioxide in 2018 U.S. Dollars, 2020-2050

Year of emissions	France	United Kingdom (Non-traded sectors)	United Kingdom (Emissions-trading sectors)[a]
2020	$103	$93	$19
2030	$295	$108	$108
2050	$916	$309	$309

Sources: GAO analysis of data from France Stratégie and the United Kingdom's Department for Business, Energy & Industrial Strategy. | GAO-20-254

Note: We converted French and UK values from 2018 euros and pounds, respectively, to U.S. dollars using daily representative exchange rates from the International Monetary Fund averaged over calendar year 2018.

[a]Converges with modeled estimates for non-traded sectors beginning in 2030.

To develop their monetary estimates, both countries used economic modeling and other techniques to determine the least costly pathway to meet their respective national emissions targets, according to documents we reviewed and officials we interviewed.[99] As a result, under both countries' approaches, the monetary estimates were determined in relation to the costs that would have to be borne by each country to reduce emissions to an agreed-to level. French and UK officials said they chose to use the target-consistent approach because their countries had

[99]France convened a commission made up of 20 experts and economists on the environment that included academics, research centers, non-governmental organizations, and government officials, according to the commission documents we reviewed. Five different modeling teams contributed to the commission's work. The United Kingdom's Department of Energy & Climate Change, which is now part of the Department for Business, Energy & Industrial Strategy, conducted economic modeling to determine the United Kingdom's monetary values, according to documents we reviewed. See appendixes VI and VII for more information on each country's approach.

set explicit emissions reduction targets aligned with their commitments to meet international climate goals, particularly the 2015 Paris Agreement's goals to keep global temperature rise this century below 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit the temperature rise to 1.5 degrees Celsius.[100] French and UK officials said the goals set in the Paris Agreement were based on leading science and economics. France calculated its monetary estimates based on a target of reaching net-zero emissions (i.e., carbon neutrality) by 2050 as outlined in its National Low Carbon Strategy.[101] The United Kingdom calculated its monetary estimates based on a target of an 80 percent reduction in emissions from 1990 levels by 2050, as stipulated in its 2008 Climate Change Act as originally enacted.[102] French and UK officials said that having monetary estimates for greenhouse gas emissions based on these targets allows their governments to identify and evaluate regulations and projects that can help meet their targets at the lowest cost.

Both countries' estimates were developed by calculating the costs of reducing emissions across sectors of their economies, such as in energy or transportation, based on how ambitious the target is and the technologies available in each sector to reduce emissions. For example, for the energy sector, French officials said the costs would represent those technologies needed to transition from fossil fuels to renewable energy sources or to improve energy efficiency. Additionally, the United

[100]The 2015 Paris Agreement is an international agreement between countries that set a goal of limiting global warming to well below 2 degrees Celsius and to pursue efforts to limit warming to 1.5 degrees Celsius. As of February 27, 2020, 189 countries had ratified the agreement.

[101]Ministère de la Transition Écologique et Solidaire (Ministry for an Ecological and Inclusive Transition), *National Low Carbon Strategy Project: The ecological and inclusive transition towards carbon neutrality* (December 2018). Net-zero emissions refers to gross greenhouse gas emissions being fully compensated by carbon absorption sinks, which are natural systems such as forests that absorb and store carbon dioxide from the atmosphere.

[102]UK Public Acts, *Climate Change Act 2008*, c. 27. See also Department for Business, Energy & Industrial Strategy, *The Clean Growth Strategy: Leading the way to a low carbon future* (October 2017). Specifically, the strategy outlines UK government actions to meet legally binding interim targets. For example, the United Kingdom has set a series of intermediate 5-year interim targets covering the period to 2032, such as a 57 percent reduction of emissions by 2032. The United Kingdom's devolved administrations—Wales, Scotland, and Northern Ireland—have additional plans and policies to deliver emissions reductions. However, in June 2019 the United Kingdom amended its legal target to net-zero emissions, as compared to 1990 levels, by 2050, which, according to UK officials, was also informed by the 2015 Paris Agreement. UK officials said they were likely to re-evaluate their monetary estimates in light of their change in target level of emissions.

Kingdom uses European Union emissions trading system prices for its monetary estimates for economic sectors, including the UK power and industrial sectors, that are covered under the system because the trading system's emissions cap is treated as a target level of emissions for those sectors, according to a UK government guidance document we reviewed.[103]

Both countries' monetary estimates increase significantly over time, reflecting that abatement costs will rise over time as emissions targets become more stringent and as more expensive abatement measures will need to be employed, according to officials we interviewed.[104] For example, France's target for 2030 of reducing overall emissions in its economy by 40 percent relative to 1990 levels rises to a target of net-zero emissions by 2050. French and UK documents we reviewed stated that more expensive abatement measures will be needed to further reduce emissions in economic sectors, such as energy and agriculture, once less-expensive abatement measures have already been implemented. As a result, the countries' monetary estimates rise as greater emissions reductions are required in these sectors to meet the national targets. In addition, French and UK documents we reviewed stated that in the least cost pathway, more expensive abatement options should be taken in later years to smooth the near-term burden on the economy and to allow for the possibility that new technology may become available to abate emissions in difficult sectors.

Officials we interviewed from both countries said the target-consistent approach was more certain than the social cost of carbon approach for several reasons. For example, they said the models used to develop social cost of carbon estimates do not take into account all relevant damages, including the potential for catastrophic damages or damages that accelerate in unforeseen ways after climate tipping points are passed, and could thereby significantly underestimate damages. The officials said their emissions targets aimed to maintain a safer level of

[103]Department of Energy and Climate Change, *Carbon Valuation in UK Policy Appraisal: A Revised Approach* (London: July 2009). The European Union emissions trading system is a market-based approach to reducing greenhouse gas emissions. A cap or limit is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system and the cap is reduced over time so that total emissions fall. Within the cap, companies receive or buy emission allowances that they can trade with one another. United Kingdom officials said the monetary values in the emissions trading system are assumed to converge with its modeled target-consistent values in 2030.

[104]Improving energy efficiency in buildings by installing insulation is an example of an emissions abatement measure.

planetary warming given the risks of irreversible or catastrophic damages that climate damages models cannot adequately take into account. Further, the officials said that monetary estimates based on climate damages were more sensitive to differences in key assumptions than estimates under the target-consistent approach, such as the discount rate and how climate impacts are converted into damages, which can therefore lead to a wide range of potential values. For example, according to a UK government guidance document, monetary estimates based on climate damages could range from £0 to over £1000 per metric ton of carbon dioxide depending on the assumptions made.[105]

Both France and the United Kingdom use their target-consistent monetary estimates for greenhouse gas emissions to plan actions meant to help them meet their emissions reductions targets. French and UK officials said that monetary estimates serve as reference values for government agencies to determine which policies, regulations, and investment projects would be most cost-effective in meeting emissions reductions targets. For example, French officials said that if a proposed policy or project's costs, such as subsidies encouraging consumers to purchase more fuel-efficient automobiles, per unit of abated emissions were greater than the government's target-consistent monetary estimates, then the proposed policy or project may not be cost-effective—that is, it is more expensive than other available abatement measures that are capable of ensuring that France meets its emissions reduction targets. Officials said their monetary estimates help guide government decision-making to avoid taking either too little action or too costly of actions to meet their targets.

France and the United Kingdom also use their monetary estimates for greenhouse gas emissions more broadly throughout their governments in policy, regulatory, and project cost-benefit analysis. For example, according to French officials, the French government must conduct an economic cost-benefit analysis for government investment projects, including major projects like improvements to the nation's electricity grid or smaller-scale projects like retrofits of public buildings or construction of hospitals, and these analyses use France's monetary estimates for greenhouse gas emissions. In addition, officials said the United Kingdom has used its monetary estimates when developing and evaluating regulations and policies, such as housing regulations and a policy providing subsidies to purchase electric vehicles. For more information on

[105]Department of Energy and Climate Change, *Carbon Valuation in UK Policy Appraisal* (July 2019).

the approaches of France and the United Kingdom, see appendixes VI and VII, respectively. For more information on the views of officials from the four selected countries we reviewed on the strengths and challenges of the social cost of carbon and target-consistent approaches, see appendix VIII.

