The Social Cost of Greenhouse Gases

A Guide for State Officials

Institute *for* Policy Integrity
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UNITED STATES CLIMATE ALLIANCE

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About This Document

The United States Climate Alliance (USCA) commissioned the Institute for Policy Integrity at New York University School of Law to produce *The Social Cost of Greenhouse Gases: A Guide for State Officials*. This document was prepared with guidance and significant contributions from the USCA Social Cost of Carbon Working Group, which includes staff from various state government agencies and offices. Not all states in the Alliance participated in this process. This document is not meant to represent a policy plan for the Alliance or any Alliance states, but is designed to serve as reference for states as they contemplate utilizing the social cost of greenhouse gases to consider the societal and environmental impacts of GHG emissions and climate change across relevant policy-making and decision-making processes.

ABOUT THE U.S. CLIMATE ALLIANCE

The United States Climate Alliance is a bipartisan coalition of governors committed to reducing greenhouse gas emissions consistent with the goals of the Paris Agreement. Smart, coordinated state action can ensure that the United States continues to contribute to the global effort to address climate change. Each member state commits to:

- Reducing collective net GHG emissions at least 26-28 percent by 2025 and 50-52 percent by 2030, both below 2005 levels, and collectively achieving overall net-zero GHG emissions as soon as practicable, and no later than 2050.
- Accelerating new and existing policies to reduce GHG pollution, building resilience to the impacts of climate change, and promoting clean energy deployment at the state and federal level.
- Centering equity, environmental justice, and a just economic transition in their efforts to achieve their climate goals and create high-quality jobs.
- Tracking and reporting progress to the global community in appropriate settings, including when the world convenes to take stock of the Paris Agreement

UNITED STATES
CLIMATE ALLIANCE

Executive Summary

States are at the forefront of efforts to reduce the greenhouse gas emissions that cause climate change. State officials who aim to consider climate change alongside their other policy and decisionmaking priorities need tools to help them weigh what potential approaches to a given sector or policy issue would mean for the climate.

In particular, they need to be able to assess the effects of agency actions (or inaction) on activities that emit climate-altering greenhouse gases in easy-to-understand terms. Such an assessment often involves comparing costs and benefits, but that comparison is no simple matter. Costs tend to include things like equipment, labor, and financing, most of which are assigned prices by the marketplace or can readily be valued in several ways, such as through competitive bidding. By contrast, the benefits of avoiding damage to society from climate change are difficult to value in monetary terms. How much is marginally greater stability with respect to sea level, global temperature, weather patterns, and other drivers of climate-related impacts on the economy worth? Without an answer to that question, comparisons of the costs and benefits of actions aimed at reducing greenhouse gas emissions will be apples-to-oranges. And valuing damages in the same way as costs can help to justify policy choices logically, legally, and politically.

The Social Cost of Greenhouse Gases (SC-GHG) offers an answer to the question above. It is a set of estimates of how much damage results, in monetary terms, from the emission of one additional metric ton of carbon dioxide (CO_2), methane (CH_4), or nitrous oxide (N_2O).[1] By indicating the monetary cost to society of releasing greenhouse emissions into the atmosphere, the SC-GHG makes it possible to say how worthwhile it would be to reduce or altogether avoid emitting activity—that is, to weigh the benefit of doing so against the costs.

The SC-GHG serves a very specific purpose: it assigns a monetary value to the climate damage done by a marginal unit of greenhouse gas emissions. It does not value all of the effects, environmental or otherwise, of operating an emitting facility, driving emitting vehicles, or engaging in other activities that give rise to climate pollution. It does not indicate whether one approach to a policy goal will be more efficient or cost-effective than another. It just assigns a value to the climate damages that follow from release into the atmosphere of carbon dioxide, methane, nitrous oxide, and other greenhouse gases.

Figure ES-1, below, which is discussed in depth in Section 2, provides a visual summary of how the SC-GHG translates a variety of types of information about the economy, climate, and passage of time into monetary estimates of the damage done by different greenhouse gases.

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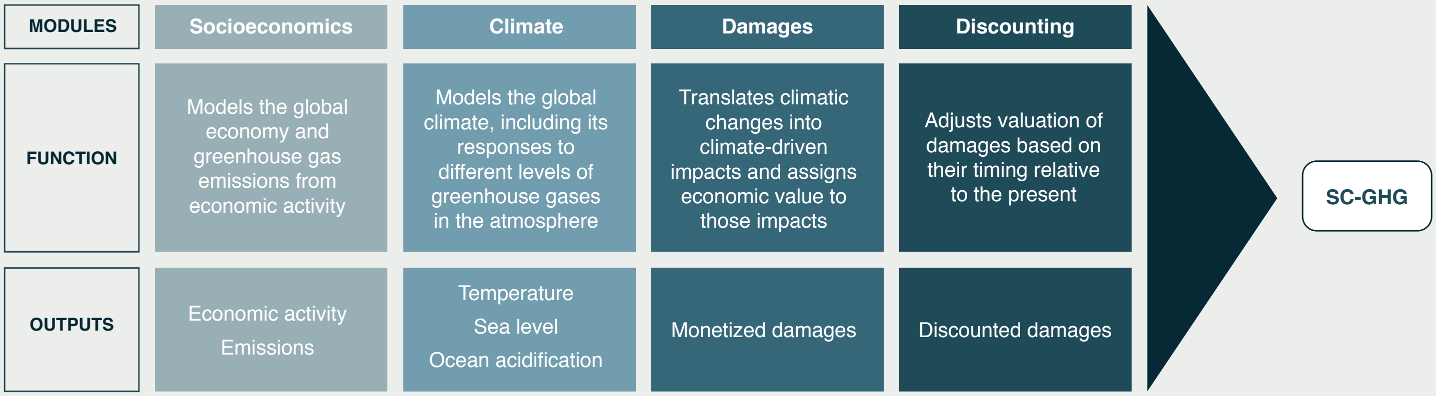
1 The SC-GHG can also be used to determine the climate damages resulting from emissions of other greenhouse gases. *See infra* Section 2.3.

Figure ES-1. SC-GHG Components



As that figure shows, the SC-GHG is the output of a series of modules, each of which draws on diverse inputs. In addition to depicting how the outputs of one module serve as inputs to the next, ES-1 highlights how key decisions about the scope of inputs and outputs inform in the SC-GHG's estimates.

The SC-GHG makes it possible to value greenhouse gas emissions reductions, but making use of the SC-GHG in state-level policymaking is not simply a matter of doing the math properly. This Guide recognizes that before an agency uses the SC-GHG, it is often necessary to first explain why states should use it, how it can be incorporated into different types of decisions, and what makes it an economically and legally defensible tool. Those explanations might be demanded by one or more of several audiences: legislators who will decide how the SC-GHG should inform analyses and decisions; agency staff who will be asked to incorporate the SC-GHG into analyses and decisions; regulated industries that are directly affected by climate-oriented policy changes; the public; and courts. This Guide is intended to support explanations to these various audiences, in part by providing examples of the SC-GHG's application in different contexts.

This Guide is divided into four main sections.

1. *Introduction* describes the SC-GHG's intellectual and institutional origins and briefly summarizes how states have applied it to date.
2. *Key Concepts and Features* describes the SC-GHG's component parts and logic. It also notes the SC-GHG's limitations and responds to common criticisms of its derivation or application.
3. *Legal Authority* frames the SC-GHG in a legal context, describing the metes and bounds of agency authority—or obligation—to apply it to particular analyses or decisions.
4. *Applications* categorizes and describes a variety of analyses and decisions in which the SC-GHG can be applied. This section draws on numerous examples of state and federal agency action.

This Guide will be updated to reflect two types of changes: Section 2 will be updated consistent with changes made to the SC-GHG by the federal Interagency Working Group; and Section 4 will be updated periodically as states apply the SC-GHG in new ways.

Glossary and Abbreviations

These phrases and terms appear in the guidebook and referenced materials.

Circular A-4 – Guidance document created by the federal Office of Management and Budget that instructs federal agencies on how to conduct cost-benefit analysis in regulatory settings, including by discussing discount rates and geographic scope.

CO_2 – Carbon dioxide

CO_2e – Carbon dioxide equivalent

CH_4 – Methane

Discount Rate (private) – A rate, often represented as a percentage, that indicates how much a person would need to be compensated today to receive a dollar amount in the future rather than in the present. Private discounts are limited by individual/firm myopia that includes private risk premiums as well as returns to market power and externalities and fails to consider future generations.

Discount Rate (social) – A rate that indicates how much society needs to be compensated tomorrow to receive benefits in the future rather than in the present. In the climate context, the wider perspective of social discount rates captures how society should trade off currents costs of greenhouse-gas mitigation against the future benefits of avoided climate impacts.

Declining Discount Rate Schedule – A set of discount rates that decline over time, so distant future costs and benefits are discounted at a lower rate than near future costs and benefits.

IWG – The Interagency Working Group on the Social Cost of Greenhouse Gases. The IWG was originally formed in 2009 and called the Interagency Working Group on the Social Cost of Carbon.

MAC – Marginal abatement cost refers to an approach to monetizing greenhouse gas emissions that is based on the cost of abating the last marginal ton in the context of a specific, binding emissions target.

N_2O – Nitrous oxide

OMB –Office of Management and Budget, a federal office responsible for publishing *Circular A-4*.

SCC – Social Cost of Carbon (carbon dioxide) developed by the IWG.

SC-CH_4 – Social Cost of Methane developed by the IWG.

SC-CO_2 – Social Cost of Carbon (carbon dioxide) developed by the IWG.

SC-GHG –Social Cost of Greenhouse Gases developed by the IWG. As of 2021, these social cost estimates exist for carbon dioxide, methane, and nitrous oxide.

SCM – Social Cost of Methane developed by the IWG.

SCN – Social Cost of Nitrous Oxide developed by the IWG.

SC-N_2O – Social Cost of Nitrous Oxide developed by the IWG.

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1. Introduction

More and more states are working to embed climate change considerations into their policy frameworks. These efforts center on two primary questions: how do we reduce climate change's impact on our state? and how do we reduce our state's contributions to climate change? This guide helps to answer the second question. Reducing greenhouse gas emissions will require a sea change of policy planning and implementation, including: analyzing decarbonization pathways to help establish the need for interventions in various sectors—transportation, power, buildings, industry—and identify policies capable of meeting that need;[1] designing new codes and standards to guide, among other things, energy use in buildings,[2] efficiently connecting distributed energy resources (like rooftop solar panels) to the electric grid,[3] reducing reliance on sources of short-lived climate pollutants;[4] and creating protocols and calculators to tally the emissions expected to result from a given policy, activity, or decision.[5] Rising to meet these needs would be easier if states could compare the costs and benefits of different policy options in consistent units. The Social Cost of Greenhouse Gases (SC-GHG) does just that, and can undergird, complement, and guide the formulation and application of policies. **The SC-GHG is a set of estimates of how much damage results, in monetary terms, from the emission of one additional ton of carbon dioxide, methane, nitrous oxide, or other greenhouse gases that contribute to climate change when released into the atmosphere.**

This guide is meant to inform and support the use of the SC-GHG by state officials and others. It is divided into four main sections. The first section introduces the SC-GHG and notes how states have used it to date. The second section describes what the SC-GHG is, how it was developed, how it was calculated, and why decisionmakers should understand not only the final numbers but also the SC-GHG development process. The third section provides a general overview of the legal authority required for a government to use the SC-GHG to inform different types of analyses or decisions. Finally, the fourth section describes applications of the SC-GHG to policymaking and regulatory decisionmaking in different types of decision or analysis, and particular economic sectors.

In addition to helping state officials use the SC-GHG, this guide can also help them explain its use to the staff of state agencies, to regulated industries, to the public, and, if necessary, to courts.

1.1. History of the SC-GHG

The SC-GHG started out as a subject of academic research but has become an integral element of federal policymaking in the United States. Academic researchers first developed in the 1990s the integrated assessment models (IAMs) on which the SC-GHG is based.[6] Those IAMs, which have since undergone multiple rounds of updates and peer review,[7] estimate the global economic damages from climate change by tracing relationships among emissions, the Earth's temperature, physical planetary systems, and economic effects. More specifically, IAMs make it possible to estimate the cost to society of each ton of greenhouse gases emitted into the atmosphere.

Governments first began exploring use of the SC-GHG, in one form or another in the early 2000s, when the United Kingdom considered potential applications of the IAMs to policy planning.[8] Shortly thereafter, in the United States, participants in the rulemaking process for emissions standards for light trucks for model years 2008–2011 noted the British government's research into how IAMs could be used by agencies to estimate climate damages.[9] The National Highway Traffic Safety Administration initiated that rulemaking process in 2003, published a proposed rule in 2005, and a final rule in 2006.[10] The final rule was immediately challenged before the U.S. Court of Appeals for the Ninth Circuit, which, in 2008, rejected the rule because it had failed to estimate the climate benefits of greater fuel efficiency in monetary terms to match its estimate of the monetary costs to manufacturers.[11] The Bush administration (2001–2008) did not respond to this decision during its final months in office, but in 2009, then-newly-elected President Obama convened the Interagency Working Group on the Social Cost of Carbon[12] (IWG or Working Group) to develop a uniform social cost of carbon dioxide value for use by all federal agencies in regulatory analysis.[13] The Working Group was led by staff at the Office of Management and Budget (OMB) and Council of Economic Advisers (CEA), and its membership to include scientific and economic experts from the White House, Environmental Protection Agency (U.S. EPA), and Departments of Agriculture, Commerce, Energy, Transportation, and Treasury.[14]

The Working Group initially developed the SC-GHG through a rigorous process and has undertaken several similarly rigorous updates.[15] The SC-GHG values were developed using the three most widely cited IAMs: DICE, FUND, and PAGE.[16] Model developers include William Nordhaus, who won a Nobel prize for this work,[17] and Chris Hope, a lead author on the Third and Fourth Assessment Reports of the Intergovernmental Panel on Climate Change.[18] Their IAMs used by the Working Group—reflect extensive peer review by economic experts.[19] The Working Group's approach gives each model's outputs equal weight to arrive at the SC-GHG.[20] The inputs to the models are all drawn from peer-reviewed literature,[21] and decisions about which inputs to use were also submitted for peer-review.[22]

The Working Group's approach to developing and updating the SC-GHG has been transparent and open throughout. That is, the Working Group has shown its work by releasing technical support documents along with its estimates, and it has solicited public and expert feedback on draft documents before finalizing its analyses.[23] When the Government Accountability Office examined the Working Group's 2010 and 2013 processes, it found that they were consensus-based, relied on sound academic research and modeling, disclosed relevant limitations, and incorporated new information via public comments and updated research.[24]

Consistent with the imperative that its work be thorough, transparent, and up-to-date, in 2016 the Working Group asked the National Academies of Sciences, Engineering, and Medicine (National Academies) to review recent research on climate modeling and to assess the technical merits and challenges of potential approaches to future updates of the SC-GHG.[25] While the National Academies's interim report advised against conducting an update to the estimates in the near term to capture changes to a revised element of the IAMs,[26] it also recommended ways to enhance the presentation and discussion of uncertainty regarding particular estimates.[27] The IWG responded to these recommendations in its 2016 technical support document,[28] which included an addendum on the social cost of methane and the social cost of nitrous oxide.[29] Consistent with its interim report, National Academies's final report, issued in January 2017, endorsed the continued near-term use of the Working Group's existing social cost estimates based on the DICE, FUND, and PAGE models, but also contained a roadmap of methodological changes to guide the Working Group when it next updated its SC-GHG estimates.[30]

But the Working Group did not have the opportunity to implement the National Academies's recommendations before President Trump issued an executive order in 2017 that disbanded it and directed federal agencies to use a revised set of climate damage estimates. Those estimates assigned far lower values to greenhouse gas emissions, owing to their use of a higher discount rate and a purportedly "domestic" (rather than global) assessment of climate damages. (Sections 2.1.3 and 2.1.4 explain these features of the SC-GHG in detail.) Because these features departed from the best available science, federal courts rejected a federal agency decision that relied on the revised estimates: reliance was inconsistent with the requirements of federal administrative law.[31] A 2020 Government Accountability Office report similarly stated that, due to the Trump executive order directing agencies to apply revised estimates, the federal government was not "well positioned to ensure agencies' future regulatory analyses [we]re using the best available science."[32]

When President Biden took office, one of his first executive orders reconvened the Working Group and directed it to update the estimates of the SC-GHG.[33] The Working Group released interim estimates in February 2021 that were identical to the 2016 estimates, adjusted for inflation.[34] The 2021 technical support document acknowledges that new data is available to support the use of a lower discount rate when calculating the SC-GHG, and advises federal agencies that they may wish to conduct sensitivity analyses with discount rates below 2.5%.[35] The Working Group is expected to publish a draft technical support document for an updated set of estimates sometime in 2022. As of this writing, the interim 2021 SC-GHG is considered the best available estimation of the climate damages resulting from a marginal ton of greenhouse gas emissions; the Working Group's updated estimate is expected to supersede it as the best available estimation of those damages.