Conclusions

The federal government is currently using interim estimates of the social cost of carbon in its regulatory impact analyses, in part, to help weigh the potential costs of taking actions to reduce emissions against their expected benefits. The federal agencies we reviewed stated that the social cost of carbon estimates that they have used are interim until more comprehensive estimates become available that reflect the 2017 recommendations of the National Academies, which called for comprehensively updating the methods used to develop the estimates in order to ensure they reflected the best available science. However, since the National Academies issued its recommendations, the IWG has been disbanded, and no federal agency has been given the responsibility of addressing the recommendations. OMB continues to play a leading role in the federal government's use of the social cost of carbon, as one of the entities that convened the IWG and as having responsibility for OMB's guidance in Circular A-4. Without identifying a federal entity or entities to be responsible for addressing the National Academies' recommendations, including monitoring scientific research and ensuring that updates to the federal estimates consider such research, the federal government may not be well positioned to ensure agencies' future regulatory analyses are using the best available science.

Recommendation for Executive Action

We are making the following recommendation to OMB:

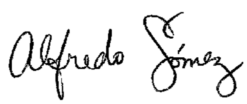
- The Director of OMB should identify a federal entity or entities to be responsible for addressing the National Academies' recommendations for updating the methodologies used to estimate the federal social cost of carbon, including monitoring scientific research and ensuring that updates to the federal estimates consider such research as appropriate. (Recommendation 1)

Agency Comments

We provided a draft of this report to the Departments of the Interior and Transportation, EPA, and OMB for review and comment. Interior and Transportation informed us that they had no formal comments on the draft report and provided technical comments only, which we incorporated as appropriate. EPA informed us that they had no comments on the draft report. At its request, we gave OMB additional time for review and comment. However, OMB did not provide comments.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to the appropriate congressional committees, the Secretaries of the Interior and Transportation, the Administrator of EPA, the Director of OMB, and other interested parties. In addition, the report will be available at no charge on the GAO website at http://www.gao.gov.

If you or your staff members have any questions about this report, please contact me at (202) 512-3841 or gomezj@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report are listed in appendix IX.



J. Alfredo Gómez
Director, Natural Resources
and Environment

List of Requesters

The Honorable Sheldon Whitehouse
Ranking Member
Subcommittee on Clean Air and Nuclear Safety
Committee on Environment and Public Works
United States Senate

The Honorable Carolyn B. Maloney
Chairwoman
Committee on Oversight and Reform
House of Representatives

The Honorable Michael F. Bennet
United States Senate

The Honorable Benjamin L. Cardin
United States Senate

The Honorable Dianne Feinstein
United States Senate

The Honorable Kamala D. Harris
United States Senate

The Honorable Jeffrey A. Merkley
United States Senate

The Honorable Elizabeth Warren
United States Senate

Appendix I: Objectives, Scope, and Methodology

Our work for this report reviewed how the federal government, U.S. states, and foreign countries have developed and used monetary estimates of the effects of carbon dioxide and other greenhouse gas emissions in regulatory and policy cost-benefit analysis—in the form of the social cost of carbon or other valuation methods. For the purposes of this report, the term social cost of carbon encompasses monetary estimates for each of three key greenhouse gases: carbon dioxide, methane, and nitrous oxide. This report examines (1) how the federal government's current estimates of the social cost of carbon compare to prior estimates and how selected federal agencies have used the current estimates in recent rulemakings; (2) how the federal government plans to address the recommendations made by the National Academies of Sciences, Engineering, and Medicine for updating estimates of the social cost of carbon; (3) how selected U.S. states have developed and used estimates of the social cost of carbon, or other valuation methods; and (4) how selected foreign countries have developed and used estimates of the social cost of carbon, or other valuation methods.

To examine how the federal government's current estimates of the social cost of carbon compare to prior estimates and how selected federal agencies have used the current estimates in recent rulemakings, we reviewed how federal agencies estimated the social cost of carbon for use in regulatory cost-benefit analyses before and after the agencies updated their estimates in response to Executive Order 13783, which was issued in March 2017.[1] To examine the federal government's current estimates, we reviewed several recent rulemakings that were issued between March 2017 and January 2019 and that used estimates of the social cost of carbon in their regulatory impact analyses and specifically mentioned the use of these estimates in the preamble to the proposed or final rules.[2] We discussed the recent relevant rulemakings we identified with staff from the Office of Management and Budget (OMB) and officials at other relevant agencies; neither staff nor officials mentioned any

[1]Exec. Order No. 13783, 82 Fed. Reg. 16,093 (Mar. 28, 2017).

[2]We used several keywords to search the Federal Register for relevant proposed and final rules that were issued between March 2017 and January 2019 and in which the preamble discussed the relevant agency's use of estimates of the social cost of carbon and other greenhouse gases. We used keywords, such as "social cost of carbon," "social cost of methane," and "social cost of nitrous oxide," to search the Federal Register.

relevant rulemakings other than those we had identified.[3] Our search results identified final and proposed rules issued by the Department of the Interior's Bureau of Land Management (BLM), the Department of Transportation's National Highway Traffic Safety Administration (NHTSA), and the Environmental Protection Agency (EPA). We interviewed officials from these agencies to learn about the guidance, assumptions, and methods they used to develop their current estimates. We also interviewed OMB staff to learn about the office's role in providing oversight and guidance to the agencies on how to conduct cost-benefit analyses for their final and proposed rules. In addition, we reviewed federal direction and guidance on how agencies are to assess costs and benefits in regulatory analysis, including Executive Order 12866 and OMB Circular A-4.[4] To compare the current federal estimates to the prior estimates, we examined the prior estimates of the social cost of carbon found in a Technical Support Document and its subsequent updates issued from 2010 to 2016 by the Interagency Working Group (IWG) on Social Cost of Carbon (later the Interagency Working Group on Social Cost of Greenhouse Gases) and compared them to the current estimates in rulemakings issued since Executive Order 13783 was issued.[5]

To examine how the federal government plans to address the National Academies' recommendations for updating estimates of the social cost of carbon, we reviewed documents on how federal agencies have

[3]In May and July 2017, the Department of Energy (DOE) finalized a small number of regulations that were originally prepared using the federal government's prior estimates of the social cost of carbon as developed by the Interagency Working Group on Social Cost of Carbon (IWG). However, our search did not identify any DOE regulations using the federal government's current estimates after the issuance of Executive Order 13783. Therefore, we did not include DOE in the scope of our review.

[4]Exec. Order No. 12866, 58 Fed. Reg. 51,735 (Sept. 30, 1993); OMB, Circular A-4: Regulatory Analysis (Sept. 17, 2003).

[5]Interagency Working Group on Social Cost of Carbon, United States Government, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866* (Washington, D.C.: February 2010) and *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866* (Washington, D.C.: May 2013); this document was reissued with minor technical corrections in November 2013 and July 2015. Interagency Working Group on Social Cost of Greenhouse Gases, United States Government, *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866* (Washington, D.C.: August 2016) and *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* (Washington, D.C.: August 2016).

considered the National Academies' recommendations and their plans, if any, for addressing them. Specifically, we reviewed the same final and proposed rules and associated regulatory impact analyses that we selected to address our first objective to learn how the agencies had addressed, or planned to address, the National Academies' recommendations.[6] We interviewed officials with the agencies that had issued the final and proposed rules to understand their plans, if any, to address the National Academies' recommendations, including their plans to collaborate with other federal agencies and offices. We also interviewed one of the co-chairs of the committee that conducted the National Academies' review. We reviewed guidance in OMB Circular A-4 on how agencies are to assess costs and benefits in regulatory analysis.

To examine how selected U.S. states have developed and used estimates of the social cost of carbon, or other valuation methods, we sought to identify states using estimates based on both the prior and current federal estimates, or other valuation methods. Through our research, which included a search of literature and interviews with knowledgeable parties (including, among others, the Institute for Policy Integrity, Resources for the Future, and Carbon Brief), we did not identify any U.S. states using the current federal estimates, or other valuation methods. We identified nine U.S. states that called for using the prior federal estimates in state decision-making. Of these, we selected and reviewed a nonprobability sample of four U.S. states—California, Minnesota, Nevada, and New York—that we determined were the most relevant for our purposes based on the frequency by which they appeared in the literature we reviewed and the recommendations we received in interviews with knowledgeable stakeholders.[7] We reviewed documents and interviewed state officials to learn how the selected state governments developed and used the estimates in regulatory and project cost-benefit analyses—including their choices on specific components of the social cost of carbon, such as discount rates and scope of damages (i.e., global or domestic). Our findings from our review of these selected U.S. states cannot be generalized to all 50 U.S. states, but they present illustrative examples of how states have accounted for the effects of

[6]National Academies of Sciences, Engineering, and Medicine, *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide* (Washington, D.C: Jan. 11, 2017).