The SC-GHG is not a carbon tax.

The SC-GHG is a metric that estimates how much economic damage results from a unit of emissions; it is not a "carbon price," a fee, or a tax on greenhouse emissions. The SC-GHG can be used to set the level of a fee or tax charged to emitters, but it does not, on its own, establish a price to be paid for emitting greenhouse gases.

One reason confusion might arise over these categories is that the SC-GHG is sometimes referred to as a "price on carbon" and is in use by many entities as a "shadow price."[36] But a shadow price does not necessarily translate to the price actually paid by emitters. It is instead a value used to estimate the damages from a particular action. Estimation of this sort can be used for planning, accounting, modeling exercises, or other forms of analysis. It is most often employed *within* an institution or organization to better understand which assets or operations are relatively emissions intensive and to plan or stress test in anticipation of policy changes—whether intra-organizational or imposed from without—that somehow limit emissions volumes.[37]

1.2. How States Have Used the SC-GHG to Date

More than a dozen states have applied the SC-GHG over the past decade in analyses that inform policymaking or in decisions with concrete implications for stakeholders. The table below lists types of applications of the SC-GHG on the left—that list aligns with the organization of Section 4 of this Guide—and each dot shows that a particular state has engaged in that application.

Table 1-1. States' Uses of the SC-GHG to Date

		States													
	Type of Use	CA	CO	DE	IL	ME	MD	MN	NV	NJ	NY	OR	VA	VT	WA
Cost-benefit analysis	*Rulemaking (informational)*	•	•								•				
Cost-benefit analysis	*Electric Utility IRPs*	•	•					•	•			•	•		•
Cost-benefit analysis	*Gas Distribution System*														
Cost-benefit analysis	*Planning Info.*		•												
Cost-benefit analysis	*Land Use*	•		•						•	•			•	
Grants & Investments		•	•[38]												•
Procurement															•
Penalties															
Royalties															
Resource Compensation		•			•	•	•				•				

The five kinds of cost-benefit analysis indicated in the table (and discussed in Section 4) are: (1) regulatory rulemakings; (2) integrated resource plans submitted by electric utilities to state utility commissions for review and approval; (3) planning and decisions about the gas distribution system; (4) multisectoral planning analyses; and (5) land use plans and decisions. The grey shading of the "land use plans and decision" row indicates that no state has, so far, clearly applied the SC-GHG in that context.

The table details five additional uses of the SC-GHG beyond cost-benefit analysis. Grants and investments involve allocating funds based in part on a showing that the resulting program or infrastructure will reduce greenhouse gas emissions relative to an alternative or baseline. Procurement refers to the purchasing of assets by government agencies for their own use. Penalties refers to civil or administrative penalties that might be meted out by any agency with enforcement authority. As the gray shading indicates, no state agency has yet clearly incorporated the SC-GHG into its calculation of the penalty to be paid for some violation that had an impact on the climate. Royalties refers to payments due to a property owner upon the extraction of a mineral resource from under its land. Here again, no state has yet applied the SC-GHG to its specification of the royalty payments it is owed by an extractive industry. Finally, resource compensation refers to payment to the owner of a resource for performing a function without generating emissions. The best known example is the zero emissions credits paid to nuclear generators not for electricity but for the emissions their generation of electricity avoids

New York's Value of Carbon

New York State's Climate Leadership and Community Protection Act, enacted in 2019, directs the state's Department of Environmental Conservation, in consultation with the state's Energy Research and Development Authority, to "establish a social cost of carbon for use by state agencies." After reviewing options and relevant research,[39] those agencies issued guidance (not a regulation) in December 2020[40]—that is, before the Biden Administration's Working Group on the Social Cost of Greenhouse Gases (Working Group) issued its Interim SC-GHG in February 2021. The December 2020 guidance recommends following the lead of the Working Group in most respects but not all. Its most important departure relates to discount rates[41]—a feature of the SC-GHG explained in Section 2.1.4 of this Guide. That departure results in SC-GHG values that are significantly higher than those recommended to federal agencies by the Working Group in 2016 and again in 2021.

Different states' uses of the SC-GHG are tracked on the *Cost of Climate Pollution* website.[42] Section 4 discusses a variety of examples of SC-GHG applications by agencies in these states, as well as uses by federal agencies. As those examples reflect, there are clear patterns across different states, but also a great deal of diversity and idiosyncrasy.

1.3. Quantifying Greenhouse Gas Emissions—A Prerequisite Analytical Step

The SC-GHG translates a quantity of greenhouse gas emissions into a monetary value.[43] That translation enables the comparison of quantities whose relative significance is difficult to weigh. For instance, purchasing and installing an electric heat pump in a home to replace a fossil-fuel-fired furnace comes at a cost—materials and labor—that is dissimilar to the benefit of the greenhouse gas emissions avoided by heating with electricity instead of fuel oil or methane gas. Putting both those costs and benefits into monetary terms makes it possible to determine whether this replacement will be net beneficial to society. Of course, comparing those costs and benefits requires first determining how many tons of greenhouse gases are emitted as a result of using the furnace and the heat pump.

Several factors can make it challenging to estimate the changes in emissions that result from a given policy intervention, and assessing a set of policy interventions can be harder still. Efforts by researchers and government officials to overcome these challenges have yielded a great many studies and tools,[44] some of which are listed on a website maintained by the U.S. Environmental Protection Agency (EPA).[45] EPA also hosts an emissions calculator webpage that convert units of fuel to emissions and vice versa, which is useful for identifying emissions factors for fuels and types of usage.[46] In general, while many of the emissions quantification tools that are publicly available embody sound methodologies and can yield technically defensible results, there is not, as of yet, a unified and standardized rubric for emissions accounting.

Although this document does not present guidance on how to quantify emissions, it does discuss potential legal risk arising from emissions quantification being unavailable, partial, or hard to verify in Section 3.4.

1 *See, e.g.*, Off. of Governor Jared Polis, Colorado Greenhouse Gas Pollution Reduction Roadmap (2021), https://energyoffice.colorado.gov/climate-energy/ghg-pollution-reduction-roadmap; N.J. Bd. Pub. Utils. et al., New Jersey Energy Master Plan: Pathway to 2050 (2019), https://nj.gov/emp/docs/pdf/2020_NJBPU_EMP.pdf; Energy & Env't Economics, Pathways to Deep Decarbonization in New York State (2020), https://www.nyserda.ny.gov/-/media/files/edppp/energy-prices/energy-statistics/2020-06-24-nys-decarbonization-pathways-report.ashx.

2 *See, e.g.*, Dep't of Energy, Off. of Energy Efficiency & Renewable Energy, *Building Energy Codes Program: Determinations*, https://www.energycodes.gov/determinations (last visited Apr. 7, 2022); *see also* Rocky Mountain Inst., Building Decarbonization Roadmap (June 2021), https://static1.squarespace.com/static/5a4cfbfe18b27d4da21c9361/t/60c9295c0d6f5b30e2a66948/1623796080027/Alliance+Building+Decarbonization+Roadmap.pdf.

3 *See, e.g.*, Michael Ingram, Akanksha Bhat & David Narang, Nat'l Renewable Energy Lab'y, A Guide to Updating Interconnection Rules and Incorporating IEEE Standard 1547 (2021), https://www.nrel.gov/docs/fy22osti/75290.pdf.

4 U.S. Climate Alliance, From SLCP Challenge to Action (Sept. 2018), https://static1.squarespace.com/static/5a4cfbfe18b27d4da21c9361/t/5b9a9cc1758d466394325454/1536859334343/USCA+SLCP+Roadmap_final+Sept2018.pdf.

5 *See, e.g.*, Washington State Office of Financial Mgmt., *Life Cycle Cost Tool* (Sept. 2020), https://ofm.wa.gov/budget/budget-instructions/budget-forms.

6 *See* Douglas J. Arent et al., *Key Economic Sectors and Services – Supplementary Material*, in Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, at SM10-4, tbl.SM10-1 (C.B. Field et al. eds. 2014) (listing peer reviewed estimates of the welfare impact of climate change in terms of global GDP, starting in the early 1990s).

7 *See, e.g.*, William Nordhaus, *Evolution of Modeling of the Economics of Global Warming: Changes in the DICE Model*, 1992–2017, 148 Climatic Change 623 (2018) (describing process and substance of model updates).

8 *See* Richard Clarkson & Kathryn Deyes, *Estimating the Social Cost of Carbon Emissions* 7–11 (Gov't Econ. Serv. Working Paper 140, 2002) (discussing damages- and cost-based approaches to emissions valuation and recommending that ministries use a particular range of shadow prices to develop or evaluate policies with effects on greenhouse gas emissions). In 2003, the UK Department for Environment, Food, and Rural Affairs commissioned a two-part Social Cost of Carbon Review, which was published in late 2005. *See* Paul Watkiss et al., The Social Costs of Carbon (SCC) Review–Methodological Approaches for Using SCC Estimates in Policy Assessment, Final Report (2005); Thomas E. Downing et al., Social Cost of Carbon: A Closer Look at Uncertainty (2005).

9 *See* Ctr. for Biological Diversity v. Nat'l Highway Traffic and Safety Admin., 538 F.3d 1172, 1188 n.19 (9th Cir. 2008) (noting reference to Watkiss et al. by commenter Environmental Defense).

10 *See id.* at 1182–93 (describing procedural history and assembling relevant citations).

11 *Id.* at 1227.

12 This group was later renamed the Interagency Working Group on the Social Cost of Greenhouse Gases.

13 Interagency Working Group on the Social Cost of Carbon, Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 3-4 (2010) [hereinafter "2010 TSD"], https://perma.cc/VTD5-VBL3. Estimates were first developed for carbon dioxide in 2009-2010 and then in 2016, the IWG came out with estimates for methane and nitrous oxide.

14 *Id.* at 2–3.

15 *Id.*; Interagency Working Group On The Social Cost Of Carbon, Technical Support Document: Technical Update Of The Social Cost Of Carbon For Regulatory Impact Analysis Under Executive Order 12866 (2013) [hereinafter 2013 TSD], https://perma.cc/6DYA-ANEX; Interagency Working Group on the Social Cost of Greenhouse Gases, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis (2016) [hereinafter "2016 TSD"], https://perma.cc/R7NC-XH6S; Interagency Working Group on the Social Cost of Greenhouse Gases, Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide, Interim Estimates under Executive Order 13,990 (2021) [hereinafter "2021 TSD"], https://perma.cc/5B4Q-3T5Q.

16 DICE (Dynamic Integrated Climate and Economy) was developed by William D. Nordhaus, https://williamnordhaus.com/dicerice-models; PAGE (Policy Analysis of the Greenhouse Effect) was developed by Chris Hope, https://www.climatecolab.org/wiki/page; and FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) was developed by Richard Tol, http://www.fund-model.org/. *See* TSD 2010, *supra* note 13, at 5.

17 *See* The Nobel Prize, *William D. Nordhaus: Facts*, https://www.nobelprize.org/prizes/economic-sciences/2018/nordhaus/facts/ (last access Apr. 12, 2022).

18 *See* Univ. of Cambridge, *Chris Hope*, https://www.jbs.cam.ac.uk/faculty-research/research-teaching-staff/chris-hope/ (last accessed Apr. 12, 2022).

19 *See* 2010 TSD, *supra* note 13, at 4–5.

20 *See* 2016 TSD, *supra* note 15, at 21.

21 *See* 2010 TSD, *supra* note 13, at 12–23.

22 2016 TSD, *supra* note 15, at 5-29. *See also* Michael Greenstone et al., *Developing a Social Cost of Carbon for U.S. Regulatory Analysis: A Methodology and Interpretation*, 7 Rev. Env't. Econ. & Pol'y 23 (2013); Frank Ackerman & Elizabeth Stanton, *Climate Risks and Carbon Prices: Revising the Social Cost of Carbon, Econ.: The Open-Access*, Open-Assessment E-Journal 6 (2012) (reviewing the IWG's methods and stating, "[T]he Working Group analysis is impressively thorough.").

23 *See* 2013 TSD, *supra* note 15.

24 Gov't Accountability Off., Regulatory Impact Analysis: Development of Social Cost of Carbon Estimates (2014).

25 *See* 2016 TSD, *supra* note 20, at 2.

26 Nat'l Acad. of Scis., Eng'g & Med., Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update 46 (2016) [hereinafter NAS 2016] ("The committee recommends against a near-term update to the social cost of carbon based simply on a recalibration of the probability distribution of the equilibrium climate sensitivity (ECS) to reflect the recent consensus statement in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Consequently, the committee also recommends against a near-term change in the distributional form of the ECS.").

27 *Id.*at 46–49.

28 2016 TSD, *supra* note 20, at 3 ("The purpose of this 2016 revision to the TSD is to enhance the presentation and discussion of quantified uncertainty around the current SC-CO2 estimates, as a response to recommendations in the interim report by the National Academies of Sciences, Engineering, and Medicine.").

29 Interagency Working Group On Social Cost Of Greenhouse Gases, Addendum To Technical Support Document On Social Cost Of Carbon For Regulatory Impact Analysis Under Executive Order 12866: Application Of The Methodology To Estimate The Social Cost Of Methane And The Social Cost Of Nitrous Oxide (2016), https://www.obamawhitehouse.gov/sites/default/files/omb/inforeg/august_2016_sc_ch4_sc_n2o_addendum_final_8_26_16.pdf [hereinafter "2016 TSD Addendum"].

30 The National Academy of Sciences accepted public comment during its review process. Policy Integrity submitted comments during that process. Inst. for Pol'y Integrity, *Recommendations for Changes to the Final Phase 1 Report on the Social Cost of Carbon, and Recommendations in Anticipation of the Phase 2 Report on the Social Cost of Carbon* (Apr. 29, 2016), http://policyintegrity.org/documents/Comments_to_NAS_on_SCC.pdf [hereinafter "Policy Integrity NAS comments"]. Specifically, NAS concluded that a near-term update was not necessary or appropriate and the current estimates should continue to be used while future improvements are developed over time. NAS 2016, *supra* note 26.

31 California v. Bernhardt, 472 F. Supp. 3d 573 (N.D. Cal 2020); see also Joint Comments to U.S. Dep't of Energy on Energy Conservation Program: Energy Conservation Standards for Room Air Conditioners, Docket No. EERE-201-BT-STD-0059 (Sept. 8, 2020).

32 Gov't Accountability Off., Social Cost of Carbon: Identifying a Federal Entity to Address the National Academies' Recommendations Could Strengthen Regulatory Analysis at 48 (2020), https://www.gao.gov/assets/gao-20-254.pdf.

33 Exec. Order No. 13,990 § 5, 86 Fed. Reg. 7037, 7040–41 (Jan. 25, 2021).

34 While interim estimates announced in February 2021 match the 2016 estimates, the February 2021 technical support document issued notes that, "based on the IWG's initial review, new data and evidence strongly suggests that the discount rate regarded as appropriate for intergenerational analysis is lower." 2021 TSD, *supra* note 15, at 4.

35 *Id.* at 19–21.

36 *See*, CDP, Putting a Price on Carbon: The State of Internal Carbon Pricing by Corporates Globally 4 (2021) ("Nearly half (226) of the world's 500 biggest companies by market capitalization are now putting a price on carbon or planning to do so within the next two years, more than doubling the number from our last report in 2017.").

37 *E.g.*, Kyle Richmond-Crosset, Raven Graf & Aurora Winslade, Developing Swarthmore College's Shadow Price on Carbon (2019), https://secondnature.org/wp-content/uploads/Swarthmore-Shadow-Price-Pilot-Policy-.pdf.

38 An April 2022 executive order requires Colorado to begin using the SC-GHG in energy efficiency related procurement. Colo. Exec. Order D 2022 016.

39 N.Y. Env't Conserv. L. § 75-0113.

40 N.Y. Dep't of Env't Conserv., Establishing a Value of Carbon: Guidelines for Use by State Agencies (2020; updated May 2022), https://www.dec.ny.gov/docs/administration_pdf/vocguid22.pdf.

41 *Id.* at 18 ("The federal IWG's central discount rate of 3 percent should be considered as a maximum discount rate. A rate of 2 percent should be used as the central value and a rate of 1 percent should be considered as the lower bound to ensure that State agencies are properly informed in their decision-making.").