[7]We may not have identified all U.S. states calling for the use of the prior federal social cost of carbon estimates in state decision-making through our review of literature and interviews with knowledgeable parties. Therefore, the nine U.S. states we identified should not be considered a complete list of states relying on the prior federal estimates.

carbon dioxide or other greenhouse gases, in monetary terms, in their decision-making. We also selected a nonprobability sample of U.S. states—Montana and Texas—that had (1) submitted written comments on aspects of the prior federal estimates for rulemaking and raised issues with using them and (2) not developed or used estimates of the social cost of carbon at the time of our review according to our interviews with state officials.[8] We reviewed documents from and interviewed officials from Montana and Texas.

To examine how selected foreign countries have developed and used estimates of the social cost of carbon, or other valuation methods, we reviewed documents and interviewed government officials from Canada, France, Germany, and the United Kingdom on how their national governments have estimated monetary estimates for carbon dioxide and other greenhouse gas emissions for use in regulatory and project cost-benefit analysis. To identify these countries, we conducted a literature search to identify national governments that use monetary values for greenhouse gases in government cost-benefit analysis. We also interviewed knowledgeable stakeholders with expertise on the topic and sought their recommendations on which countries might be most relevant for our purposes. Our literature review included over 85 reports and studies from the National Academies, academia, international organizations, other governments, non-profits, and think tanks. Knowledgeable stakeholders we interviewed included academic researchers who focus on how to develop monetary estimates for greenhouse gas emissions in cost-benefit analysis and also officials from key international organizations or think tanks that have knowledge on how national governments have developed and used monetary estimates for greenhouse gas emissions in cost-benefit analysis and policy analysis more generally, such as the Organisation for Economic Co-operation and Development, the World Bank, and the International Monetary Fund.[9] We

[8]We approached officials from three states that had commented on the prior federal estimates of the social cost of carbon for proposed rulemaking. State officials from Kentucky (i.e., Kentucky’s Energy and Environment Cabinet) declined to speak with us on the social cost of carbon, so we did not include the state in our review.

[9]Reports we reviewed from knowledgeable stakeholders include the following: Organisation for Economic Co-operation and Development, Stephen Smith and Nils Axel Braathen, *Monetary Carbon Values in Policy Appraisal: An Overview of Current Practice and Key Issues* (Paris, OECD Environment Working Papers, No. 92, 2015); World Bank Group, *Pollution Prevention and Abatement Handbook*, (Washington, D.C.: 1998); and the International Monetary Fund, Ian Parry, Victor Mylonas, and Nate Vernon, *IMF Working Paper: Mitigation Policies for the Paris Agreement: An Assessment for G20 Countries*, WP/18/193 (Washington, D.C.: 2018).

selected the four countries for our review because we found them to be the most relevant for our purposes based on the literature we reviewed, and they were recommended as strong or particularly relevant illustrative examples in our interviews with knowledgeable stakeholders. Due to resource constraints, we could not review every country that has developed and used monetary estimates for greenhouse gas emissions for use in cost-benefit analysis. As a result, findings from the nonprobability sample of selected countries cannot be generalized to all countries worldwide but provide illustrative examples. Table 9 shows the national agencies for foreign countries from which we gathered documents and interviewed officials.

Table 9: Countries and National Agencies from which GAO Gathered Documents and Interviewed Officials about Development and Use of Monetary Estimates for Greenhouse Gas Emissions

Canada	France	Germany	United Kingdom
Environment and Climate Change Canada	Agence de l'environnement et de la maîtrise de l'energie (ADEME, or Environment & Energy Management Agency)	Umweltbundesamt (UBA, or German Environment Agency)	Committee on Climate Change
	CITEPA (Technical Reference Center for Air Pollution and Climate Change)	Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (BMU, or German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety)	Department for Business, Energy & Industrial Strategy
	Cours des comptes (Court of Audit)	Bundesrechungshof (German Supreme Audit Institution)	Department for Environment, Food & Rural Affairs
	France Stratégie		Department for Transport
	Direction générale du Trésor (General Directorate of the Treasury)		Her Majesty's Treasury
	Secrétariat générale pour l'Investissement (SGPI, or General Secretariat for Investment)		Ministry of Housing, Communities & Local Government
	Ministère de la transition écologique et solidaire – Direction générale de l'énergie et du climat (Ministry for the Ecological and Inclusive Transition – General Directorate for Climate and Energy)		

Canada	France	Germany	United Kingdom
	Ministère de la transition écologique et solidaire – Commissariat générale (Ministry for the Ecological and Inclusive Transition – Office of the Commissioner General)		

Source: GAO. | GAO-20-254

We conducted this performance audit from May 2018 to June 2020, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Current Federal Estimates of the Social Costs of Carbon Dioxide, Methane, and Nitrous Oxide

Following the issuance of Executive Order 13783 in March 2017, the Environmental Protection Agency (EPA) developed the current federal estimates of the social cost of carbon (for carbon dioxide, methane, and nitrous oxide) using the same models it had used to calculate the prior federal estimates.

Carbon Dioxide

EPA used its current estimates of the social cost of carbon dioxide in its regulatory impact analyses for the 2019 rulemaking that repealed the Clean Power Plan and replaced it with the Affordable Clean Energy Rule (see table 10).[1]

Table 10: Current Federal Estimates of the Social Cost of Carbon Dioxide per Metric Ton in 2018 U.S. Dollars, 2020-2050

Year of emissions	3 percent discount rate	7 percent discount rate
2020	$7	$1
2030	$8	$1
2040	$9	$2
2050	$11	$2

Source: GAO analysis of data from the Environmental Protection Agency (EPA). | GAO-20-254

Note: The current federal estimates of the social cost of carbon dioxide were originally reported in 2016 U.S. dollars in EPA's regulatory impact analysis for the 2019 Affordable Clean Energy Rule. We adjusted the values for inflation and expressed them in 2018 U.S. dollars using the United States Gross Domestic Product Price Index from the U.S. Department of Commerce, Bureau of Economic Analysis.

Methane

For its 2018 final regulation rescinding and revising certain requirements of the 2016 Waste Prevention Rule, the Bureau of Land Management (BLM) relied on EPA's current estimates of the social cost of methane in its regulatory impact analysis.[2] In terms of its impacts on climate, BLM's regulatory impact analysis focused primarily on the impacts of expected changes in methane emissions resulting from the regulation and,

[1]Environmental Protection Agency, Office of Air Quality Planning and Standards, *Regulatory Impact Analysis for the Repeal of the Clean Power Plan, and the Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units* (Research Triangle Park, NC: June 2019).

[2]Bureau of Land Management, *Regulatory Impact Analysis for the Final Rule to Rescind or Revise Certain Requirements of the 2016 Waste Prevention Rule* (Washington, D.C.: Aug. 31, 2018). For the final rule, *see* Waste Prevention, Production Subject to Royalties, and Resource Conservation; Rescission or Revision of Certain Requirements, 83 Fed. Reg. 49,184 (Sept. 28, 2018).

according to officials we interviewed, used estimates that EPA provided (see table 11).

Table 11: Current Federal Estimates of the Social Cost of Methane per Metric Ton in 2018 U.S. Dollars, 2020-2030

Year of emissions	3 percent discount rate	7 percent discount rate
2020	$184	$57
2030	$242	$85

Source: GAO analysis of data from the Bureau of Land Management (BLM). | GAO-20-254

Note: The current federal estimates of the social cost of methane were originally reported in 2016 U.S. dollars in BLM's regulatory impact analysis for the 2018 Final Rule to Rescind or Revise Certain Requirements of the 2016 Waste Prevention Rule. We adjusted the values for inflation and expressed them in 2018 U.S. dollars using the United States Gross Domestic Product Price Index from the U.S. Department of Commerce, Bureau of Economic Analysis. Unlike EPA, BLM included estimates only to 2030.