[42] Inst. for Pol'y Integrity, COST OF CARBON PROJECT, *States Using the SCC*, https://costofcarbon.org/states (last access Apr. 12, 2022).

[43] As explained more fully in Section 2 of this Guide, applying the SC-GHG actually yields a *set* of four values. Three of those values correspond to the three discount rates used by the Working Group—2%, 3%, and 5%—and the fourth corresponds to an estimate of a more extreme climate scenario. A decisionmaker may choose to focus on one estimate or to use the full range of estimates.

[44] *See, e.g.*, Gina Filosa & Carson Poe, Fed. Transit Admin., Transit Greenhouse Gas Emissions Estimator v2.0 User Guide, Report Number: DOT-VNTSC-FTA-21-02 (2021), https://rosap.ntl.bts.gov/view/dot/55900; ICLEI – Local Governments for Sustainability USA, U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions, Version 1.2 (July 2019), https://icleiusa.org/us-community-protocol/; The Climate Registry, General Reporting Protocol, Version 3.0 (May 2019), https://www.theclimateregistry.org/protocols/General-Reporting-ProtocolV3.pdf; Am. Pub. Transit Ass'n, Quantifying Greenhouse Gas Emissions from Transit, APTA SUDS CC-RP-001-09, Rev. 1 (2018), https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-SUDS-CC-RP-001-09_Rev-1.pdf.

[45] U.S. EPA, *Emissions Estimation Tools*, https://www.epa.gov/air-emissions-factors-and-quantification/emissions-estimation-tools (last visited Apr. 1, 2021); Greenhouse Gas Protocol, *Calculation Tools*, https://ghgprotocol.org/calculation-tools (last accessed Apr. 1, 2021).

[46] U.S. EPA, *Greenhouse Gas Equivalencies Calculator*, https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator (last accessed Apr. 1, 2021).

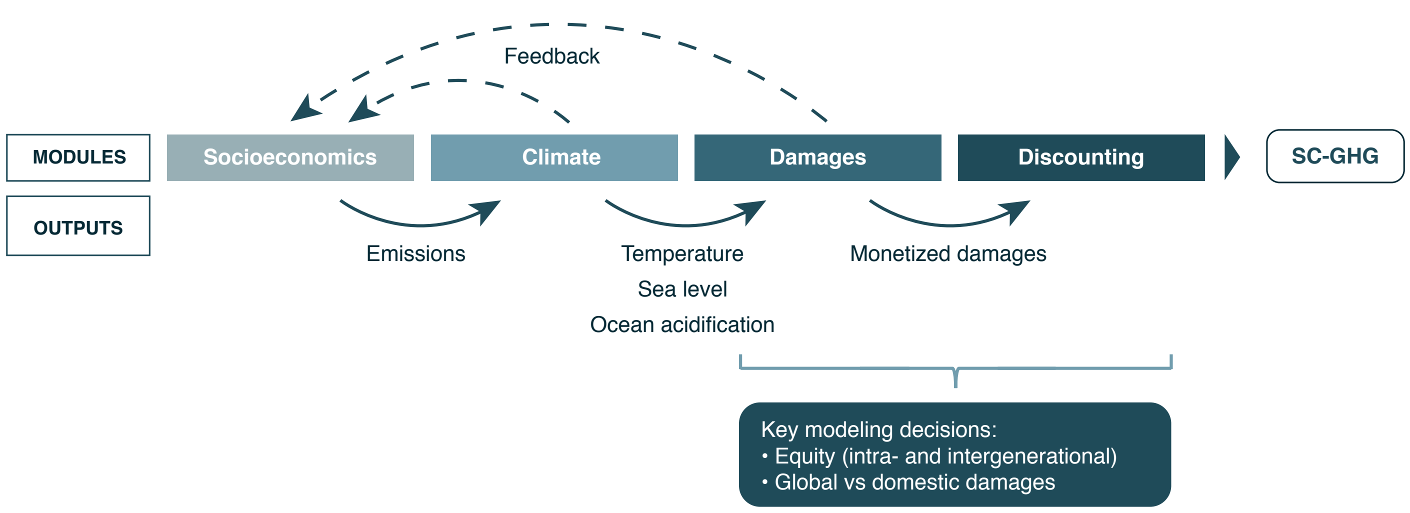
2. Key Concepts and Features

This section is meant to help users of the Social Cost of Greenhouse Gases (SC-GHG) understand the tool's key features and limitations. It proceeds in four main subsections. The first subsection describes the components of the SC-GHG itself, including modeling and discount rates. The second explains differences between the SC-GHG, which estimates the *damage* caused by each additional ton of greenhouse gas emissions, and the marginal abatement cost approach, which estimates how much it would *cost* to reduce greenhouse gas emissions by a ton. This subsection notes that each approach is appropriate in certain situations and that the two can function as analytical complements. The third subsection discusses the valuation of greenhouse gases for which the Working Group does not yet have estimates, such as CFCs, HFCs, and other refrigerants. And the fourth walks through common criticisms of the SC-GHG and the estimation of climate damages more generally. Some of those criticisms tend to come from academics and researchers working to improve upon scientific understanding of climate change and its effects. Other criticisms are commonly heard from opponents of climate action.

2.1. Components and Decisions Embodied in the SC-GHG

The interim SC-GHG estimates—adopted by the Interagency Working Group in February 2021—characterize the relationship between society and climate change using four components: socioeconomics, physical climate, damages, and discounting. Each module serves as a source of inputs to the next. Socioeconomic factors drive emissions, which inform changes to the climate. Climatic changes result in physical climatic damages. Those damages inform economic damages, in turn, and those damages are then discounted. This modeling methodology includes a linear progression through each module toward the SC-GHG, but also captures how some outputs of those modules feed back into one another. Just as socioeconomics affects climate, climate and climate damages affect socioeconomic factors. Figure 2-1 shows how these modules interconnect and highlights which modules reflect key decisions about the scope of inputs and outputs to be reflected in the SC-GHG's estimates.

Figure 2-1. SC-GHG Components



The rest of this subsection describes the components shown in this figure and the decisions that inform their ultimate outputs. Note that this subsection does *not* describe the SC-GHG that is expected to be issued by the Working Group in the latter half of 2022.

2.1.1. The Models of the Economy and Climate, and Damage Functions

The interim SC-GHG adopted in 2021 is estimated by combining data from three models, known as reduced-form integrated assessment models (IAMs): DICE, FUND, and PAGE.[1] These IAMs rely on a mix of empirical evidence and modelers' expert judgment about the relationships between physical aspects of a changing climate and market and nonmarket effects in society.[2] The model developers include William Nordhaus, a Nobel Prize winner and professor at Yale University; David Anthoff, a professor at University of California Berkeley and University Fellow at Resources for the Future; and Richard Tol, a professor with appointments at universities in Britain and the Netherlands and member of the Academia Europaea; and Chris Hope, the lead author reviewer of the Third and Fourth Assessment Reports of the Intergovernmental Panel on Climate Change. The models translate greenhouse gas emissions into changes in atmospheric greenhouse concentrations; atmospheric concentrations into climate drivers like temperature, sea level, and ocean acidification; climate drivers into environmental impacts; and environmental impacts into economic damages.[3] As summarized here, each of these three models works slightly differently.

DICE examines the interplay between carbon emissions and global productivity at an aggregate global level.[4] It treats emission reductions as "natural capital" that reduce the harmful effects of climate change and assumes that greenhouse gas emissions "are a function of global [gross domestic product]" and the pollution intensity of economic output, "with the latter declining over time due to technological progress."[5] DICE then calculates the effect of temperature on the global economy using a global damage function that is not disaggregated by impacts to specific sectors.[6] Although DICE does not explicitly model adaptive behaviors, some adaptation measures are implicitly modeled because some of the underlying studies used to calibrate DICE's aggregate damage function do model adaptation.[7]

PAGE looks at economic, noneconomic, and catastrophic damages in eight different geographic regions.[8] For each region, climate damages are expressed as a portion of economic output, where the portion of lost output is tied to regional temperature change.[9] Unlike DICE, PAGE explicitly takes adaptation into account.[10] Essentially, PAGE assumes that adaptation lessens the severity of climate impacts at a certain degree of warming.[11]

FUND considers a number of specific market and nonmarket components of climate impacts, including agriculture, forestry, water, energy use, sea level rise, ecosystems, human health, and extreme weather.[12] Damages for each component are modeled differently and are calculated for 16 geographic regions.[13] Unlike in PAGE, where damages are tied to temperature change, FUND assumes damages are a function not only of temperature change, but also of the *rate* of temperature change (for some types of impacts), and relative regional income.[14] Adaptation is reflected both explicitly in certain components, like sea level rise and agriculture, and implicitly in others, like energy and health, where income affects vulnerability to impacts.[15] A number of FUND's characteristics mean it could, in theory, produce a negative damage estimate—that is, the model allows for the possibility that climate change is net beneficial.[16]

The Working Group has integrated updates to the models into SC-GHG estimates several times.[17]

It is important to note that these models omit, or do a poor job of quantifying, certain significant damages.[18] As mentioned above, each modeler makes assumptions using a combination of empirical research and their expert judgment about the relationship between changes in global temperature, physical effects, and economic damages.[19] These assumptions are represented by the damage functions that underlie each model.[20] Many experts believe the Working Group's SC-GHG underestimates climate damage—though those experts generally endorse continued use of the SC-GHG for the time being as the best available estimate.[21] Since the SC-GHG was last updated in 2016, new research has added to available knowledge of climate impacts and economic damages.[22] The modeling gaps that inform the 2021 SC-GHG estimates are discussed further below.

2.1.2. Modeling Limitations Underlying the SC-GHG

There are factors and impacts that the models underlying the SC-GHG do not currently capture. In some cases, the models omit important damages, such as fire risk and disease. (These omissions are much of the reason that current estimates of the SC-GHG should be considered a lower bound.[23]) In other cases, the models do not consider benefits of climate action, such as improved health outcomes from decreased emissions of particulate matter and other harmful local pollutants. The models also do not consider potential distributional effects of climate impacts and policy.

2.1.2.1. Omitted Damages

The SC-GHG's estimates of climate damage (discussed further in 2.1.4 below) represent the federal government's best available estimates of the marginal climate damages caused by an additional unit of greenhouse gas emissions. However, those estimates should be treated as a lower-bound estimate of true climate damages. Due to technical and modeling limitations, many climate damages have not been reflected in the Working Group's SC-GHG estimates. Specifically, the Working Group's social cost estimates are based on models that place no value on some major climate impacts like increased fire risk, the geographic spread of pests and pathogens, slower economic growth, mass extinctions, large-scale migration, increased social and political conflict, violence borne of resource scarcity, and the loss of coral reefs and other aquatic life.[24]

The models do a better job of measuring the market costs of average temperature increases compared to how well they capture other types of impacts, but in all cases, the models omit important interactions between large ecosystem and climatic changes, which the Intergovernmental Panel on Climate Change (IPCC) refers to as impact drivers. These impact drivers, such as flooding and extreme temperatures are difficult to model, but nonetheless important.

The models also omit other variables discussed in the IPCC's 5th Assessment Report (AR5), such as the role of social factors in projecting climate impacts,[25] owing in part to the technical challenges of reflecting variability and tipping points in models.[26]

The tables below show which effects are included and which are excluded from the reduced-form social cost IAMs underlying the 2021 interim SC-GHG. The contents of these tables can be found on the Cost of Climate Pollution project website.[27]

Table 2-1. How the Working Group's SC-GHG Accounts for IPCC Climate Impact Drivers

Status	Climate-Related Drivers of Impacts
Excluded	Extreme temperature *The health impacts of extreme temperatures are the only impact considered by IAMs*
	Drying trend
	Extreme precipitation
	Snow cover
	Ocean acidification
Partially Included	Flooding *Coastal flooding is included and inland flooding is excluded*
	Storm surge *Partially included, fails to account for combine effect of sea level rise and increased intensity of coastal storms*
Included	Warming trend
	Precipitation
	Damaging cyclones
	Carbon dioxide concentration
	Sea level rise

Table 2-2. IPCC Climate Impacts in the Working Group's SC-GHG Estimates

Sector	Status	Impact
Economic		
Agriculture	Included	Impacts on average crop yields due average temperature increases CO_2 fertilization effect *More optimistic than current observation, potentially due to optimistic assumptions about CO_2 fertilization effect*
	Excluded	Increases in yield variability
	Excluded	Change in food quality, including nutrition content
	Excluded	Increased pest and disease damage
	Excluded	Flood and sea level impacts on food infrastructure and farmland
	Excluded	Food security
	Excluded	Food price stability, and price spikes
Forestry	Included	CO_2 fertilization
	Included	Shifting geographic range
	Excluded	Increased pest and disease damage
	Excluded	Increasing risk of wildfire

Sector	Status	Impact
Fresh water availability	Included	Changing precipitation
	Excluded	Melting snowpack
	Excluded	Changing water quality
	Excluded	Competing uses, including overexploitation of groundwater resources
	Excluded	Water security, and water prices
	Partially included	Water supply system losses and disruptions *While general infrastructure costs of coastal extreme events (flooding and storms) are included, inland extreme events are omitted. Also, IAMs exclude more long term costs from these infrastructure losses, including human suffering.*
Fisheries and aquatic tourism	Excluded	Shifted geographic ranges, seasonal activities, migration patterns, abundances, and species interactions
	Excluded	Reduced growth and survival of shellfish and other calcifiers
	Excluded	Coral bleaching
	Excluded	Decrease in catch potential at some latitudes
Energy	Partially included	Energy system losses and disruptions *While general infrastructure costs of coastal extreme events (flooding and storms) are included, inland extreme events are omitted. Also, IAMs exclude more long term costs from these infrastructure losses, including human suffering and increases in energy prices.*
Property and infrastructure loss	Included	Coastal property losses due to storms, flooding, and sea level rise
	Excluded	Inland property loss due to extreme weather events, including flooding
	Excluded	Melting permafrost
	Excluded	Wildfires
Declining economic growth	Excluded	Labor productivity
	Excluded	Prolong existing and create new poverty traps
	Excluded	Diverted R&D funds for adaptation research
	Excluded	Lost land, capital, and infrastructure

Sector	Status	Impact
Non-market		
Human health *Cardiovascular, respiratory disorders, diarrhea, and morbidity for some health impacts are included in FUND and partially included in PAGE*	Included	Coastal mortality from flooding and storms
	Included	Spread in geographic range of vector-borne diseases *Significant diseases are included, though Lyme disease is excluded.*
	Excluded	Wildfires
	Excluded	Mortality from inland extreme weather events
	Excluded	Food and water availability
	Partially included	Heat related deaths
	Partially included	Water-borne diseases
	Partially included	Morbidity: non-fatal illness and injury
	Partially included	Air quality *Air quality is included in DICE, though does not account for changes due to pollen or wildfire*
Terrestrial, freshwater, and marine ecosystems and wildlife	Included	Shifted geographic ranges, seasonal activities, migration patterns, abundances, and species interactions *The value of ecosystems and biodiversity are included in general terms not specific to any one damage.*
	Included	Extinction and biodiversity loss
	Excluded	Non-climate stressors: habitat modification, over-exploitation, pollution, and invasive species
	Excluded	Abrupt and irreversible regional-scale change in the composition, structure, and function of ecosystems *Environmental tipping points in non-climate systems are excluded.*
	Excluded	*Effects of ocean acidification on polar ecosystems and coral reefs* *Ocean acidification is excluded.*
	Partially included	Loss of habitat to sea level rise *Wetland loss explicitly modeled in FUND, and thus partially in PAGE*
Social		
Migration	Excluded	Increased displacement *FUND partially accounts for migration, but uses arbitrary measurements of resettlement and costs*
Social and political instability	Excluded	Violence, civil war, and inter-group conflict
	Excluded	National Security
Stressors		
Non-climate stressors	Excluded	Climate-related hazards exacerbate other non-climate stressors
Multidimensional inequalities	Excluded	Inequalities including income
Violent conflict	Excluded	Violent conflict increases vulnerability

Sector	Status	Impact
Tipping points		
Climate tipping points *Known tipping points are modeled as a single event, instead of multiple events. Furthermore, fat tails, which capture unknown tipping points, are excluded*	Partially included	Reduction in terrestrial carbon sink
	Partially included	Boreal tipping point
	Partially included	Amazon tipping point
	Partially included	Other tipping points
Ecosystem tipping points	Excluded	Abrupt and irreversible regional-scale change in the composition, structure, and function of ecosystems *Environmental tipping points in non-climate systems are excluded.*

2.1.2.2. Co-benefits

The SC-GHG does not capture the adverse effects of local pollutants that are often emitted along with greenhouse gases. For example, burning coal releases fine particular matter ($PM_{2.5}$) and sulfur-dioxide along with greenhouse gases. These local pollutants can have significant adverse impacts on the environment and public health, and so are important for decisionmakers to consider when making and implementing policy. Notably, some greenhouse gas pollutants, like methane, may have local effects, which are also not captured in the SC-GHG.[28]

Although the SC-GHG currently omits local pollution, states still can and should separately consider local pollution co-benefits in assessing policies. Calculating the value of the co-benefits of avoided local pollution can be very complex because even when global and local pollutants flow from the same facility they do damage in very different ways.[29] Fortunately, there are well-established monetized estimates of some co-benefits of greenhouse gas reductions that have been used by federal agencies,[30] as well as detailed qualitative assessments of non-monetized co-benefits.[31] Two reports published by the Institute for Policy Integrity, *Valuing Pollution Reductions*[32] and *Making the Most of Distributed Energy Resources*,[33] set forth a basic methodology for how to calculate location-specific environmental and health effects.[34]

For examples of how a government agency has included co-benefits from reduced ozone and other co-pollutants in cost-benefit analysis, states can look to the U.S. Environmental Protection Agency's (EPA) December 2021 regulatory impact statement for updated vehicle emissions standards or EPA's 2016 regulatory impact analysis for the new source emissions standards for the oil and gas sector.[35]

2.1.2.3. Distributional Consequences

Another important consideration is that the Working Group's social cost estimates do not reveal how the various effects of climate change—physical and economic—are distributed across geographic areas and populations.[36] Existing inequities, stemming from historical and ongoing unjust treatment, has made certain communities—especially communities of color and low-income communities—more vulnerable to the costs of a given action or policy. The coronavirus pandemic has shone a bright light on how public health outcomes are tied to uneven underlying conditions across communities, even if the hazard or adverse event appears to be uniform. Communities of color and low-income communities have consistently faced higher infection and death rates during successive waves of the virus, owing to many factors, including disproportionate exposure to local pollution.[37] Similarly, multiple factors—such as infrastructure or access to air conditioning—can contribute to uneven distributions of climate-driven effects on a community, some more closely tied to policy measures than others.[38]

Several states, as well as the federal government, are exploring how to give due consideration to populations that were disproportionately harmed by past policies.[39] The SC-GHG does not tell policymakers about the disproportionate effects of past energy and climate policies, much less how to consider or remedy those effects. Evaluating or addressing past or present distributional effects of climate policy decisions therefore requires supplementing the SC-GHG with other tools and analytical techniques.