Nitrous Oxide

We did not find a recent rulemaking for the selected agencies we reviewed using monetary estimates for nitrous oxide that were based on the social cost of carbon approach. Instead, in its preliminary regulatory impact analysis for its proposed Safer Affordable Fuel-Efficient Vehicles Rule of 2018, the National Highway Traffic Safety Administration (NHTSA) used a Global Warming Potential factor to convert EPA's social cost carbon dioxide estimates to monetary estimates for nitrous oxide. According to the NHTSA document, the monetary estimates the agency used in sensitivity analyses involving nitrous oxide were estimated by applying the 100-year Global Warming Potential factor for nitrous oxide (which is 298) to the central estimates of the social cost of carbon dioxide for each future year. This resulted in an average estimate for nitrous oxide of $2,491 per metric ton for the analysis' forecast period.[3]

[3]After we provided a draft of this report to NHTSA for its review and comment, NHTSA issued the final Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Truck in April 2020. Because the final rule was issued after January 2019 (the end date of our search for rulemakings using the current federal estimates of the social cost of carbon), we did not include the final rule in the scope of this review. In its regulatory impact analysis for the final rule, NHTSA included sensitivity analyses using the social cost of carbon approach for both methane and nitrous oxide—that is, estimates of the social costs of methane and nitrous oxide based on domestic climate damages and a 3 percent discount rate (as developed by EPA for use in regulatory analyses conducted under the guidelines specified in Executive Order 13783 and OMB Circular A-4). For comparison, NHTSA stated that using the social cost of carbon approach results in estimates that average $2,820 per metric ton for nitrous oxide for the analysis' forecast period—about 13 percent higher than the estimates NHTSA used in its preliminary regulatory impact analysis.

Appendix III: Views of State Officials from Montana and Texas on the Social Cost of Carbon

Montana

Montana state officials we interviewed said they had not developed and do not use estimates of the social cost of carbon and that the federal government's prior social cost of carbon estimates used in some rulemakings could overstate the benefits of emissions reductions. In comments submitted in response to the Environmental Protection Agency's (EPA's) proposed Clean Power Plan, Montana's utility regulator stated using a social cost of carbon overstated the benefits of the proposed rulemaking. The Montana utility regulator stated that although carbon dioxide emissions may be a global issue, the federal government had received only "anemic global commitments" from other major carbon-producing countries, like China.[1] The Montana regulator raised concerns that accounting for the global impacts of emissions from the United States in federal regulatory analysis without receiving stronger reciprocal commitments from other countries ignores the economic problem of free ridership and is therefore fundamentally flawed.

Texas

Texas state officials we interviewed said they had not developed and do not use estimates of the social cost of carbon and that the federal government's prior social cost of carbon estimates overstated the benefits of emissions reductions. In comments submitted in response to EPA's proposed Clean Power Plan, Texas Commission on Environmental Quality officials stated that, by calculating the social cost of carbon based on global damages, EPA had overstated the benefits of its proposed Clean Power Plan rule.[2] According to the officials, using a social cost of carbon based on global, as opposed to domestic, climate damages incorrectly showed that the overall benefits of the proposed rule (largely from the avoided climate damages resulting from reductions in carbon dioxide emissions) exceeded the rule's economic costs—when in fact the rule may not have provided a net benefit to the United States itself.

Furthermore, commission officials told us they had concerns about how EPA had presented the timing of the benefits of the Clean Power Plan as calculated using the social cost of carbon. Specifically, these officials expressed concern that EPA was not clear that the benefits of avoiding

[1]Montana Public Service Commission, Letter to the United States Environmental Protection Agency (EPA) regarding EPA's proposed Carbon Pollution Emission Guidelines for Existing Stationary Sources, Docket ID: EPA-HQ-OAR-2013-0602, November 21, 2014.

[2]Texas Commission on Environmental Quality, Letter to the United States Environmental Protection Agency (EPA) regarding proposed Carbon Pollution Emission Guidelines for Existing Electric Utility Generating Units, Docket ID NO. EPA-HQ-OAR-2013-0602, December 1, 2014.

carbon dioxide emissions would be experienced over several decades. In its comments on the proposed Clean Power Plan, the commission stated that EPA had misrepresented the near-term climate benefits of the proposed rule because the assumed benefits were derived using the social cost of carbon, which is based on long-term impacts. Furthermore, in its comments, the commission stated that the federal government should include social cost of carbon estimates calculated at the 7 percent discount rate in order to follow the guidance in OMB Circular A-4.

Appendix IV: Canada's Social Cost of Carbon Approach to Developing Monetary Estimates for Greenhouse Gas Emissions

Why Canada Developed Monetary Estimates for Greenhouse Gas Emissions

Canadian departments and agencies are to conduct cost-benefit analyses of regulatory proposals, and the Canadian government considers it necessary to have an appropriate monetary estimate for the consequences of reducing or increasing greenhouse gas emissions, according to guidance we reviewed issued by Canada's environmental regulator and officials we interviewed.[1] To support these analyses, the Canadian government developed monetary estimates for greenhouse gas emissions based on the social cost of carbon (i.e., damage costs) approach. Specifically, Canada adopted some of the prior U.S. federal estimates of the social cost of carbon, which were developed by the U.S. Interagency Working Group on Social Cost of Carbon (IWG).[2] These estimates are based on global climate damages.

How Canada Developed Monetary Estimates for Greenhouse Gas Emissions

From 2010 to 2011, Environment and Climate Change Canada—Canada's environmental department and regulator—led an interdepartmental review of approaches for developing monetary estimates for greenhouse gas emissions and, as a result of this review, recommended the adoption of some of the IWG's estimates of the social cost of carbon.[3] According to Canadian officials and the guidance document we reviewed, Canada adopted the IWG's approach for several reasons:

- The social cost of carbon approach is consistent with other approaches to valuation typically used in cost-benefit analysis, where externalities are accounted for based on their impacts (i.e., marginal damages) to society.
- The IWG's estimates were based on the work of a number of highly respected academic and government experts and had been thoroughly vetted and reviewed.
- The IWG's estimates were the result of a robust attempt to identify and address the uncertainty in social cost of carbon estimates.

[1]When we refer to Canada, we mean the Canadian federal government. For the guidance we reviewed, see Environment and Climate Change Canada, *Technical Update to Environment and Climate Change Canada's Social Cost of Greenhouse Gas Estimates* (Quebec, Canada: March 2016).

[2]When we reference the social cost of carbon, we mean carbon dioxide and other greenhouse gases (i.e., methane and nitrous oxide). In addition to the IWG's estimates of the social cost of carbon dioxide, Canada also adopted the IWG's estimates for the social cost of methane and the social cost of nitrous oxide.

[3]Environment and Climate Change Canada, *Technical Update.*

- The IWG's decisions on key assumptions, such as basing its estimates on global climate damages and including estimates that reflect the possibility of low-probability, high-impact events, were consistent with insights from climate science. Further, the IWG calculated some of its social cost of carbon estimates using a 3 percent discount rate, which was consistent with Canadian federal discount rate guidance.

According to the guidance document we reviewed and officials we interviewed, Environment and Climate Change Canada chose to use estimates based on global climate damages because the agency viewed climate change as a global issue and believed that Canadian emissions have effects beyond Canada's borders.[4] Canadian guidance we reviewed and officials we spoke with stated that if all countries only accounted for the domestic damages caused by their emissions then not all relevant climate damages would be accounted for globally, a practice that could limit the potential for global action to mitigate climate change. The officials said this was because some countries that emit at high levels may not experience climate damages that are proportional to their emissions. Further, officials said that the integrated assessment models used to create the social cost of carbon estimates are not designed to deliver national-level results, although some can produce results for different regions.