2.1.3. Global vs. Domestic Damages

Decisionmakers should use SC-GHG values that reflect global climate damages—doing otherwise would almost certainly undercount the costs of climate change and so under-regulate its causes. There are several reasons for using global values, all of them relevant to decisions made at the state as well as federal level. For one, because of the world's interconnected financial, political, health, security, and environmental systems, climate impacts that occur beyond the geographic borders of the United States—or any given U.S. state—will tend to cause significant costs that accrue directly or indirectly to U.S. residents.[40] Further, because U.S. climate policy, which is made up in part of subnational policies, can strategically influence the climate policies of other nations, actions in the United States can trigger reciprocal reductions of foreign emissions, directly benefiting the United States in ways not accounted for through a rigid domestic-only perspective.[41] In addition, U.S. residents have direct interests in climate-related impacts that will occur overseas, including those affecting citizens living abroad or U.S. assets located abroad, and those harming international habitats or species that U.S. citizens value.[42] As an empirical matter, moreover, there are very few region-specific estimates in the literature to date, and those that do exist ignore international spillovers and reciprocity and so are incomplete.[43]

For a more in-depth discussion of the reasons for using a global rather than a domestic estimate of climate damages, see *Strategically Estimating Climate Pollution Costs in a Global Environment* and *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*.[44]

2.1.4. Discounting

Answers to the two questions posed here establish the rudiments of why discounting is necessary when calculating climate damages and how discount rates are derived.

What is a discount rate?

A discount rate identifies the present value of some future cost or benefit. If offered $1 now or $1 in a year, most people would choose to receive the $1 now; they would only opt to be paid next year if they were offered more than $1. A similar pattern holds for society as a whole. The discount rate captures how much more, in percentage terms, people would have to receive in the present to be willing to wait until next year.

The less value that is assigned to the future effect in the present, the higher the discount rate. The closer the value of the future effect to its present value, the lower the discount rate. And, because discounting compounds, applying a discount rate over a long span of time reveals that a distant future effect has a *much* lower value in the present: even at a 1% discount rate, $1 million accrued 300 years in the future is worth about $50,000 today; at a 5% rate, it is worth less than 50 cents.[45]

Why is there not just one discount rate?

There are several reasons why a future effect might be valued less in the present. Those reasons include: the pure rate of time preference (i.e., impatience); the expectation that future generations will grow richer than the present generation; or the opportunity cost of capital for a private investor who must decide whether to invest or retain access to liquid capital for a future use.[46]

These different reasons correspond to different empirical bases for specifying a discount rate. Empirical estimates of a discount rate based on the expectation of future growth look to government bonds. This yields a "consumption based" rate.[47] Empirical estimates based on private investors' opportunity cost of capital look to pre-tax marginal rates of return on private investments,[48] which generally yield a higher "capital based" rate of return than government bonds.[49]

Further, in addition to these "descriptive" approaches that seek to identify a discount rate from empirical evidence of observed market outcomes, there are also "prescriptive" approaches that ground a discount rate in ethical considerations.[50] For instance, some have argued that impatience, as represented by a positive pure rate of time preference, is an indefensible basis for discounting future value in an inter-generational timeframe because doing so would unfairly discriminate against future generations. These arguments propose that the only defensible pure rate of time preference is either zero or close to it, because this better reflects society's aversion to such unequal treatment of later generations.[51]

The White House Office of Management and Budget's *Circular A-4*, which was issued in 2003, directs agencies analyzing the effects of a proposed regulation within an intra-generational time horizon (i.e., less than 30 years) to apply both a 3% and 7% discount rate.[52] The document explains that using a range—rather than a single rate—is appropriate because the proper rate depends in part on the share of policy costs to be borne by consumers and investors, an allocation that is impossible to foresee with precision.[53] Circular A-4 also directs agencies to apply lower discount rates to analyses of effects over a longer, intergenerational timeframe, consistent with the discussion of prescriptive rates above.[54] This instruction owes to several factors, including uncertainty about future growth rates, the expectation that the long-run rate of economic growth will decline, and to the basic fact that rates based on the private cost of capital cannot reflect an inter-generational perspective.[55]

2.1.4.1. How discounting informs the SC-GHG

Because greenhouse gases emitted today stay in the atmosphere and warm the climate for centuries, the Working Group bases its estimation of climate damages on modeling that extends from the present out to the year 2300.[56] The estimation of the SC-GHG is highly sensitive to how future damages are discounted to estimate their present value. Figures 2-1 and 2-2 illustrate this point by showing the significant effect of applying different discount rates—2.5%, 3%, and 5%—to the damages resulting from one ton of CO_2.

Figure 2-1. Undiscounted Damages from 1 Metric Ton of CO_2 Emissions in 2015.[57]

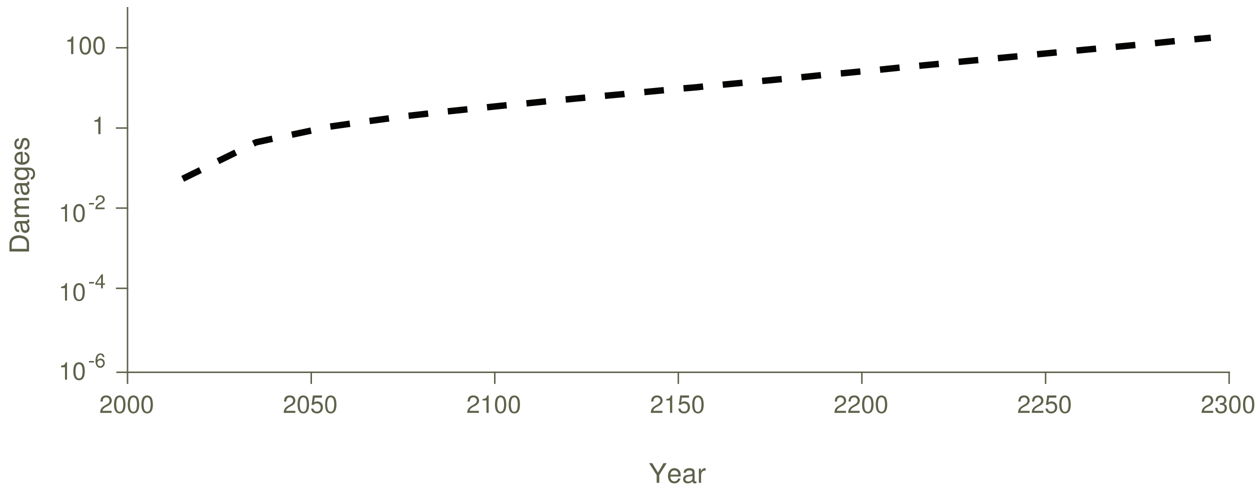
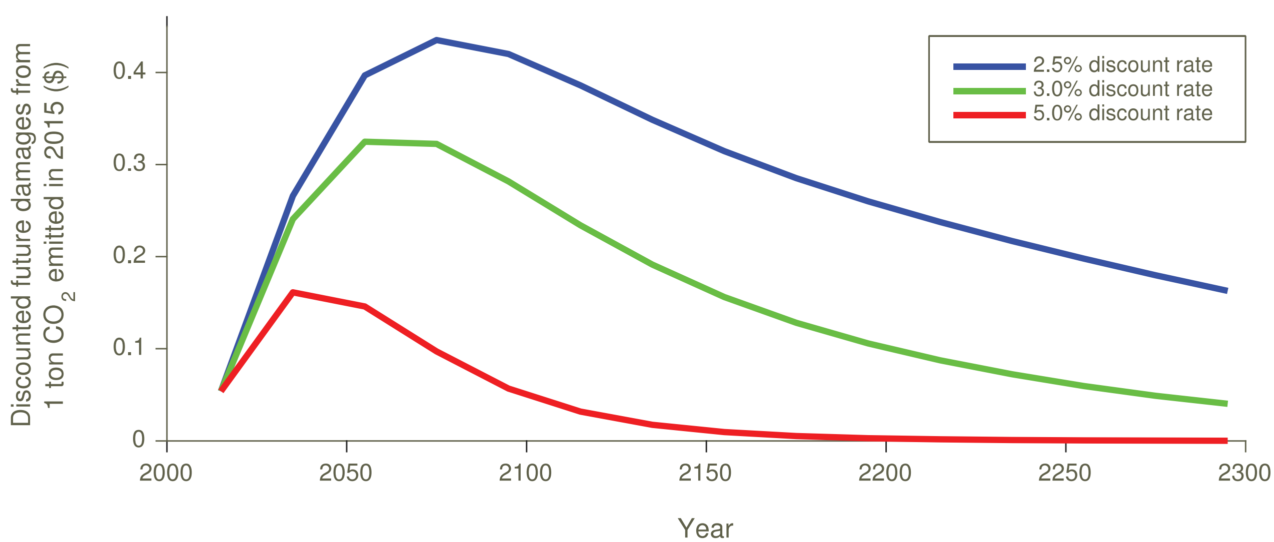


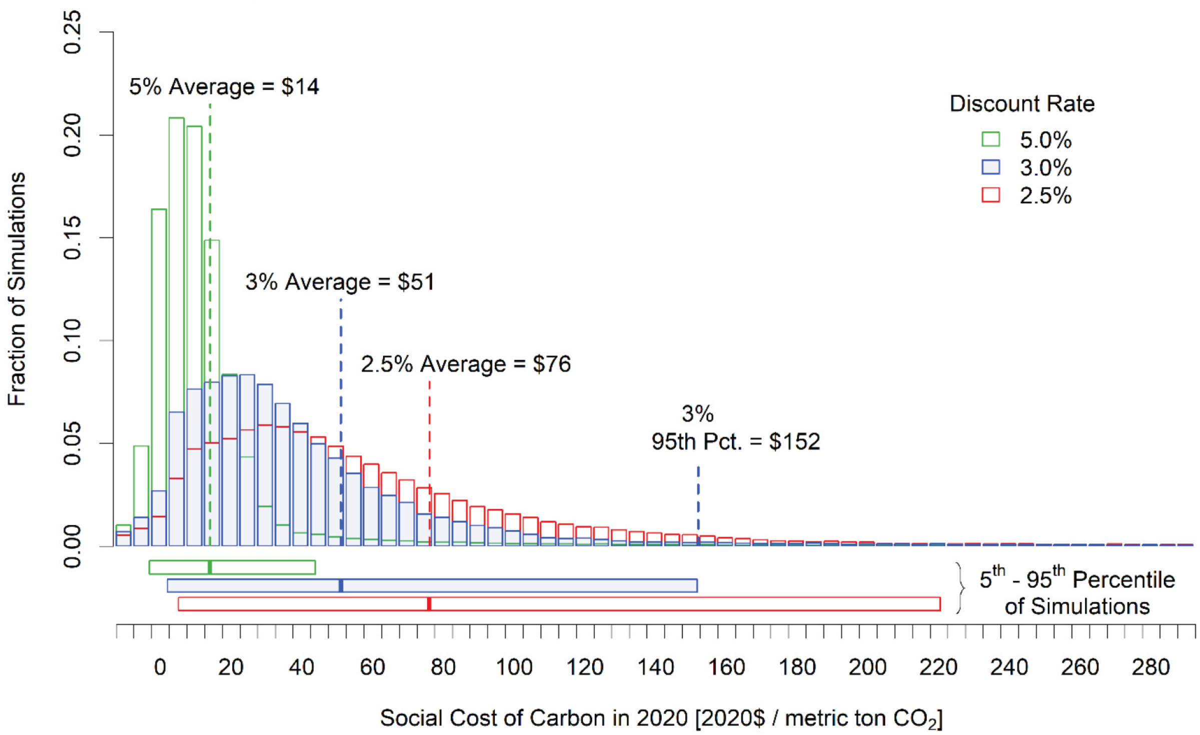
Figure 2-2. Annual Damages from Emissions of 1 Metric Ton of CO_2 Discounted Using Three Different Discount Rates.[58]



To understand how a discount rate is applied to the numbers generated by the combined socioeconomics, climate, and damage function modules of the IAMs, it helps to first explain how the modeling is done. Recall that each model incorporates numerous input parameters, most of which are represented not by a single value but by a range of possible values. For each of the 15 - possible combinations of scenario and discount rate, the three climate-economic models are each run thousands of times, each time in a slightly different way, as determined by drawing a value at random from the appropriate ranges for each parameter.[59] This yields 150,000 SC-GHG estimates per discount rate. After taking the average of the 150,000 model runs per discount rate across all 15 model-scenarios, the Working Group was left with 10,000 SC-GHG estimates per discount rate.[60] For each discount rate, the result of those model runs is a frequency distribution that shows how often different SC-GHG estimates occur conditional on the discount rate, as well as the mean and variance of the distribution.

Consistent with the discussion above about why governments might use more than one discount rate, the Working Group's process generates several SC-GHG values, each corresponding to the mean SC-GHG estimate of a particular discount rate—2.5%, 3%, and 5%.[61] Figure 2-3, below, shows that each of those values relates to a frequency distribution of model outputs described above.

Figure 2-3. Frequency Distribution of SC-CO_2 Estimates for 2020[62]



In addition to the three mean SC-GHG estimates, each based on a different discount rate, the Working Group also includes the 95th percentile SC-GHG estimate of the distribution corresponding to the 3% rate. The bottom of Figure 2-3 shows the 5th to 95th-percentile ranges of each frequency distribution representing the range of likely outcomes.[63] Of these outcomes, the Working Group focused on the low-probability, high-impact scenario corresponding to the 3% discount rate based on its recognition that omitted damages and tipping points made the SC-GHG a conservative estimate.[64]

The Working Group's 2010, 2013, and 2016 technical support documents recommend using the 3% discount rate as the "central estimate" of climate damages. However, the technical support document for the 2021 interim SC-GHG does not recommend using a central estimate and recommends that users consider using lower discount rates (discussed further below).[65] Therefore, when applying the SC-GHG, states should not feel bound to use a central estimate, and should consider using estimates based on the lower discount rates discussed below.