Canada chose discount rates that took into account the long-term nature of climate damages, according to officials we interviewed and the guidance we reviewed. While Canada adopted the IWG's general approach, officials explained that Canada chose to primarily use the IWG's central estimates, which were discounted at a 3 percent rate, rather than the full range of estimates used by the IWG.[5] Officials said that Canada chose estimates based on a 3 percent discount rate because its federal guidance calls for using a 3 percent discount rate in

[4]Environment and Climate Change Canada, *Technical Update.*

[5]The IWG created four estimates of the social cost of carbon for each emissions year. In addition to the central estimate based on a 3 percent discount rate, the IWG created other estimates using discount rates of 2.5 and 5 percent. The IWG also created a fourth high-impact estimate, which as described later Canada also adopted, meant to represent higher-than-expected impacts from temperature changes (i.e., low-probability but high-impact damages "further out in the tails" of the social cost of carbon distributions). The high-impact estimate is the result of averaging the damages in the 95th percentile—that is higher than 95 percent of the damage results for each model—across all three of the integrated assessment models, which is then discounted at a 3 percent rate.

circumstances where impacts occur over a long time horizon or where environmental and human health are involved. Further, Canadian officials said using a 3 percent discount rate is generally aligned with academic literature on this topic. Canadian officials said that because climate damages occur over a long time span, using a discount rate higher than 3 percent—such as OMB Circular A-4's 7 percent discount rate representing the opportunity cost of capital or the IWG's 5 percent discount rate—would significantly and inappropriately diminish how future damages are valued. Environment and Climate Change Canada also adopted the IWG's high-impact estimates for use in sensitivity analysis to reflect lower-probability, higher-cost climate change impacts.[6]

How Canada Uses Monetary Estimates for Greenhouse Gas Emissions

According to Canadian officials, Canada uses its monetary estimates of the social cost of carbon as part of government cost-benefit analyses for all regulations affecting such emissions, including those regulations that are part of its national climate strategy. Monetary estimates are essential for evaluating the costs and benefits regulations that reduce emissions, according to Canadian government guidance on its social cost of carbon.[7] For example, the Canadian federal government used monetary estimates as part of its regulatory impact analysis for the following types of regulations:

- coal-fired electricity emissions standards;
- heavy-duty vehicle emissions standards;
- light-duty vehicle emissions standards;
- oil and gas industry standards for methane;
- renewable fuel standards in gasoline (5 percent ethanol); and
- biodiesel fuel standards (2 percent renewable fuels).

How Canada Plans to Continue to Develop and Use Monetary Estimates

According to Canadian officials and guidance we reviewed, Environment and Climate Change Canada plans to monitor research and analysis related to the social cost of carbon and consider updating its estimates as

[6]Environment and Climate Change Canada determined that the use of the high-impact estimates are a way to capture a fuller sense of the costs associated with higher than expected climate damages, including potentially catastrophic impacts from climate change.

[7]Environment and Climate Change Canada, *Technical Update.*

new information becomes available.[8] According to the guidance, Canadian social cost of carbon estimates should be treated as provisional, with the expectation that they will be revised with further advancements in scientific and economic research, particularly in regards to the 2017 review of the social cost of carbon by the U.S. National Academies of Sciences, Engineering, and Medicine.[9]

[8]Environment and Climate Change Canada, *Technical Update*.

[9]National Academies of Sciences, Engineering, and Medicine, *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide* (Washington, D.C: Jan. 11, 2017).

Appendix V: Germany's Social Cost of Carbon Approach to Developing Monetary Estimates for Greenhouse Gas Emissions

Why Germany Developed Monetary Estimates for Greenhouse Gas Emissions

The Umweltbundesamt (German Environment Agency, or UBA) first developed and continues to update monetary estimates for greenhouse gas emissions because it is important for the national government to have a measure for how greenhouse gas emissions will impact society and to take this into account in its proposed policies and projects, according to German officials we interviewed. Use of the monetary estimates, officials said, helps them know which proposals may be the most cost-effective in abating emissions, thereby helping ensure that the government takes actions that are a net benefit to society. Furthermore, the Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, or BMU) released the German Climate Action Plan in 2016, specifying that Germany's long-term emissions goal is net-zero emissions by 2050.[1] According to officials we interviewed, proposed policies developed by national ministries to help implement this plan are to be evaluated through cost-benefit analysis, including the use of Germany's monetary estimates for greenhouse gas emissions.

German officials said they chose to use the social cost of carbon (i.e., damage costs) approach to develop their monetary estimates because it was the most appropriate way to measure the impacts of greenhouse gases on society for cost-benefit analysis when evaluating policies and projects in impact assessments. According to officials, this is because other approaches of developing monetary estimates—such as the target-consistent approach—do not measure the monetary damages or benefits to society but rather the costs associated with meeting a given target.

How Germany Developed Monetary Estimates for Greenhouse Gas Emissions

The German Environment Agency developed the national government's most recent monetary estimates for carbon dioxide emissions using a social cost of carbon approach, which included equity weighting and discount rates meant to reflect the intergenerational aspect of climate damages. Germany adopted estimates based on global climate damages that were developed using the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) integrated assessment model.[2] German officials said they adopted estimates based on global climate

[1]German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, *Climate Action Plan 2050: Principles and goals of the German government's climate policy* (Berlin: November 2016).

[2]Specifically, Germany adopted climate damages estimates from FUND integrated assessment model runs. See David Anthoff, *Report on marginal external damage costs inventory of greenhouse gas emissions* (Hamburg: Hamburg University, 2007).

damages because greenhouse gases cause damages around the world and not exclusively in the countries where they are originally emitted.

German officials we interviewed said their choice of discount rates reflected their view that climate change is an intergenerational issue, given the long timeframe in which damages will occur. Germany chose to use discount rates that are not constant and that instead change over time based on the level of projected economic growth, according to German officials.[3] Specifically, for its primary (i.e., central) estimates, Germany's discount rate starts near 3 percent and declines to 2 percent by 2250. For estimates used in sensitivity analyses, the discount rate starts near 2 percent and declines to 1 percent by 2250.[4]

Germany also chose to weight climate damages based on a region's relative wealth—that is, a method known as equity weighting—according to German officials.[5] Officials said they used estimates that incorporated equity weighting because climate damages that happen in a region with relatively less wealth—measured in gross domestic product (GDP) per capita—will have a greater negative impact on the region than in a richer region. For example, a GDP per-capita loss of $500 is weighted more heavily in a region with a GDP per-capita of $2,000 than in one with a GDP per-capita of $40,000, because the climate damage is a higher percentage of the region's income. The main argument for this method, according to one of its proponents, is that a loss of $500 in a relatively poorer region causes a greater reduction in overall welfare than does the same loss in a wealthy region. Consequently, German officials said they chose estimates that weighted climate damages to be higher in less

[3]This is reflected in the FUND model's Ramsey-based discounting formula. Specifically, the discount rate based on the Ramsey formula incorporates the pure rate of time preference (i.e. the rate of discount of future welfare), the marginal utility of income (i.e. the change in the value of money as society gets wealthier), and the projected growth in gross domestic product per capita. In this setup, the FUND model assumes that the gross domestic product per capita growth rate declines over time, which causes the overall discount rate to go down over time in the FUND model.

[4]One component of the FUND model's Ramsey formula is the pure rate of time preference between future and current generation's welfare (a higher rate favors current welfare over future welfare). German officials chose a 1 percent pure rate of time preference for its central estimates and 0 percent for its estimates for sensitivity analysis. An official said a 0 percent pure rate of time preference treats the welfare of different generations equally.

[5]For the purposes of this report, equity weighting refers to the approach described by German officials based on their social cost of carbon—we did not evaluate other potential methods of conducting equity weighting in integrated assessment models.

wealthy regions to reflect that losses are more severe than those in richer regions.

To develop monetary estimates for other greenhouse gases (i.e., methane, nitrous oxide, and others), Germany multiplies its monetary estimates for carbon dioxide emissions by Global Warming Potential factors from the United Nation's Intergovernmental Panel on Climate Change.

How Germany Uses Monetary Estimates for Greenhouse Gas Emissions

According to German officials and documents we reviewed, Germany uses monetary estimates for greenhouse gas emissions as part of government cost-benefit analyses for policies and projects, including policies meant to help implement the national climate change strategy. For example, Germany's Environment Agency (UBA) used monetary estimates to evaluate policies developed to meet its 2030 contribution to the country's Climate Action Plan. Furthermore, German officials said that monetary estimates will be used to conduct cost-benefit analyses for all proposed policies submitted by other ministries as part of implementing the Climate Action Plan. The German Federal Ministry of Transport and Digital Infrastructure also uses monetary estimates to evaluate transport infrastructure investment projects through cost-benefit analysis.

How Germany Plans to Continue to Develop and Use Monetary Estimates for Greenhouse Gas Emissions

According to officials, the German Environment Agency is starting a new project to examine the FUND model, and potentially other integrated assessment models, in detail to determine whether to update it or instead create a new integrated assessment model. The FUND model has not been updated significantly since 2009, and it may be possible that the model could incorporate new information based on more recent research on climate damages, according to officials we interviewed. German officials said that a 5-year cycle for updating integrated assessment models, such as the FUND model, would be sufficient for keeping the models' use of science and economics current.

Appendix VI: France's Target-Consistent Approach to Developing Monetary Estimates for Greenhouse Gas Emissions

Why France Developed Monetary Estimates for Greenhouse Gas Emissions

France developed monetary estimates for greenhouse gas emissions as part of a long-term emissions reduction strategy for achieving its national target of net-zero emissions by 2050, according to documents we reviewed and officials we interviewed.[1] Officials told us that agencies use France's monetary estimates to determine what policies and investments the government should make to reach the target most cost-effectively. Also, according to French officials, under a 2012 statute and subsequent decree, government investment projects undergo economic cost-benefit analyses, and these analyses use France's monetary estimates for greenhouse gas emissions. The French Prime Minister requested that France Stratégie—an independent government agency that reports to the Prime Minister—form a high-level commission to develop monetary estimates for carbon dioxide for use in regulatory, policy, and project analysis that would be consistent with meeting France's emissions target.[2] According to the commission report we reviewed and French officials we interviewed, meeting France's target would require expanding the use of France's monetary estimates in the government to be as systematic and wide as possible—including in assessing government investments, regulations, and policies.[3]

How France Developed Monetary Estimates for Greenhouse Gas Emissions

France Stratégie developed France's monetary estimates for emissions by appointing a high-level commission, known as La commission Valeur de l'action pour le climat (Commission on the Value for Climate Action), which consisted of government officials, academics, and representatives from industry, among others. The 2019 commission expanded on the work of a previous commission from 2008. The commission developed monetary estimates for carbon dioxide using a target-consistent approach instead of a social cost of carbon (i.e., damage costs) approach for several reasons, according to officials we interviewed, including that

[1]Ministère de la Transition Écologique et Solidaire (Ministry for an Ecological and Inclusive Transition), *National Low Carbon Strategy Project: The ecological and inclusive transition towards carbon neutrality* (December 2018).

[2]According to officials, France Stratégie is an autonomous institution reporting to the Prime Minister that helps to stimulate and inform policy debate by conducting original research on major economic and social developments and sustainability issues. It also produces public policy evaluations at the request of the government. The results of its work are addressed to public authorities and citizens.

[3]France Stratégie, the commission chaired by Alain Quinet, and Julien Bueb, Boris Le Hir, Bérengère Mesqui, Aude Pommeret, and Matthieu Combaud, *The Value for Climate Action: A shadow price of carbon for evaluation of investments and public policies* (Paris: February 2019).

France has an explicit national target to reduce emissions to net-zero by 2050.

Additional reasons for choosing the target-consistent approach, according to officials, was that the social cost of carbon approach was viewed as more uncertain, more sensitive to key assumptions (such as the discount rate), and could not easily be used to create domestic monetary estimates for greenhouse gases. French officials said that the social cost of carbon approach was more uncertain than the target-consistent approach because climate damages models are currently unable to adequately incorporate the risk of catastrophic damages or the potential for climate tipping points that would cause damages to rise steeply or in an unpredictable manner. For example, an official from the French environment and energy management agency said that the current climate damages models cannot adequately account for the potential for France's coasts to be covered by a significant amount of sea level rise or for extreme levels of damage to French agricultural production. As a result, basing decisions on the social cost of carbon approach would risk the potential for irreversible or dangerous levels of climate change, according to officials. Additionally, because climate damages are calculated centuries into the future, estimates are especially sensitive to the discount rate, according to a commission document we reviewed and officials we interviewed. Furthermore, according to officials we spoke with and documents we reviewed, it is difficult to determine a domestic social cost of carbon.

The commission used five different economic models to estimate the marginal abatement costs that would be necessary to meet France's emissions reductions target of carbon neutrality by 2050, among other techniques.[4] According to officials, the models used the target year of 2050 and interim emissions reductions targets, such as a 43 percent reduction in 2030 and 75 percent reduction in 2040, as inputs to guide the trajectory of emissions reductions in the models. The commission used microeconomic and macroeconomic models, according to officials. The microeconomic models used current and future assumptions about technology to estimate marginal abatement costs to meet France's target, and the macroeconomic models applied a theoretical carbon tax across

[4]The costs associated with meeting emissions reductions targets are known as abatement costs. The target-consistent approach is also known as a marginal abatement cost approach because the approach uses abatement costs to determine the cost of meeting a given target. Marginal is an economics term that refers to the incremental cost associated with a change in quantity of something, such as greenhouse gases.

different sectors to determine what value for greenhouse gas emissions would spur switches to less greenhouse gas-intensive energy use throughout the French economy, according to officials we interviewed. The models were calibrated to meet emissions reduction targets at the least cost and assumed that France's target would be met by abatement measures in the French economy alone. The commission also used technology-forecasting reports, such as the technology road maps produced by the International Energy Agency, to help estimate the marginal abatement costs, according to officials.[5]

According to officials and the report we reviewed, the commission explicitly wanted to model the marginal abatement costs associated with France being able to meet its target domestically, rather than assuming that it could pay for some greenhouse gas abatement in other countries as part of a future global greenhouse gas market. However, officials said that the French government's monetary estimates could decline in the future if there is significant international cooperation on reducing greenhouse gas emissions either through an international greenhouse gas emissions trading market or international cooperation in technology research and development for reducing emissions. For example, France's monetary value for 2050 is 775 euros. However, the commission report stated that significant international cooperation in research and development could lead to technology advances that would reduce marginal abatement costs—so that France's monetary value for 2050 could be closer to 450 euros with respect to meeting its target.

According to French officials, France's monetary estimates for carbon dioxide can be used for a range of greenhouse gases, such as methane and nitrous oxide, by using the Global Warming Potential of different gases to determine their impact on warming.[6]

[5]The International Energy Agency is an international body that, according to its website, provides authoritative statistics and analysis, examines the full spectrum of energy issues, and advocates policies that will enhance the reliability, affordability and sustainability of energy in its 30 member countries and beyond.

[6]Global Warming Potential expresses a given gas' impact on global warming in comparison with carbon dioxide, within a given timeframe (usually 100 years). This enables conversion of different gas masses into a single unit, the metric ton of carbon dioxide equivalent, which represents the mass of carbon dioxide required to generate the same impact on global warming as a metric ton of the gas under consideration.

How France Uses Monetary Estimates for Greenhouse Gases

According to French officials we interviewed, the logic of the target-consistent approach is that it provides a road map and monetary reference value to determine which policies and projects would be most cost-effective in meeting emissions reductions targets.[7] French officials said that if a policy's or project's costs per unit of abated emissions exceed the monetized benefits, as calculated using France's target-consistent monetary estimates as reference values, then the intervention may not be cost-effective. As France's emissions target becomes more stringent over time, use of more expensive technologies or policies can be economically justified based on higher monetary estimates.[8] At the same time, if technology improves or a global greenhouse gas market emerges over time, then more cost-effective options will be available or monetary estimates could be reassessed to be lower.

France uses its monetary estimates to help plan which actions to implement as part of meeting its emissions reduction targets, as well as more broadly throughout its government in policy, regulatory, and project cost-benefit analysis. For example, according to French government documents we reviewed and officials we interviewed, government investment projects in France are subject to economic cost-benefit analysis, and such analyses include the use of France's monetary estimates for greenhouse gas emissions.[9] The French government also uses monetary estimates for greenhouse gases for policy and regulatory analysis. For example, the Ministère de la Transition écologique et solidaire (Ministry for an Ecological and Inclusive Transition) uses monetary estimates in economic cost-benefit analyses for policy impact assessments, according to officials. In addition, French officials said the

[7]Target-consistent monetary values for greenhouse gas emissions can be used in cost-benefit analysis (i.e. measuring the full costs and benefits of an action) and in planning which projects, regulations, or policies abate greenhouse gas emissions in the most cost-effective way (i.e., comparing the abatement costs per unit of greenhouse gases abated between government actions and comparing these to the target-consistent monetary estimates).

[8]For example, France has a 2030 emissions reductions target of 40 percent relative to 1990 greenhouse gas emissions levels, and then a net-zero emissions target by 2050. The monetary estimates go up over time to reflect the growing cost of additional emissions reductions needed to meet those targets because of, among other things, the higher costs of abating emissions in industry sectors where it is more difficult to abate emissions and technology to abate emissions is more expensive.