As Figures 2-2 and 2-3 make clear, the choice of discount rate has significant implications for the ultimate social cost value. And applying lower discount rates—as recommended by the Working Group and New York's Department of Environmental Conservation—extends the pattern further: whereas the average of the distribution at a 3% discount rate yields a value of $51 per ton of carbon dioxide emissions,[66] the average of the distribution at a 2% discount rate is $129 per ton, and at a 1% discount rate, $418 per ton.[67]

2.1.4.2. Beyond discounting basics

Three further points deserve mention in this overview of discount rates and their role in estimating the value of climate-damaging emissions: first and most important is why some high discount rates are inappropriate in the climate context; second is the logic and potential application of declining discount rates; and third is that recent research findings that suggest the SC-GHG should reflect lower discount rates than have been applied to date.

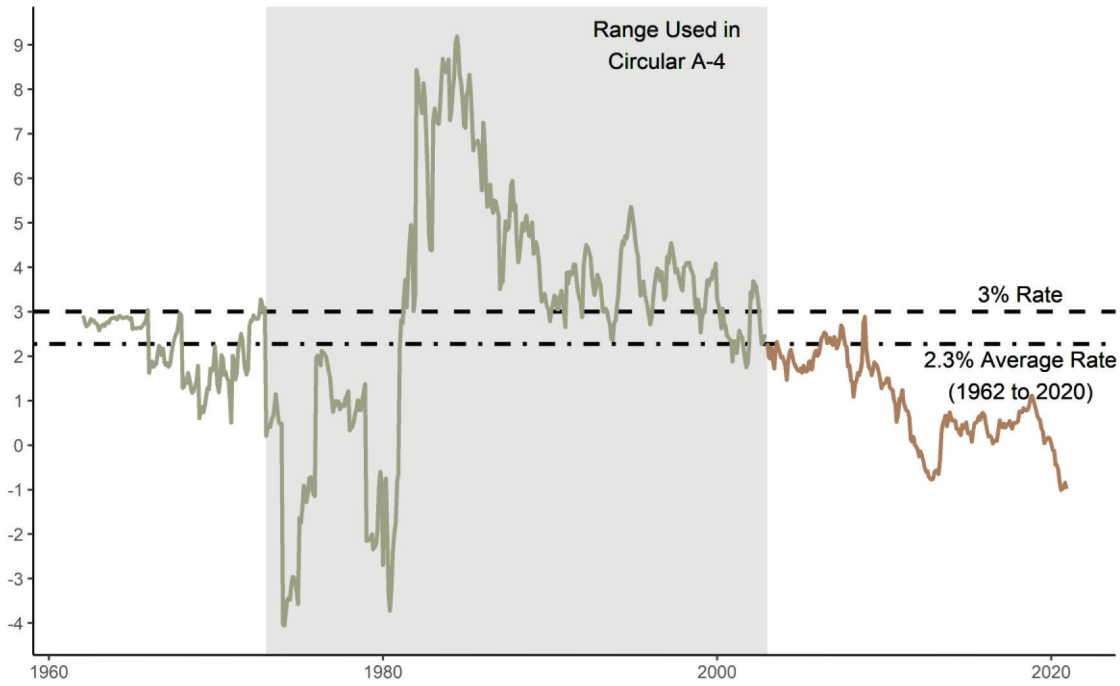
Inappropriately high discount rates. The Working Group recommends against using a 7% discount, which reflects the opportunity cost of capital,[68] to estimate the value of the SC-GHG.[69] It identifies several reasons for this recommendation, which are consistent with findings and recommendations of the National Academies,[70] as well as the findings of recent expert elicitations.[71] Those reasons, some of which are quite technical, are premised, fundamentally, on the principle that such a higher rate is grounded in an approach to discounting that focuses on the shorter-term and largely adopts the perspective of private investor.[72] Those elements are both a mismatch for the climate-related intergenerational and society-wide effects that the SC-GHG aims to value.

Declining discount rates. So far, this document has discussed only constant discount rates, but some prominent commentators have suggested that declining discount rates are more appropriate for analyses of intergenerational effects.[73] Indeed, there is an emerging but strong consensus in the economics literature that uncertainty over future social and economic conditions supports both a declining discount rate schedule, under which effects further into the future are discounted at gradually lower rates.[74] The government of the United Kingdom has published guidance on discounting that recommends agencies use a graduated set of discount rates: 3.5% for the first 30-year period of analysis, then 3% for the subsequent 45-year period, and so on down to 1% after year 300.[75] The guidance explains that this recommendation reflects both prescriptive and normative considerations.[76] On this basis, the Working Group made a rate of 2.5% the lowest of the rates it applied.[77]

Lower discount rates. The National Academies recommended in 2017 that updates to the SC-GHG reflect recent research findings, including that discount rates appear to be lower than they were when *Circular A-4* issued in 2003.[78] This approach accorded with the view of the Council of Economic Advisors and that of New York's Department of Environmental Conservation.[79] There are several bases for that finding, some empirical, others the result of methodological innovations by researchers, all of which point in the same direction:

- Real interest rates on U.S. treasuries have fallen steadily and substantially since at least 2000, and even recently hit negative numbers;[80]
- Forecasts for future real interest rates have also fallen;[81]
- These patterns are not unique to the United States, and reflect demographic shifts worldwide;[82]
- Applying an updated methodology to the same data used to inform *Circular A-4* yields a lower discount rate—1% to 2% instead of 3%;[83]
- Expert elicitations, which reflect considerations for uncertainty about the future and ethics as well as empirical findings, also indicate that the SC-GHG should reflect lower discount rates.[84]
- Theoretical research into discounting also increasingly supports the finding that discount rates used for intergenerational analyses should be lower than those used in the past.[85]

Figure 2-4. Monthly 10-Year Treasury Rates, Inflation Adjusted[86]



More information on all of the aspects of discounting mentioned above, as well as others, such as how to apply a Ramsey framework to discounting, can be found in the Policy Integrity report, *About Time: Recalibrating the Discount Rate for the Social Cost of Greenhouse Gases.*[87]

2.2. SC-GHG vs Marginal Abatement Cost

A damage-based approach like the SC-GHG is not the only way to assign a value to greenhouse gas emissions for the purpose of making and implementing climate policy. Another approach is to set a deadline for reducing emissions by a set amount and then estimate the cost of that abatement. This approach, which involves keeping to an emissions budget, is sometimes called "target-consistent," though economists (and this document) refer to it as the marginal abatement cost (MAC)-based approach.[88] The SC-GHG and MAC-based approach are distinct in several important respects and are useful for different but potentially complementary purposes.

Decisionmakers should be aware of several fundamental distinctions between the SC-GHG and a MAC-based approach. The SC-GHG values emissions based on how much damage an additional unit of greenhouse gas in the atmosphere would cause. It also can be used to identify the point at which the benefits of a project or decision exceed its emissions-related costs. By contrast, a MAC-based approach does not embody a direct estimate of climate damages or indicate the value of avoiding them. Nor does it suggest a target date for zeroing out emissions based on its analysis. Instead, it relies on someone else to set an emissions reduction target or deadline and estimates how much it would cost to remove the last, or most expensive, unit of pollution in the course of reaching that target. Further, unlike the SC-GHG, which considers both local and global effects, a MAC-based approach can apply to a particular jurisdiction or economic sector,[89] or to a sector within a jurisdiction.[90]

The legal context in which these approaches might be applied matters a great deal. For instance, federal agencies are typically required to compare the costs and benefits of major regulations.[91] So, if a regulation would result in a significant reduction of greenhouse gas emissions, the responsible agency is obliged to estimate the benefits of those reductions—something that the SC-GHG can reveal but a MAC-based valuation of emissions cannot. In contrast, in the United Kingdom, where a 2008 law (updated in 2019) imposes an economy-wide net-zero emissions target, policies are oriented to the cost-effective compliance with that MAC-based target.[92] Consequently, although the SC-GHG might be generally informative for a British government agency, because it does not tell agencies how to comply with the legislated emissions reduction target, it does not have clear regulatory significance.

Using somewhat more generic terms helps to summarize how the legal basis for an agency decision can determine which metric is more appropriate. An agency charged with conducting a cost-benefit analysis before adopting a regulation must, if the regulation would have emissions impacts, determine how much harm those emissions would impose (or avoid). The SC-GHG helps to make that determination in a way that a MAC-based value cannot. But the SC-GHG will not help an agency tasked with deciding what premium should be paid for a good that reduces or avoids greenhouse gas emissions, consistent with a binding, economy-wide emissions-reduction target. Instead, that agency would have to calculate the MAC for that good or the sector that good comes from.

Because of these differences, it is misguided to present the SC-GHG and MACs as substitutes. Analytically, they answer different questions. One is not "better" or "worse" than the other in the abstract. Each is suited for particular contexts and analyses.

Indeed, these two metrics can be used in analytically complementary ways. For instance, suppose a regulator is tasked with reducing greenhouse-gas emissions by some amount as cheaply as possible. They may employ MACs to help guide how much the state should expect to spend on meeting this target and where that funding should be allocated. They may also employ the SC-GHG to determine the net social benefits this regulation produces. The former might help inform how much the state as a whole should allocate to emission-reduction efforts in one sector versus other sectors, as policymakers can also monetize and compare those other sectors' values. The comparative values of the SC-GHG and the relevant MAC may also reveal that the state is spending too little (or too much) on emission reduction, which would in turn imply that the target reductions are too modest (or too ambitious).[93] In other words, an optimal scenario is where the SC-GHG, representing the marginal damage cost, is equal to the MAC.[94]

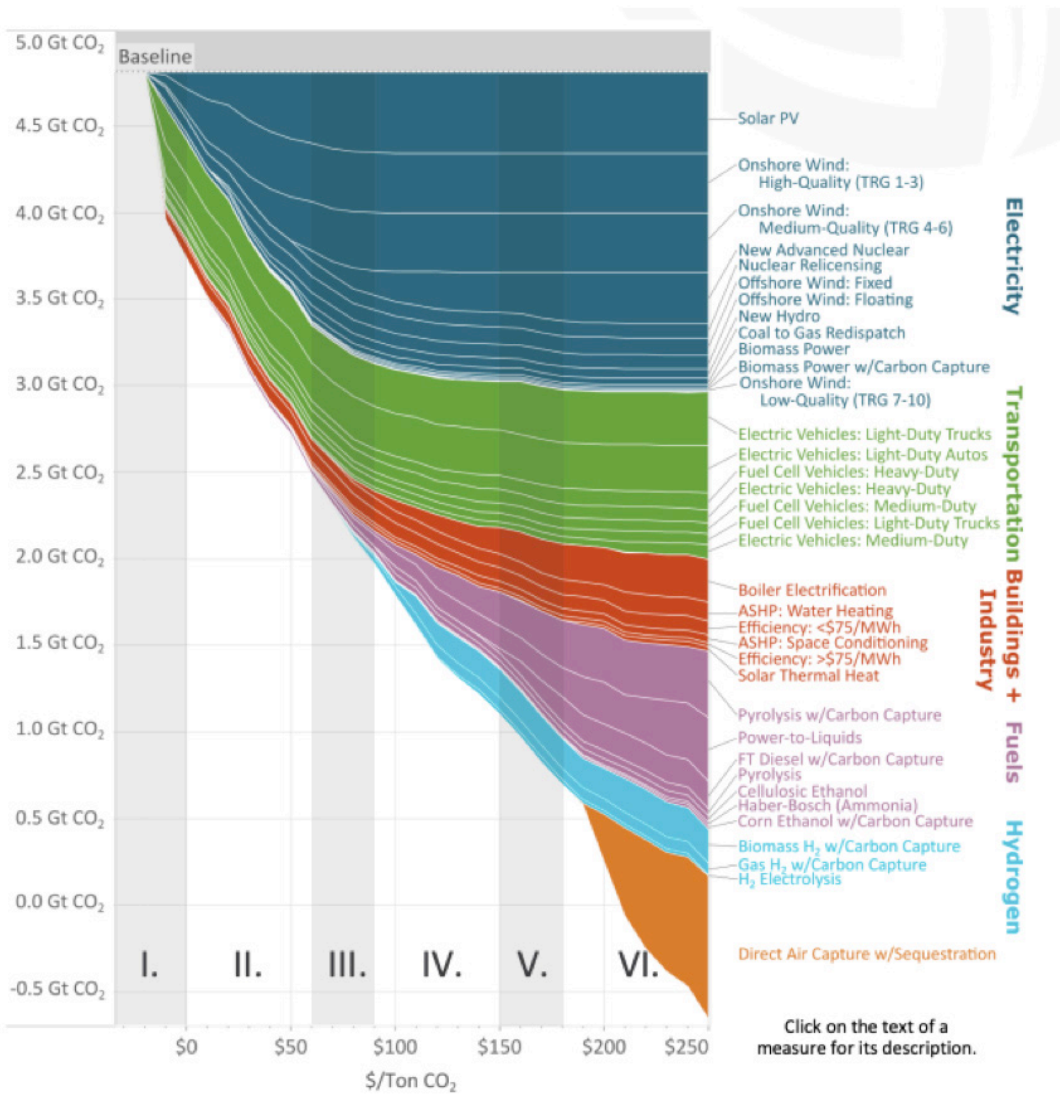
2.2.1. Marginal Abatement Cost Curves

MAC values are generally derived using a MAC curve. A MAC curve requires an emissions reduction target and a geographic and/or sectoral scope of analysis. The Paris Agreement embodies a scientifically determined global target: it adopts average global temperature increases of 1.5°C or 2°C as thresholds to be avoided through policy interventions by signatory states.[95] A number of state governments have adopted emissions reduction commitments for 2050 (or earlier) that align with the Paris Agreement.[96] Whatever the source of a target, in order for it to inform a MAC-based approach to valuing emissions, that target must be both legally and economically binding. Legally binding means that the state is responsible for achieving the target and consequences of some sort would follow from noncompliance. Economically binding means that the target is set lower than the level of emissions that would be achieved in its absence. MAC analysis cannot make use of hazy or flexible targets.[97] While the United States as a whole lacks the sort of binding emissions reduction targets required for a MAC-based emissions value, several states have adopted targets that appear to be sufficiently binding.[98]

A MAC curve typically lines up options for greenhouse gas emissions reductions by technology or sector.

Consider Figure 2-4, below, which shows the cost per ton of greenhouse gases abated using different interventions in five sectors: electricity, transportation, buildings and industry, fuels, and hydrogen.[99] Each category of technology appears as a wedge, sized to show how costly it would be to reduce emissions from the baseline emissions scenario.[100] In general, it is more expensive to reduce emissions when a jurisdiction is closer to meeting its goals than it is at the outset (since jurisdictions typically begin with the lowest-hanging fruit). Note that this is a static curve, and that a dynamic curve would reflect regular updates to inputs related to technologies, costs, and policies.[101]

Figure 2-5. A 2050 MAC Curve for U.S. Energy and Industry CO_2 Relative to a Baseline Scenario[102]



Several notable points are captured by this curve: first, that a variety of measures, or technologies, can be adopted at the same marginal abatement cost;[103] second, that each technology has a range of costs depending on the distance from the emissions baseline;[104] and third, that multiple interventions can be deployed in combination to reach a least-cost solution.[105]

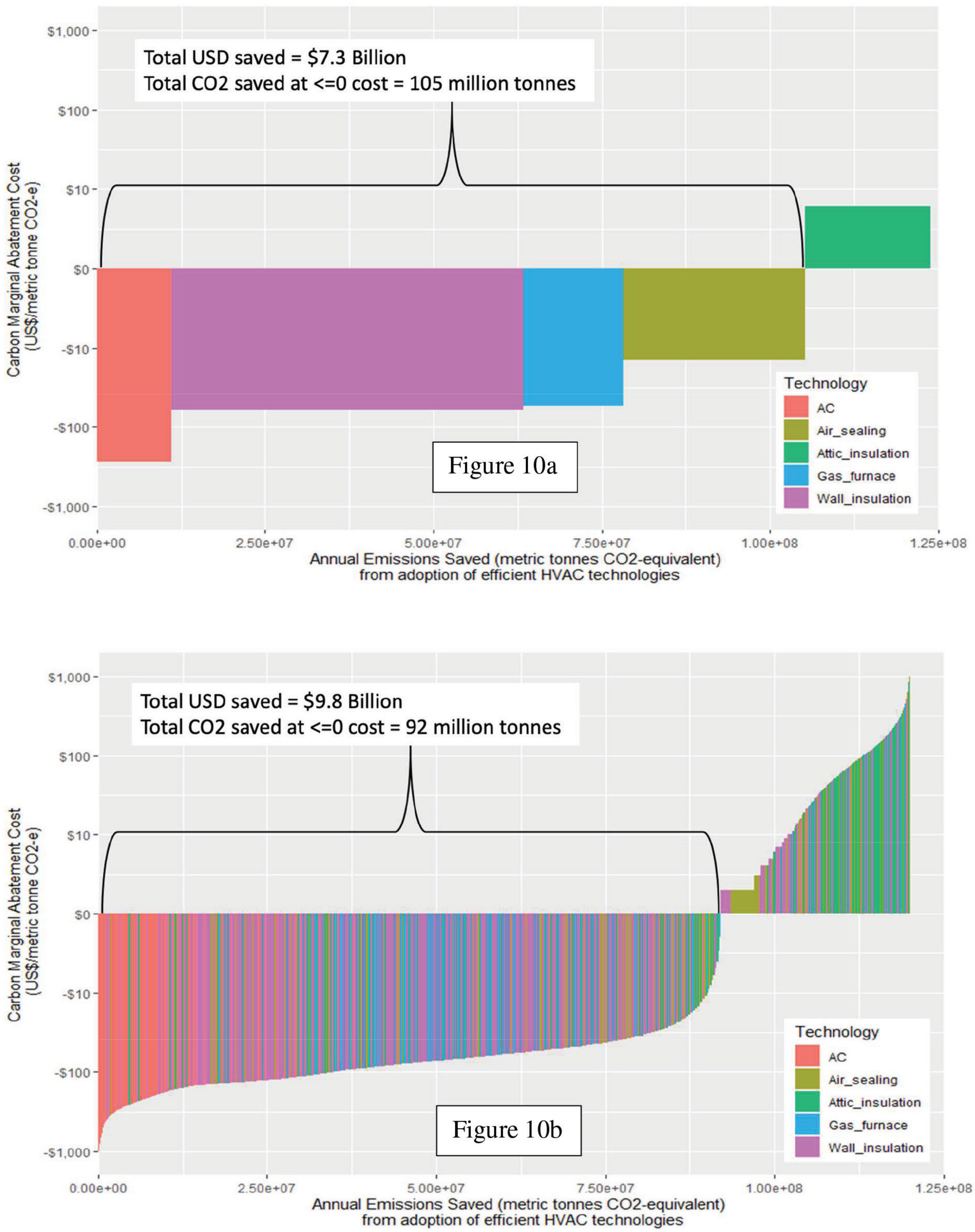
2.2.2. *Using MAC Curves: An Example and a Caveat*

MAC analysis can be useful for state governments, but should be undertaken in a way that seeks to capture—or at least not ignore—all relevant factors, even if they are potentially difficult to measure. Two studies help to illustrate these points. The first study focuses on residential decarbonization in California.[106] The second builds on the first, highlighting the importance of tenant behavior to the cost-effectiveness of different residential decarbonization measures, and notes the variability of that behavior across climatic regions.[107]

California is home to a legally and economically binding economy-wide greenhouse gas emissions reduction target,[108] and to a building energy use code that is periodically updated in line with state greenhouse gas emissions reduction requirements.[109] In a 2019 paper, White and Niemeier examine the cost-effectiveness of emissions reductions from different approaches to compliance with California's 2019 building energy codes.[110] The paper develops a MAC curve, based on a typology of homes with different energy use characteristics, notionally situated across California's different climatic zones.[111] Its findings indicate the potential for cost-effective greenhouse gas emissions abatement in California's residential building sector and suggest designs and equipment that are likely to yield more or less cost-effective abatement in different parts of the state.[112]

A second study, authored by Das et al., highlights that the factors considered in the first study—building envelopes, HVAC equipment, and climatic context—do not provide a complete picture of whether a particular set of energy efficiency measures are likely to yield cost-effective emissions reductions. Behavioral differences across tenants are also a major determinant of such measures' cost-effectiveness, and so ought to be incorporated into an analysis of how well and at what cost those measures can be expected to reduce emissions. Indeed, the authors find that "particulars of a household are often more important than technology in determining energy and economic savings for an efficiency upgrade."[113] Further, integrating tenants' preferences and heterogeneous behaviors into the MAC analysis complicates that analysis—but in a useful way that sheds light on how programs that encourage technology adoption should be designed. As the authors explain, with reference to the paired figure below, "[a]ccounting for heterogeneity changes the nature of the MAC[curve]: it is no longer segregated by technology, but rather mixes consumer characteristics with technologies."[114] Adding those factors into the analysis reveals that "[t]here are subsets of consumers who benefit much more than average, and subsets who pay much more."[115]

Figure 2-6. MAC Curves for Five Residential Energy Efficiency Technologies (a) Without and (b) With Heterogeneous Tenant Preferences and Behavior.[116]



Based on their findings, Das et al. recommend that "the organization of energy efficiency programs around technology type should be reconsidered. Currently, utilities decide rebates by technology type, generally assuming an average user. Compensating consumers for savings rather than purchase of a particular technology could yield larger energy savings with lower subsidy cost."[117]

In combination, these two studies serve to indicate the potential usefulness of MAC analyses, but also the importance of conducting such analyses in a way that captures salient features of the relevant context and actors involved.

2.3. Non-CO_2 Greenhouse Gases

Although carbon dioxide is the most prevalent of the greenhouse gases, it is not the most potent—and it is not the only greenhouse gas states should consider. Note that when assessing the climate damages from different greenhouse gases, using carbon dioxide equivalent units may not yield the same values as using the Working Group's social cost modeling process for each gas. This fact was recognized and addressed by the Working Group when it developed estimates for the social cost of methane (SC-CH_4 or SCM) and the social cost of nitrous oxide (SC-N_2O). EPA likewise chose to use the Working Group's methodology to develop social cost estimates for hydrofluorocarbons when it recently issued a rule on these pollutants.

2.3.1. Methane and Nitrous Oxide

In 2016, the Working Group adopted estimates for methane and nitrous oxide, to accompany its social cost estimates for CO_2.[118] States that rely on the Working Group's values for CO_2 should also do so for methane and nitrous oxide, and should not just multiply the values for CO_2 by the global warming potential (GWP) coefficient that *approximates* the different impacts of each gas on the climate. This "CO_2-equivalent" (CO_2e) proxy for different gases' impacts is often used to convey the significance of emissions other than CO_2, but the Working Group has made clear that it "is not optimal" because it ignores meaningful physical differences in how each gas behaves and affects the climate.[119] One such difference relates to have greenhouse gases vary with respect to their warming effect and their rate of decay in the atmosphere over time: as shown in Figures 2-7 and 2-8, whereas methane remains in the atmosphere for mere decades and begins decaying quickly, CO_2 remains for centuries and decays little over that time.[120]

Figure 2-7. Atmospheric Decays Following Pulses of Carbon Dioxide and Methane in Year 0.[121]

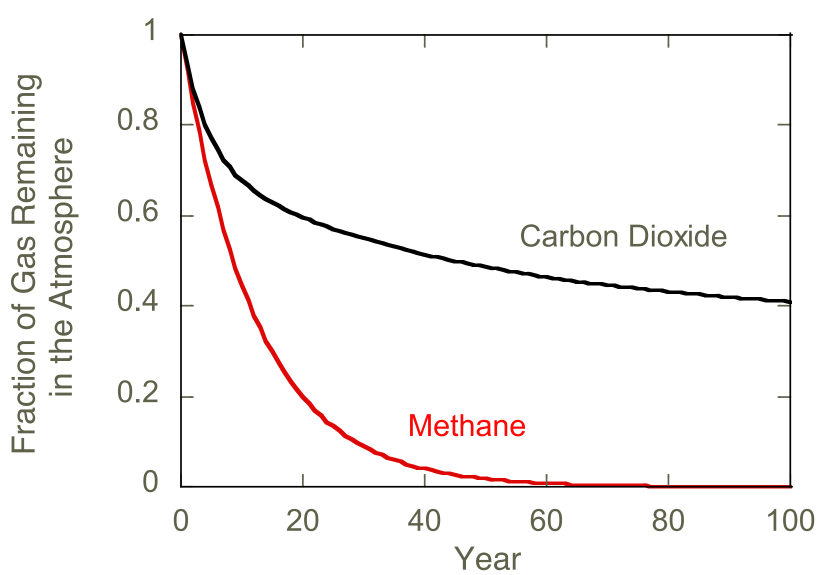
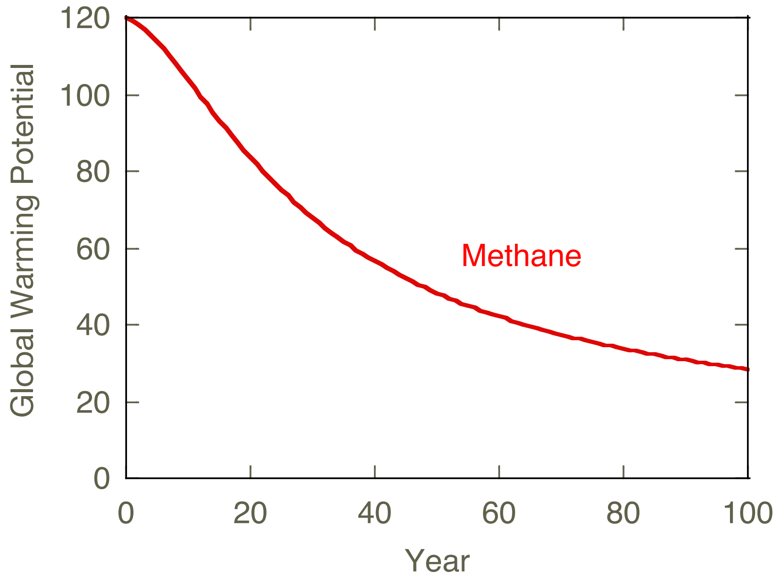


Figure 2-8. Global Warming Potential for Methane over Time; $GWP_{20yrs} = 84$, $GWP_{100yrs} = 28$.[122]



Consequently, treating the warming effect of methane emissions as different from carbon dioxide *only* in terms of the two gases' average warming potential over a 20 or 100-year timeframe results in a mischaracterization of methane emissions' impact, which changes significantly over decades rather than—as with carbon dioxide—over centuries.

These and other differences explain why researchers and policymakers continue to discuss whether to use a 100-year timeframe for the impact of a unit of emissions, a 20-year timeframe, or both.[123] Applying the SC-CO_2, SC-CH4, and SC-N2O to a quantity of the appropriate greenhouse gas largely avoids this issue by simply modeling the impact of a particular gas on the climate.

The Working Group's caution against relying on CO_2e values is especially important for agencies that are required to use the SC-CO_2 and have opted to ignore the Working Group's SC-CH_4 and SC-N_2O values.[124] In short, relying on just CO_2 valuation as a proxy for greenhouse gas valuation generally yields an incomplete result and relying on CO_2e yields a result that is somewhat more complete but also incorrect. To ensure accuracy and consistency, states should use the available Working Group values for all greenhouse gases.

2.3.2. HFCs

HFCs were initially developed to replace the chlorofluorocarbons that damaged the Earth's ozone layer, but have since also been found to be a source of tremendous global warming. In 2021, the U.S. EPA adopted a regulation to guide the phase-down of hydrofluorocarbons (HFCs).[125] EPA's analysis of its rule applied estimates of the social cost of HFCs.[126] These estimates were developed by EPA, not the Working Group, but EPA used the Working Group's methodologies and assumptions.[127] New York State also published its own estimates for HFCs in early 2022 adapting the Working Group's methodology to its range of discount rates (1%, 2%, and 3%).[128] Applying EPA's HFCs estimates would give states a methodologically consistent set of values to use alongside the Working Group's SC-GHG.

HFCs and other refrigerants may be of particular interest to states as these chemicals play a significant role in building electrification efforts, for example through their use in heat pumps.[129]

2.3.3. *Other Greenhouse Gases*

The comprehensive table of greenhouse gases below appears in the IPCC's Fifth Assessment Report. For each gas, the table indicates estimates from 2005 and 2011 of atmospheric concentration and the amount of global warming—termed "radiative forcing"—that results from emission of a unit of the gas.[130]

Table 2-3. Concentrations and GWP Coefficients for Greenhouse Gases[131]

	Concentrations (ppt)		Radiative forcing[a] ($W\ m^{-2}$)	
Species	**2011**	**2005**	**2011**	**2005**
CO_2 (ppm)	391 ± 0.2	379	1.82 ± 0.19	1.66
CH_4 (ppb)	1803 ± 2	1774	0.48 ± 0.05	0.47[e]
N_2O (ppb)	324 ± 0.1	319	0.17 ± 0.03	0.16
CFC-11	238 ± 0.8	251	0.062	0.065
CFC-12	528 ± 1	542	0.17	0.17
CFC-13	2.7		0.0007	
CFC-113	74.3 ± 0.1	78.6	0.022	0.024
CFC-115	8.37	8.36	0.0017	0.0017
HCFC-22	213 ± 0.1	169	0.0447	0.0355
HCFC-141b	21.4 ± 0.1	17.7	0.0034	0.0028
HCFC-142b	21.2 ± 0.2	15.5	0.0040	0.0029
HFC-23	24.0 ± 0.3	18.8	0.0043	0.0034
HFC-32	4.92	1.15	0.0005	0.0001
HFC-125	9.58 ± 0.04	3.69	0.0022	0.0008
HFC-134a	62.7 ± 0.3	34.3	0.0100	0.0055
HFC-143a	12.0 ± 0.1	5.6	0.0019	0.0009
HFC-152a	6.4 ± 0.1	3.4	0.0006	0.0003
SF_6	7.28 ± 0.03	5.64	0.0041	0.0032
SO_2F_2	1.71	1.35	0.0003	0.0003
NF_3	0.9	0.4	0.0002	0.0001
CF_4	79.0 ± 0.1	75.0	0.0040	0.0036
C_2F_6	4.16 ± 0.02	3.66	0.0010	0.0009
CH_3CCl_3	6.32 ± 0.07	18.32	0.0004	0.0013
CCl_4	85.8 ± 0.8	93.1	0.0146	0.0158
CFCs			0.263 ± 0.026[b]	0.273[c]
HCFCs			0.052 ± 0.005	0.041
Montreal gases[d]			0.330 ± 0.033	0.331
Total halogens			0.360 ± 0.036	0.351[f]
Total			2.83 ± 0.029	2.64

Notes:
[a] Pre-industrial values are zero except for CO_2 (278 ppm), CH_4 (722 ppb), N_2O (270 ppb) and CF_4 (35 ppt).
[b] Total includes 0.007 $W\ m^{-2}$ to account for CFC-114, Halon-1211 and Halon-1301.
[c] Total includes 0.009 $W\ m^{-2}$ forcing (as in AR4) to account for CFC-13, CFC-114, CFC-115, Halon-1211 and Halon-1301.
[d] Defined here as CFCs + HCFCs + CH_3CC_{l3} + CC_{l4}.
[e] The value for the 1750 methane concentrations has been updated from AR4 in this report, thus the 2005 methane RF is slightly lower than reported in AR4.
[f] Estimates for halocarbons given in the table may have changed from estimates reported in AR4 owing to updates in radiative efficiencies and concentrations.

States (individually or as a group) with sufficient resources might choose to supplement the Working Group's estimates of the social costs of CO_2, methane, and nitrous oxide with estimates of some of the gases listed in Table 2-3. Should they do so, states should ground their estimates in the same Integrated Assessment Models—and versions of those models—used by the Working Group to ensure that inputs and key methodological elements are consistent. Key features of such an estimation would include: a business-as-usual emissions path; a discount rate (or discount rate schedule) consistent with the one used for other greenhouse gases;[132] and an equilibrium climate sensitivity value set near the median value of 3°C. Note that these features may change with the updated estimates from the Working Group.

Consistency is particularly important for the discount rate across greenhouse gases, as changes to the discount rate would yield drastically different values, discussed in Section 2.1.4. If no rigorously developed, multiple-model estimates exist for a particular gas, states could consider using the radiative forcing coefficients listed in Table 4-3 for both 20-year and the 100-year global warming potential time horizons to convert those gases to CO_2e units and so approximate the damages from other greenhouse gases.

2.4. Responding to Common Criticisms of the SC-GHG and the Damage Cost Approach

This subsection is meant to alert readers to common criticisms of the SC-GHG to date and to help them understand the nature and flaws of those criticisms, so that they might respond as appropriate.

2.4.1. The Working Group's Process

Recent criticisms of the SC-GHG, including those raised in litigation, often focus on the Working Group's process, and allege that it lacked transparency or scientific rigor.[133] On the contrary, the Working Group's process was rigorous, transparent, and based on the best available science and economics. This subsection summarizes that process, as it has been conducted since 2009. Further process details are available from each of the Working Group's technical support documents.

Starting in 2009, the Working Group assembled experts from a dozen federal agencies and White House offices to "estimate . . . of the monetized damages associated with an incremental increase in carbon emissions in a given year" based on "input assumptions grounded in the existing scientific and economic literatures."[134] As discussed in Section 2-2, the Working Group combined three of the most frequently used models built to predict the economic costs of the physical impacts of each additional ton of carbon dioxide.[135] The underlying models themselves were the subject of extensive expertise and peer review.