[9]According to French officials, the requirements for economic cost-benefit analyses are more stringent depending on the level of government funding. For example, any project that exceeds 20 million euros must be submitted to a national inventory and any project that exceeds 100 million euros is subject to an independent second cost-benefit analysis, according to French government documents we reviewed and officials we interviewed.

Direction générale du Trésor (Treasury Department) uses monetary estimates for policy planning and to assess potential policies to determine which would be most cost-effective, such as, for example, a policy encouraging consumers to buy electric cars. This involves a cost-effectiveness test where the abatement costs of the policy or regulation are compared with France's monetary estimates for greenhouse gas emissions as a reference. If the abatement costs are higher than France's monetary estimates, then there may be other technologies already available or presumed to be available in the future that would abate emissions more cost-effectively. According to Treasury Department officials, monetary estimates can also be used to determine in what year certain policies or regulations would become cost-effective and rank different policies and projects based on their cost-effectiveness.

How France Plans to Continue to Develop and Use Monetary Estimates for Greenhouse Gas Emissions

According to French officials, a goal of the commission and the French government is to ensure that monetary estimates are used systematically throughout the French government. The officials said that it was important to incorporate the use of monetary estimates for greenhouse gas emissions throughout the government because meeting the nation's emissions target will require French agencies to create policy, regulatory, and investment measures that achieve reductions in a cost-effective way throughout a number of economic sectors. According to officials and the commission's report, the estimates will be updated every 5 to 10 years.

Appendix VII: The United Kingdom's Target-Consistent Approach to Developing Monetary Estimates for Greenhouse Gas Emissions

Why the United Kingdom Developed Monetary Estimates for Greenhouse Gas Emissions

According to a key guidance document we reviewed and officials we interviewed, the United Kingdom's purpose for creating monetary estimates for greenhouse gas emissions is to allow for a more objective, consistent, and evidence-based approach to determine whether policies, regulations, or projects that affect greenhouse gas emissions should be implemented. Given that the United Kingdom has a greenhouse gas emissions reduction target specified in its 2008 Climate Change Act, as amended, according to officials, having a monetary estimate for emissions is important for evaluating and deciding which policies, regulations, and projects reduce emissions to meet the target most cost-effectively. Further, according to a guidance document we reviewed and officials we interviewed, monetary estimates for greenhouse gas emissions are also useful in cost-benefit analyses more generally to help assess whether, taking into account all relevant costs and benefits (including impacts on climate change), a particular policy, regulation, or project may be expected to improve or reduce the overall welfare of society.

How the United Kingdom Developed Monetary Estimates for Greenhouse Gas Emissions

In 2009, an interdepartmental review led the United Kingdom to switch from using a social cost of carbon (i.e., damage costs) approach to using a target-consistent approach to develop its monetary estimates for greenhouse gas emissions.[1] The interdepartmental review included chief economists from several government departments and was peer reviewed by academics. The review concluded that the United Kingdom should shift to a target-consistent approach because, under its Climate Change Act of 2008, the government had set an explicit 2050 target level of emissions and the target-consistent approach was significantly less uncertain than the social cost of carbon approach. According to a UK government guidance document we reviewed and officials we interviewed, the target-consistent approach aligns monetary estimates for greenhouse gas emissions with meeting a target level of emissions,

[1]Department of Energy & Climate Change, *Carbon Valuation in UK Policy Appraisal: A Revised Approach* (London: July 2009). The approach was not a pure social cost of carbon approach because it was modified to be more aligned with a target level of emissions recommended by a separate UK commission called the Stern Review. The Stern Review was issued by Her Majesty's Treasury of the UK government in October 2006 and assessed a wide range of evidence on the impacts and economic costs of climate change and concluded the benefits of strong and early action to reduce greenhouse gas emissions far outweighed the economic costs of not acting.

thereby making it more certain that actions taken based on the estimates will help ensure that the target will be achieved.[2]

UK officials said that the target-consistent approach is precautionary in nature and less uncertain than the social cost of carbon approach because the models underpinning the social cost of carbon approach are unlikely to adequately account for all potential damages, including the possibility of catastrophic damages or climate tipping points that cause damages to escalate rapidly and in unforeseen ways. Further, UK officials said that the social cost of carbon approach was more sensitive to key assumptions, such as the discount rate or how climate impacts are converted into damages. According to the UK guidance document we reviewed, climate damages models must make complex calculations involving both scientific and economic assumptions over more than a century. UK officials said uncertainty about these assumptions could lead to a wide-range of different climate damages estimates.

According to a guidance document we reviewed, the 2008 Climate Change Act specified the United Kingdom's target level of greenhouse gas emissions as an at least 80 percent reduction by 2050 relative to 1990 levels. The United Kingdom's target was recommended by the Committee on Climate Change—an independent government oversight body created by the 2008 Climate Change Act to provide scientific expertise, accountability, and review of the government's efforts, according to the guidance we reviewed. The Committee on Climate Change evaluated what emissions reductions would be needed by 2050 to help the United Kingdom be consistent with the wider international target of keeping global warming to no more than 2 degrees Celsius. The committee recommended a target of at least an 80 percent reduction of greenhouse gas emissions compared to 1990 levels by 2050, which was then accepted by the UK Government.[3] UK officials said the national target was meant to contribute to achieving the Paris Agreement's goal of limiting global temperature rise to 2 degrees Celsius, which was informed

[2]The UK guidance document we reviewed stated and officials we interviewed said that there were challenges to aligning monetary estimates developed under the social cost of carbon approach with meeting their target level of emissions.

[3]However, in June 2019, the United Kingdom amended its legal target to be net-zero emissions, as compared to 1990 levels, by 2050 at the recommendation of the United Kingdom's Committee on Climate Change, according to a UK government announcement.

by an international consensus on how to significantly reduce the risks associated with climate change.[4]

Following the 2009 interdepartmental review, the United Kingdom's Department of Energy & Climate Change developed target-consistent monetary estimates that were aligned to the nation's emissions target set in the 2008 Climate Change Act, according to UK officials.[5] For economic sectors not in the European Union emissions trading system (such as agriculture, transportation, and building construction) the United Kingdom developed monetary estimates using two different economic models, according to documents we reviewed and officials we interviewed.

For estimates through 2020, the UK government used a model that estimated domestic abatement costs based on the technology and actions available to UK individuals and firms that could sufficiently reduce emissions to meet the country's emissions target for 2020. For 2030 and 2050, the UK government used a global abatement cost model, called the Global Carbon Finance model, to determine abatement costs consistent with a global emissions pathway that would limit global temperature rise to 2 degrees Celsius.[6] This assumed that a global greenhouse gas emissions trading market would be functioning by 2030, which would give the United Kingdom the potential to pay for greenhouse gas abatement measures abroad to offset some of its domestic greenhouse gas emissions and thereby meet its national target. According to the government document that describes the United Kingdom's approach, it was appropriate to assume that there will be a comprehensive global greenhouse gas emissions trading market from 2030 onwards, as this is an efficient method for tackling climate change. A global market would allow for the most cost-effective emissions abatement actions to take place, which could allow the United Kingdom and other governments to avoid having to undertake significantly more expensive actions than may be necessary, according to a guidance document we reviewed. As a

[4]However, according to a government guidance document we reviewed, the United Kingdom cannot shift the global trajectory of greenhouse gas emissions alone and would need other countries to act as well if the 2-degree Celsius target is to be met.

[5]In July 2016, the United Kingdom's Department of Energy & Climate Change merged with the Department for Business, Innovation & Skills to form the Department for Business, Energy & Industrial Strategy.

[6]The UK government calculated monetary estimates for each year by linearly interpolating between the 2020, 2030 and 2050 estimates. Linear interpolation assumes a straight line between two points to obtain values for intermediate points.

result, the UK government's monetary estimates from the Global Carbon Finance model represent the lowest monetary estimates for emissions consistent with reaching the global 2-degree goal.[7]

For economic sectors that are covered under the European Union emissions trading system, such as the power and industrial sectors, the United Kingdom uses emissions-trading permit values as its monetary estimates, because the trading system's emissions cap is treated as a target level of emissions for those sectors, according to the guidance document we reviewed.[8] However, by 2030, both the estimates for the traded and non-traded sectors are assumed to converge, according to officials we interviewed.