The Working Group first issued its social cost of carbon estimates in 2010 and has updated those several times.[136] These estimates have been subject to public comment both in the context of dozens of agency proceedings as well as a Working Group comment period in 2013.[137] Following the development of social cost estimates for CO_2, at the recommendation of the National Academies of Sciences, Engineering, and Medicine (National Academies), the Working Group applied the same basic methodology in 2016 to develop the social cost of methane and social cost of nitrous oxide.[138] These additional metrics used the same economic models, the same treatment of uncertainty, and the same methodological assumptions that the Working Group applied to the SC-CO_2, and these new estimates underwent rigorous peer review.[139]

The Working Group's methodology has been repeatedly endorsed by independent reviewers. In 2014, the U.S. Government Accountability Office concluded that the Working Group had followed a "consensus-based" approach, relied on peer-reviewed academic literature, disclosed relevant limitations, and adequately planned to incorporate new information through public comments and updated research.[140] In 2016 and 2017, the National Academies issued two reports that, while recommending future improvements, supported the continued use of the Working Group's estimates.[141] In particular, the National Academies reports led the Working Group to expand its representation of uncertainty in the 2016 technical support document. Leading economists and climate policy experts, including the late Nobel laureate Kenneth Arrow, have also endorsed the Working Group's values as the best available estimates.[142] And the U.S. Court of Appeals for the Seventh Circuit has upheld agency reliance on the Working Group's valuations.[143]

Because the Trump administration disbanded the Working Group in early 2017,[144] the Working Group was—until now—unable to implement suggestions from the National Academies to update the social cost valuations to reflect more recent data. Moreover, without consulting the then-defunct Working Group, several agencies developed their own social cost estimates that devalued the SC-GHG using a few makeshift methodologies that bucked expert recommendations, citing an executive order from then-President Trump.[145] Furthermore, the Trump administration made no attempt to update or improve those valuations by incorporating recent research as recommended by the National Academies.[146] Finally, application of the Trump-era figures was struck down as arbitrary and capricious in federal court.[147]

In early 2021, the Working Group, after being reconvened by President Biden, released interim values that were the same as the 2016 estimates, only adjusted for inflation.[148] Like their predecessors, these interim numbers are the best available estimates. The Working Group has been directed to publish updated social cost estimates in 2022, pursuant to President Biden's Executive Order 13,990,[149] and open those estimates up to a public comment process. Until those updates are published following the completion of this public comment process, however, both federal and state agencies should feel confident relying on the interim values released by the Working Group in February 2021, as no superior government-wide estimates exist.

2.4.2. The Working Group's Methodological Choices

Criticisms of the Working Group's estimates often focus on four methodological choices in particular:

- inclusion of global damages—not just domestic damages;
- exclusion of a 7% discount rate from the range of discount rate values for which estimates are calculated;
- handling of uncertainty; and
- treatment of positive externalities.

Recent attacks against the SC-GHG also call into question additional issues, such as whether the Working Group:

- correctly modeled the pace of climate change;
- used an appropriate emissions baseline; and
- used reasonable damage functions.

This section discusses in some depth the first set of criticisms, and touches on some of the second set. A more detailed description of the latter set of criticisms and their rebuttals can be found in the Institute for Policy Integrity report, *Playing with Fire: Responding to Criticism of the Social Cost of Greenhouse Gases*[150] and a Yale Journal on Regulation article by Richard Revesz and Max Sarinsky, *The Social Cost of Greenhouse Gases: Legal, Economic, and Institutional Perspective*.[151]

2.4.2.1. Global Damages

The Working Group—and agencies that have used its estimates—has been criticized by opponents of sensible climate policy for focusing on global, rather than U.S. domestic, climate damages. But the focus on global climate damages is appropriate and attempts to restrict damage estimates to the geographical borders of the United States are misguided. The use of global damage valuations reflects U.S. strategic interests, is widely regarded as appropriate for global pollutants like greenhouse gases, and is consistent with federal guidance. As the U.S. Court of Appeals for the Seventh Circuit has stated, it is reasonable for agencies to determine that because greenhouse gas emissions cause "global effects . . . those global effects are an appropriate consideration when looking at a national policy."[152] Similarly, the U.S. District Court for the Northern District of California recently held that a global focus is critical for an agency to reliably assess climate impacts.[153]

For the sake of its own territory, population, and other interests, every government worldwide, including that of the United States, should set climate policy using the global SC-GHG. There are significant, indirect costs to trade, human health, and security likely to "spill over" to the United States as other regions experience climate change damages.[154] 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 and its constituent jurisdictions are particularly vulnerable to effects that will spill over from other regions of the world. Spillover scenarios could entail a variety of serious costs, ranging from impacts on investments and supply chains to more direct effects like surges of international migration, 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.[155]

Finally, using a social cost estimate based on a rigid concept of U.S. or state borders or share of world GDP will fail to capture some of the climate-related costs and benefits that matter to U.S. citizens,[156] including significant U.S. ownership interests in foreign businesses, properties, and other assets, as well as consumption abroad including tourism,[157] and even the 8.7 million Americans living abroad.[158]

In addition, because greenhouse gas pollution does not stay within geographic borders but rather mixes in the atmosphere and affects the climate worldwide, each ton emitted from any given jurisdiction not only creates domestic harms within that jurisdiction, but also imposes large externalities on the rest of the world. Conversely, each ton of greenhouse gases abated elsewhere benefits the United States along with the rest of the world. If all countries set their climate polices based on only domestic costs and benefits, ignoring the large global externalities, the aggregate result would be unduly weak climate protections and significantly increased risks of severe harms to all nations, including the United States. The same holds true for state policies that ignore global externalities. Thus, the United States stands to benefit greatly if all countries apply global SC-GHG 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.[159]

Using the SC-GHG, which incorporates global climate damages, is a good way to secure an economically efficient outcome from climate policy for the United States and its constituent states.[160] 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.[161] For example, Canada and Mexico have explicitly borrowed U.S. estimates of a global social cost to set their own fuel efficiency standards.[162] States have also entered into this international dynamic, with California coordinating with Canada on its cap-and-trade program[163] and with a coalition of states and cities agreeing to uphold the pledges from the Paris Agreement.[164] For the United States or any individual state to now depart from this collaborative dynamic by selecting a domestic-only estimate could undermine the country's long-term interests because it may lead other countries to follow suit, thus jeopardizing emissions reductions underway in other countries, which are already benefiting all 50 U.S. states and territories.[165]

Policy Integrity has a number of reports and papers that dive deeper into the justifications for using global values, including *Strategically Estimating Climate Pollution Costs in a Global Environment*,[166] *Think Global*,[167] and *Foreign Action, Domestic Windfall*.[168]

2.4.2.2. Selection of Discount Rates

The Working Group has been criticized on numerous occasions by opponents of common-sense climate policy for omitting a 7% discount rate when deriving the SC-GHG estimates. Critics tend to make two arguments to support this point: that a 7% rate correctly approximates the private cost of capital; and that federal policy, embodied in *Circular A-4*, directs government agencies conducting a regulatory cost-benefit analysis to use a 7% rate.[169] Each of these arguments is unpersuasive—for both state and federal officials' purposes.

Regardless of whether a 7% discount rate reflects the private cost of capital, it does not usefully describe individuals' or society's valuation of future climate damages. In its most recent technical support document, the Working Group discusses at length the economic evidence supporting its choice of discount rates. Among other things, that evidence indicates that high discount rates, like 7%, are inappropriate for effects that occur over longer, inter-generational time horizons such as the impacts of climate change.[170] When considering such time horizons, there is broad agreement among economists that a consumption-based discount rate of 3% or lower is appropriate for evaluating climate impacts.[171] This view is consistent with the latest economic literature,[172] and has been echoed by OMB, the Council of Economic Advisers,[173] and the National Academies.[174]

Circular A-4's prescribed use of a 7% discount rate for federal agencies' analysis of regulations is similarly irrelevant to the question of whether government agencies, and especially state agencies, should discount climate damages at that rate. For one, *Circular A-4* itself recognizes that inter-generational calculations should be handled differently than intra-generational ones.[175] Further, it does not govern states' analytical or decisionmaking processes. Finally, since it was published in 2003, new research, discussed in Section 2.1.4, has found that lower discount rates are appropriate for a variety of purposes, and especially for use in analyses with an inter-generational time horizon.

For further explanation as to why lower discount rates are appropriate for estimating the social cost values, please see the Institute for Policy Integrity report, *About Time: Recalibrating the Discount Rate for the Social Cost of Greenhouse Gases*.[176]

2.4.2.3. Uncertainty

Estimates of how climate change will affect the economy are necessarily characterized by uncertainties. Some critics argue that the Working Group's social cost valuations embody too much uncertainty—about the nature and severity of climate change impacts, about what the models should include, and about how the models should translate climatic effects into economic impacts—to be useful. For example, a 2022 article by Nicholas Stern, Joseph Stiglitz, and Charlotte Taylor argue that profound uncertainties undermine the validity of the damage-cost approach taken by the SC-GHG.[177] Several features of the SC-GHG, they say, make it incapable of accurately characterizing the economic system it aims to interpret and of specifying an optimal emissions reduction target.[178] In their view, because the three IAMs used by the Working Group fail to capture climatic tipping points, do not take economic inequality into account, and disregard the role of information problems and irrationalities in markets, they do an irretrievably bad job of describing the effects of climate change.[179] As explained below, these arguments are incorrect in several respects.

There are, broadly speaking, four responses to these criticisms:

First, uncertainty cannot be avoided. Because federal law requires agencies to estimate climate damages (see Section 3.2), analytical solutions that sidestep the estimation of damages by looking instead to an emissions reduction target (see Section 2.2) cannot substitute for the SC-GHG's damage-based approach. And although states with binding emissions reduction targets arguably can make recourse to this sort of solution, such an alternative approach would not so much reduce the presence of uncertainties as change their source and nature: instead of climate damages being the main source of contention, it would likely be patterns and rates of technological change and adoption.[180]

Second, recognizing that living with (rather than avoiding) uncertainties is intrinsic to its task, the Working Group's methodology accounts for parametric uncertainty (uncertainty in model inputs), structural uncertainty (uncertainty in model design), and stochastic uncertainty (uncertainty in predicting future events such as the pace of climate change and economic development), and does so transparently. This is consistent with the recommendations of the National Academies, and addresses several of the criticisms levelled by Stern et al., and others.[181] Some further details about the Working Group's process helps to illustrate how it embodies rigor and transparency with respect to its characterization of uncertainties. To develop the SC-GHG estimates, the Working Group ran the models 150,000 times for each greenhouse gas and each discount rate, took random draws of different uncertain parameters to develop a probability distribution of social cost values, used a Monte Carlo simulation to make thousands of random draws from the probability distribution, and then averaged across those results to develop the estimates that agencies apply.[182] In addition to reporting the average valuations, the Working Group also published the results of each model run and summarized results for each scenario.[183] In other words, the Working Group made methodological choices to reflect uncertainty in the SC-GHG estimates.

Third—and contrary to the view that uncertainty warrants disregarding the SC-GHG's estimates—experts broadly agree that the presence of uncertainty in the social cost valuations counsels for more stringent climate regulation, not less.[184] This is due to various factors including risk aversion, the informational value of delaying greenhouse gas emissions, insurance value, and the possibility of irreversible climate tipping points that cause catastrophic damage.[185] In fact, uncertainty is a factor justifying lowering the discount rate, particularly in intergenerational settings.[186] Furthermore, the current omission of key features of the climate problem such as catastrophic damages and certain cross-regional spillover effects further suggests that the true SC-GHG values are likely higher than the Working Group's best estimates. According to the Working Group, "these limitations suggest that the SC-CO_2 estimates are likely conservative."[187] In short, critics' claim that there is too much uncertainty to use the social cost estimates is misguided. If anything, the presence of uncertainty is a reason to view the Working Group's estimates as a lower bound.

Fourth, federal courts have repeatedly recognized that agency analysis necessitates making predictive judgments under uncertain conditions, explaining that "[r]egulators by nature work under conditions of serious uncertainty"[188] and "are often called upon to confront difficult administrative problems armed with imperfect data."[189] As the U.S. Court of Appeals for the Ninth Circuit has explained, "the proper response" to the problem of uncertain information is not for the agency to ignore the issue but rather "for the [agency] to do the best it can with the data it has."[190] Courts generally grant broad deference to agencies' analytical methodologies and predictive judgments so long as they are reasonable, and do not require agencies to have complete certainty before acting.[191] Critics are thus incorrect to suggest that the presence of some uncertainty in the social cost values merits their abandonment.

In addition to these responses, it is important to note the interplay between good faith criticisms of the SC-GHG's treatment of uncertainty and arguments made by opponents of climate policy. An especially clear example of this is the uses to which Professor Robert Pindyk's research have been put. Pindyck criticized the 2013 update to the SC-GHG for mischaracterizing key uncertainties and so undervaluing climate damages.[192] His criticisms were then misread by opponents of ambitious climate policy as arguing that economic valuations of climate change were simply useless and wholly misleading.[193] Pindyck subsequently clarified that his criticism of the Working Group's estimates did not amount to a call for jettisoning them: "My criticism of IAMs should not be taken to imply that because we know so little, nothing should be done about climate change right now, and instead we should wait until we learn more. Quite the contrary."[194] In fact, Pindyck's own best "high confidence" estimate of the social cost of carbon dioxide in a 2019 paper is between $80 and $100.[195] Nonetheless, Pindyck continues to be cited as a critic of the SC-GHG, most often by those who disagree with his fundamental conclusion that a robust accounting of climate damage externalities should inform regulatory decisionmaking.[196] In other words, the best critic of the Working Group's methodology that opponents of sensible climate policy could find actually considers the Working Group's methodology to yield conservative underestimates of greenhouse gases emissions' true cost to society.

2.4.3. Benefits of Climate Change

Some critics argue that the SC-GHG ignores the potential benefits of increased carbon dioxide.[197] However, some of these benefits, such as potential increases in agricultural yields at low-level temperature increases, are captured in the SC-GHG estimates.[198] These benefits reduce the magnitude of the SC-GHG, and are likely overestimated (not underestimated) in the models.[199] Other benefits that are the result of climate change are omitted, including the lower cost of supplying renewable energy from wind and wave sources, the increased availability of oil due to higher temperatures in the Arctic.[200] However, omitted negative impacts overwhelm omitted benefits.[201]

The other (not climate-related) benefits from the use of carbon fuels that are unrelated to climate change (such as economic output) are omitted from the SC-GHG, but they are typically included in any analysis in which the SC-GHG is used. In a benefit-cost analysis, the cost of regulations, such as the potential loss of output, is balanced against the benefits of greenhouse gas emissions reductions as measured by the SC-GHG.

[1] *See* Interagency Working Group on the Social Cost of Greenhouse Gases, Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide, Interim Estimates under Executive Order 13,990 at 22 (2021) [hereinafter "2021 TSD"], https://perma.cc/5B4Q-3T5Q.

[2] Interagency Working Grp. on Soc. Cost of Carbon, Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12,866, at 5 (2010) [hereinafter "2010 TSD"], https://perma.cc/VTD5-VBL3.

[3] *Id.*

[4] *Id.* at 6.

[5] *Id.*

[6] *Id.*

[7] *Id.* The National Academies of Sciences, Engineering, and Medicine's 2017 report on valuing climate damages explains that the damages component of an IAM "translates streams of socioeconomic variables (e.g., income and population and gross domestic product) and physical climatic variables (e.g., changes in temperature and sea level) into streams of monetized damages over time. To do this, it must represent relationships among physical variables, socioeconomic variables, and damages." Nat'l Acads. of Scis., Eng'g, & Med., Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide 130 (2017) [hereafter "NAS 2017"].

[8] 2010 TSD, *supra* note 2, at 7.

[9] *Id.*

[10] *Id.*

[11] *Id.*

[12] *Id.* at 7–8.

[13] *Id.* at 8. Those regions are: United States, Canada, Western Europe, Japan and South Korea, Australia and New Zealand, Central and Eastern Europe, the former Soviet Union, the Middle East, Central America, South America, South Asia, Southeast Asia, China, North Africa, Sub-Saharan Africa, Small Island States. Stephanie Waldhoff et al., *The Marginal Damage Costs of Different Greenhouse Gases: An Application of FUND*, 8 Economics: The Open-Access, Open-Assessment E-Journal 1, 3 (2014).

[14] 2010 TSD, *supra* note 2, at 8.