According to UK officials we interviewed, the United Kingdom's monetary estimates (which are for carbon dioxide) can be used for other greenhouse gases, such as methane and nitrous oxide, by multiplying them by the other gases' respective Global Warming Potential factors.[9]

How the United Kingdom Uses Monetary Estimates for Greenhouse Gas Emissions

The United Kingdom uses monetary estimates for greenhouse gas emissions to help plan which actions would be most cost-effective in reaching the country's target level of emissions and throughout its central government in cost-benefit analysis for policy, regulatory, and project planning more generally, according to UK documents we reviewed and officials we interviewed.

According to a UK guidance document we reviewed and officials we interviewed, monetary estimates can be used in assessing potential policies or regulations to determine which would be most cost-effective at helping achieve the national emissions targets. Officials said this involves an economic efficiency test where the abatement costs of a policy or

[7]According to the UK guidance document, if a global market is not achieved by 2030, then the United Kingdom's monetary estimates for greenhouse gas emissions would need to increase considerably.

[8]The European Union emissions trading system covers the power and heat sector, energy-intensive industry sectors, and commercial aviation. The trading system covers around 45 percent of the European Union's greenhouse gas emissions, limiting emissions from nearly 11,000 power plants and manufacturing installations as well as slightly over 500 aircraft operators flying between European Economic Area airports.

[9]Global Warming Potential factors are calculated and published by the Intergovernmental Panel on Climate Change. See Piers Forster and Venkatachalam Ramaswamy, *Changes in Atmospheric Constituents and in Radiative Forcing* (Intergovernmental Panel on Climate Change, New York).

regulation are compared with the United Kingdom's monetary estimates for greenhouse gas emissions as a reference. If the abatement costs of the policy or regulation are higher than the United Kingdom's monetary estimates, then there may be other technologies already available (or presumed to be available in the future) that will abate emissions more cost-effectively. For example, one official said the Committee on Climate Change uses the United Kingdom's monetary estimates to determine policy opportunities for the UK government to meet its emissions targets—such as the committee's recommendation that by 2025 all newly built housing should be net-zero emissions and that heat pumps are a viable way to cut greenhouse gas emissions in homes. As the United Kingdom's emissions target tightens over time, use of more expensive technologies or policies can be economically justified based on higher monetary estimates, according to a guidance document.

Officials with several UK agencies we spoke with said they used the United Kingdom's monetary estimates as part of cost-benefit analyses to evaluate potential policies, regulations, or projects more generally—such as a regulation requiring emissions standards for new housing, a policy providing subsidies for electric cars, and policies encouraging household waste reduction and new woodland planting.

How the United Kingdom Plans to Continue to Develop and Use Monetary Estimates for Greenhouse Gas Emissions

UK officials said that in light of the Paris Agreement and the United Kingdom's changing relationship to the European Union, they would likely reevaluate their monetary estimates for greenhouse gas emissions. In addition, according to officials, the UK government has recently legislated a target of net-zero greenhouse gas emissions by 2050, as recommended by the Committee on Climate Change, which could cause the United Kingdom's estimates to change.

However, according to a UK government guidance document we reviewed, there is a trade-off between having the most up-to-date monetary estimates and ensuring consistency in application of the estimates. A situation where the monetary estimates for greenhouse gas emissions are changed too often would be undesirable, as this would mean that over short periods of time policy or regulatory options were being assessed against different criteria. According to the document, changes affecting the evidence or policy context would need to be significant in order to warrant a reevaluation of the monetary estimates.

Appendix VIII: Foreign Officials' Views on Strengths and Challenges of the Social Cost of Carbon and Target-Consistent Approaches for Monetary Estimates of Emissions

According to foreign officials we interviewed, both the social cost of carbon (i.e., damage costs) and target-consistent approaches for valuing greenhouse gas emissions have strengths and challenges.

Social Cost of Carbon Approach

The social cost of carbon approach has several strengths, according to foreign officials—including that it values emissions based on how externalities are typically valued for cost-benefit analysis. For example, Canadian and German officials said that a key strength of the social cost of carbon approach is that it is aligned with how externalities are typically valued by governments for cost-benefit analysis—that is, by estimating the monetary damages to society resulting from an externality. In contrast, the target-consistent approach does not directly measure damages to society and is based on the cost of meeting an emissions target, according to these officials. Additionally, German officials said that because social cost of carbon estimates are calculated separately from a specified target level of emissions, they can serve as a more independent means of evaluating the benefits of government action. In contrast, they said target-consistent estimates could be circular and less independent from policies being evaluated because they are developed using the costs of technologies that would need to be employed to meet the emissions target.

The social cost of carbon approach also has several challenges, according to other foreign officials we interviewed. For example, according to French and UK officials, the social cost of carbon approach is not necessarily aligned with a target level of emissions—such as the Paris Agreement goal of holding the increase in the global average temperature to well below 2 degrees Celsius above pre-industrial levels. According to these officials, this may mean that monetary estimates based on climate damages would not be high enough for a government to economically justify the policies or regulations necessary to meet its targets, and it would be unclear how much action a government should take to meet its targets cost-effectively. UK and French officials also said that the social cost of carbon approach is significantly more uncertain than the target-consistent approach for several reasons. For example, they said that climate damages models are not able to adequately incorporate the potential for catastrophic damages from climate change and that scientific knowledge is still incomplete in regard to how the climate might respond after passing the 2-degree Celsius threshold.[1] One French modeling official said that climate damages models may crash or provide unreliable results when trying to include extreme assumptions to mimic a catastrophic event, such as 10 percent of France being submerged by sea level rise or a sharp decrease in agricultural productivity. While there is ongoing academic work to better understand potential catastrophic climate risks, the official said it is unclear if these risks or their levels of damages can be adequately incorporated into climate damages models. Additionally, officials said the social cost of carbon approach is more sensitive to key assumptions than the target-consistent approach, such as the discount rate and how climate impacts are converted into damages, which can lead to a wide range of potential estimates.

Target-Consistent Approach

The target-consistent approach has several strengths, according to foreign officials—including that it best allows a country to meet its emissions target and is seen as less uncertain than the social cost of carbon approach. For example, UK and French officials said that a key strength of the target-consistent approach is that it aligns with meeting a specific emissions target. According to these officials, using a target-consistent approach best ensures that national governments can meet their emissions targets and that the resulting monetary estimates also serve as a planning guide for actions the government can take. For example, target-consistent monetary estimates can be used to rank different policies and projects based on cost-effectiveness, according to French officials. French and UK officials also said that the target-consistent approach is more certain than the social cost of carbon approach, as discussed earlier. In addition, French officials said another advantage is that the target-consistent approach allows a country to develop a domestic value for greenhouse gas emissions based on their emissions reductions target, whereas it is difficult to develop a domestic monetary value using a social cost of carbon approach. For example, Canadian and French officials said that not all climate damages models can easily provide results at a domestic or national level.

The target-consistent approach also has several challenges, according to officials. For example, according to officials we interviewed from France,

[1]According to a 2009 UK government technical review paper, climate change impacts are likely to be non-linear, with temperature increases above 2 degrees Celsius leading to potentially catastrophic but difficult to value outcomes. See Department of Energy and Climate Change, *Carbon Valuation in UK Policy Appraisal: A Revised Approach* (London: July 2009).

Germany, and the United Kingdom, and the literature we reviewed, the target-consistent approach has uncertainty as well. French officials said that it is challenging to model monetary estimates after 2040 because there is significant uncertainty about the technologies needed to abate greenhouse gas emissions from industry sectors where it is more difficult—partly because the technologies that could abate emissions in those sectors are less mature. French officials said their economic models showed that France could achieve a 75 percent reduction in emissions by 2040, from the country's 1990 levels, through existing or relatively well-understood technologies, but it would have to rely on more expensive and less mature technologies to abate the remaining amount of emissions to meet its 2050 goal. Further, as discussed earlier, German officials said the target-consistent approach was a less independent means of evaluating the benefits of government action. Also, according to UK officials and a document we reviewed, setting a short-term target for sectors in an emissions trading system based on the system's emissions cap and permit values may lead to monetary estimates that are lower than is required to meet a government's overall economy-wide emissions target because such traded values can be subject to political choices and market fluctuations.

Appendix IX: GAO Contact and Staff Acknowledgments

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