[15] *Id.*

[16] *Id.*; *but see* Frances C. Moore et al., *New Science of Climate Change Impacts on Agriculture Imply Higher Social Cost of Carbon*, 8 Nature Communications 1607, 6 (2017) (criticizing this potential outcome).

[17] 2021 TSD, *supra* note 1, at 2–4.

[18] *See* Peter Howard, Inst. for Pol'y Integrity, Omitted Damages: What's Missing from the Social Cost of Carbon (2014), https://policyintegrity.org/publications/detail/omitted-damages-whats-missing-from-the-social-cost-of-carbon [hereinafter "Omitted Damages"]; Inst. for Pol'y Integrity, A Lower Bound: Why the Social Cost of Carbon Does Not Capture Critical Climate Damages and What That Means for Policymakers (2019), https://policyintegrity.org/publications/detail/a-lower-bound [hereinafter "A Lower Bound"].

[19] 2010 TSD, *supra* note 2, at 8.

[20] *Id.* at 8–9.

[21] *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. Env't Econ. & Pol'y 23, 42–43 (2013); Richard L. Revesz et al., Global Warming: Improve Economic Models of Climate Change, 508 Nature 173 (2014) (co-authored with Nobel Prize winner Kenneth Arrow) (explaining that the Working Group's values, though methodically rigorous and highly useful, are very likely underestimates).

[22] 2021 TSD, *supra* note 1, at 32–33.

[23] *See* A Lower Bound, *supra* note 19, at 1–2.

[24] *See* Omitted Damages, *supra* note 19.

[25] *See* A Lower Bound, *supra* note 19, at 3.

[26] Omitted Damages, *supra* note 19, at 9–10.

[27] Inst. for Pol'y Integrity, *Climate Impacts Reflected in the Social Cost of Greenhouse Gases Estimates*, Cost of Climate Pollution, https://costofcarbon.org/scc-climate-impacts (last visited July 18, 2022).

[28] *See* Interagency Working Grp., 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 11–12 (2016), https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/august_2016_sc_ch4_sc_n2o_addendum_final_8_26_16.pdf, [hereinafter "2016 TSD Addendum"] (highlighting limitations in methane valuations).

[29] *See* Jeffrey Shrader, Burçin Ünel & Avi Zevin, Inst. for Pol'y Integrity, Valuing Pollution Reductions: How to Monetize Greenhouse Gas and Local Air Pollutant Reductions from Distributed Energy Resources (2018) (describing analytical steps required to estimate effects of global and local pollution).

[30] *E.g.*, U.S. Env't Prot. Agency, Regulatory Impact Analysis for the Clean Power Plan Final Rule 4-11 to 4-41 (Oct. 2015) (monetizing health-related co-benefits of avoided particulate matter and ozone).

[31] *E.g.*, *id.* at 4-46 to 4-56.

[32] Shrader et al., *supra* note 30.

[33] Matt Butner et al., Inst. for Pol'y Integrity, Making the Most of Distributed Energy Resources (2020), https://policyintegrity.org/files/publications/Making_the_Most_of_Distributed_Energy_Resources.pdf.

[34] This methodology was developed for distributed energy resources, so an agency seeking to apply it would need to consider how it should be modified for centralized generators.

[35] EPA, Regulatory Impact Analysis of the Revised 2023 and Later Model Year Light Duty Vehicle GHG Emissions Standards 7-1 to 7-30 (2021); *see also* EPA, Regulatory Impact Analysis of the Final Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources at 4-1 to 4-37 (2016).

[36] *See, e.g.*, Climate Leadership and Community Protection Act (CLCPA) § 2, N.Y. Env't Conserv. L. § 75-0109(3)(c) & (d); CLCPA § 2, N.Y. Env't Conserv. L § 75-0111(1)(b); CLCPA § 2, N.Y. Env't Conserv. L § 75-0119(2)(g); CLCPA § 7(3).

[37] Min Li & Faxi Yuan, *Historical Redlining and Resident Exposure to COVID-19: A Study of New York City*, 14 Race & Social Probs. 85 (2022). For a discussion of broader relationships between past policies and environmental health burdens, see Haley M. Lane et al., *Historical Redlining Is Associated with Present-Day Air Pollution Disparities in U.S. Cities*, 9 Env't Sci. & Tech. Ltrs. 345 (2022).

[38] *See* Omitted Damages, *supra* note 18, at 24–25.

[39] *See State and Federal Environmental Justice Efforts*, Nat'l Conf. State Legislatures (Jan. 13, 2022), https://www.ncsl.org/research/environment-and-natural-resources/state-and-federal-efforts-to-advance-environmental-justice.aspx (noting and providing links to examples of legislative and non-legislative efforts).

[40] *See* Jason Schwartz, Inst. for Pol'y Integrity, Strategically Estimating the Social Cost of Greenhouse Gases (2021) [hereinafter "Strategically Estimating"].

[41] *Id.*

[42] *Id.*; *see also* Peter Howard & Jason Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 Colum. J. Env't L. 203, 241–44 (2017).

[43] 2021 TSD, *supra* note 1, at 15–16.

[44] Strategically Estimating, *supra* note 41; Howard & Schwartz, *Think Global*, *supra* note 42.

[45] Dallas Burtraw & Thomas Sterner, *Climate Change Abatement: Not "Stern" Enough?* (Resources for the Future Policy Commentary Series, Apr. 4, 2009), http://www.rff.org/Publications/WPC/Pages/09_04_06_Climate_Change_Abatement.aspxhttps://www.resources.org/common-resources/climate-change-abatement-not-quotsternquot-enough/.

[46] For an extended discussion of each of these in the context of valuing climate damage, see Richard L. Revesz & Matthew R. Shahabian, *Climate Change and Future Generations*, 84 So. Cal. L. Rev. 1097, 1101 (2011). Revesz and Shahabian describe the four categories of approaches to discounting considered in the literature as follows: "(1) discounting for pure time preference on the basis of ethical norms ('prescriptive pure time preference discounting'); (2) discounting for pure time preference because that is how people actually treat the future ('descriptive pure time preference discounting'); (3) discounting because future generations will be richer than our own ('growth discounting'); and (4) accounting for opportunity costs ('opportunity cost discounting')." In the real-world where the future is uncertain, additional motivations include consumption smoothing and insurance. *See* Peter Howard & Jason A. Schwartz, *Valuing the Future: Legal and Economic Considerations for Updating Discount Rates*, 39 Yale J. Regul. 595, 626–31 (2022).

[47] U.S. EPA, Guidelines for Preparing Economic Analysis 6-1 (2010) (distinguishing between a social, "society-as-a-whole point of view" and private discounting, which takes "the specific, limited perspective of private individuals and firms").

[48] *Id.* at 6–8 (describing "social opportunity cost of capital," an estimate of the discount rate based on investments potentially displaced by government spending or regulation); *see also* Cost of Capital: Applications and Examples 3, 36 (Shannon P. Pratt & Roger J. Grabowski eds., 2014) (defining opportunity cost of capital as "the expected rate of return that market participants require in order to attract funds to a particular investment").

[49] This higher rate reflects several factors: capital is taxed leading to additional public consumption from government provided services; in addition, market power, private risk premiums, and returns from externalities that should not be factored in from society's perspective all yield financial returns. As a consequence, the private return to capital represents an upper bound on the social return to capital that excludes these market distortions, except for consumption from tax revenue. Howard & Schwartz, *Valuing the Future*, *supra* note 46, at 619.

[50] 2021 TSD, *supra* note 1, at 3 ("The IWG recommends that discount rate uncertainty and relevant aspects of intergenerational ethical considerations be accounted for in selecting future discount rates.").

[51] Nicholas Stern et al., Stern Review: The Economics of Climate Change 31 –33 (2006); *see also* Nicholas Stern, *The Economics of Climate Change*, 98 Amer. Econ. Rev. 1 (2008) (revising 2006 conclusion and arguing for use of a rate just above zero). Notably, this approach requires

specifying the level of risk aversion at play, including aversion to inequality over time, as well as specifying the interaction between risk aversion and the growth rate of per capita income. Therefore, a zero pure rate of time preference is not synonymous with a zero-discount rate. *See also* Richard Revesz, *Environmental Regulation, Cost-Benefit Analysis, and the Discounting of Human Lives*, 99 Colum. L. Rev. 941 (1999).

52 Office of Mgmt. & Budget, *Circular A-4 on Regulatory Analysis* 36 (2003) [hereinafter "Circular A-4"].

53 Qingran Li & William Pizer, *Use of the Discount Rate for Public Policy Over the Distant Future*, 107 J. Env't Econ. & Mgmt. 102428, at 16 (2021) ("This result also assumes that benefits accrue entirely to consumption."). To explain more fully: the derivation of this range assumes all of the benefits of the project go to consumers, but also that it is uncertain whether consumers or capital owners will bear the costs of the project.

54 Circular A-4, *supra* note 52, at 35–36. Although *Circular A-4* does not define "intergenerational," it is useful to note that Britain's Treasury defines it as longer than 30 years. HM Treasury, Green Book, Annex 6 (2020) (directing government departments on how to employ discounting in their analyses); *see also* Joseph Lowe, HM Treasury, Intergenerational Wealth Transfers and Social Discounting: Supplementary Green Book Guidance 4 (2008). Relatedly, 30 years is the longest available duration for a U.S. Treasury. *Cf.* U.S. EPA, Guidelines for Preparing Economic Analysis 6-12 (explaining that intergenerational discounting is complicated by the fact that "the 'investment horizon' is longer than what is reflected in observed [market] interest rates" representative of intertemporal consumption tradeoffs made by the current generation).

55 The very limited market evidence on intergenerational assets, based on long-run leases in certain real estate markets, finds that market rates may also decline over time. Howard & Schwartz, *Valuing the Future*, *supra* note 47, at 619.

56 2010 TSD, *supra* note 2, at 25.

57 NAS 2017, *supra* note 7, at 158 fig.6-1.

58 *Id.* at 159 fig.6-2.

59 Consistent with proper Monte Carlo simulation technique, each uncertain input parameter is represented based on a random draw, not selection by a person or a predetermined specification. 2021 TSD, *supra* note 1, at 26.

60 *Id.* at 27.

61 2010 TSD, *supra* note 2, at 1.

62 2021 TSD, *supra* note 1, at 728 fig. 2.

63 2010 TSD, *supra* note 2, at 3 (explaining that this value is included to represent "higher-than-expected impacts" from climate change).

64 *Id.* at 3, 25.

65 2021 TSD, *supra* note 1, at 19–21.

66 *Id.* at 7.

67 *See* N.Y. Dep't of Env't Conserv., Establishing a Value of Carbon: Guidelines for Use by State Agencies 36 tbl.I1 (2020; updated May 2022) [hereinafter "NY DEC Guidance"].

68 *See* Circular A-4, *supra* note 52, at 33–34.

69 2021 TSD, *supra* note 1, at 18–19.

70 *Id.* at 19 n.22 (citing National Academies); NAS 2017, *supra* note 8, at 236–37; *see also* Qingran Li & William Pizer, *Use of the Consumption Discount Rate for Public Policy Over the Distant Future*, 107 J. Env't Econ. & Mgmt. 102,428 (2021) ("This result is important because it provides a strong argument against the idea that it is appropriate to use a rate as high as 7 percent as we discount benefits further in the future. This is true even when costs displace investment and even over horizons as short as a few decades.").

71 Peter Howard & Derek Sylvan, Expert Elicitation and the Social Cost of Greenhouse Gases, 32–33 (2021); Moritz A. Drupp et al., *Discounting Disentangled*, 10 Am. Econ. J. 109, 109 (2018) (finding "consensus among experts" that use of a 2% discount rate is acceptable).

72 For an extended discussion of the issues at play, see Howard & Schwartz, *Valuing the Future*, *supra* note 46, at 603–04.

73 NAS 2017, *supra* note 7, at 167–69.

74 2021 TSD, *supra* note 1, at 4 ("based on the IWG's initial review, new data and evidence strongly suggests that the discount rate regarded as appropriate for intergenerational analysis is lower. * * * [T]his TSD discusses how the understanding of discounting approaches suggests discount rates appropriate for intergenerational analysis in the context of climate change that are lower than 3 percent."); *see also* Peter Howard & Jason Schwartz, *About Time: Recalibrating the Discount Rate for the Social Cost of Greenhouse Gases* (Inst. for Pol'y Integrity, Working Paper, 2021), https://policyintegrity.org/publications/detail/about-time.

75 HM Treasury, Intergenerational Wealth Transfers and Social Discounting: Supplementary Green Book Guidance 5 (2008).

76 *Id.* at 3–4.

77 In 2010, the Working Group decided to make a 5% discount rate the highest of the rates it applied. At the time, it was believed that economic growth and damages were positively correlated, making a higher discount rate appropriate based on insurance principles. Recent research calls this logic into question, and suggests that a lower rate may be justified on insurance grounds for several reasons, including the role

of adaptation and non-linear tipping points. Howard & Schwartz, *Valuing the Future*, *supra* note 47, at 629–31.

78 NAS 2017, *supra* note 7.

79 *See* White House Council of Econ. Advisors, Issue Brief: Discounting for Public Policy: Theory and Recent Evidence on the Merits of Updating the Discount Rate 2 (2017) [hereafter "CEA Issue Brief"]; NY DEC Guidance, *supra* note 68, at 15, 18–19.

80 2021 TSD, *supra* note 1, at 19–20; OMB, Table of Past Years Discount Rates from Appendix C of OMB Circular No. A-94 (Dec. 21, 2020), https://perma.cc/5VYS-LAFH (showing that rates on 30-year bonds have also fallen steadily); *see also* CEA Issue Brief, *supra* note 80, at 5 (explaining past negative real rates were due largely to very high inflation, whereas recent negative numbers are because of very low nominal rates and not because of high inflation).

81 CEA Issue Brief, *supra* note 79, at 2, 6; *see also id.* at 7 (citing similar data from futures markets); Edward Gamber, Cong. Budget Off., *The Historical Decline in Real Interest Rates and Its Implications for CBO's Projections* at 4-7 (Working Paper 2020-09, 2020) (listing other factors, including: slowed labor force growth, a global savings glut, a shortage of safe assets, and secular stagnation); *id.* at 39 (showing medium-term and long-term forecasts of the interest rate).

82 CEA Issue Brief, *supra* note 80, at 6 (showing rates in Japan, France, Germany, the United Kingdom, Canada, and Korea); Gamber, CBO, *supra* note 82, at 22, 24-25 (showing declining global rates).

83 Michael D. Bauer & Glenn D. Rudebusch, *The Rising Cost of Climate Change: Evidence from the Bond Market* (Fed. Reserve Bank, Working Paper 2020-25, 2021); *see also* IWG, 2010 TSD, *supra* note 3, at 20 (calculating the rate as 2.7%).

84 Peter Howard & Derek Sylvan, *Wisdom of the Experts: Using Survey Responses to Address Positive and Normative Uncertainties in Climate-Economic Models*, 162 Climate Change 213, 224 (2020), https://policyintegrity.org/publications/detail/wisdom-of-the-experts; Drupp et al., Discounting Disentangled, *supra* note 71, at 109–11.

85 Howard & Schwartz, *Valuing the Future*, *supra* note 47, at 624–34.

86 2021 TSD, *supra* note 1, at 20 fig. 1.

87 Howard & Schwartz, *About Time*, *supra* note 74.

88 *See, e.g.*, Lina Isacs et al., Choosing a Monetary Value of Greenhouse Gases in Assessment Tools: A Comprehensive Review, 127 J. Cleaner Production 37, 38 (2016).

89 For example, the United Kingdom uses a marginal abatement cost approach across a range of policies. *See, e.g.*, U.K. Dep't for Business, Energy & Industrial Strategy, Green Book Supplementary Guidance: Valuation of Energy Use and Greenhouse Gas Emissions for Appraisal (last updated Oct 2021), https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal.

90 *See, e.g.*, Benjamin White & Debbie Niemeier, Quantifying Greenhouse Gas Emissions and the Marginal Cost of Carbon Abatement for Residential Buildings Under California's 2019 Title 24 Energy Codes, 53 Env't Sci. Technol. 12121 (2019); Annum Rafique & A. Prysor Williams, Reducing Household Greenhouse Gas Emissions from Space and Water Heating Through Low-Carbon Technology: Identifying Cost-Effective Approaches, 248 Energy & Buildings 111162 (2021).

91 Exec. Order 12,866, 58 Fed. Reg. 51,735 (1993).

92 Climate Change Act 2008, c.27 (UK).

93 Justin Gundlach & Michael A. Livermore, *Costs, Confusion, and Climate Change*, 39 Yale J. Regul. 564 (2022).

94 *Id.* at 569.

95 Paris Agreement to the United Nations Framework Convention on Climate Change art. 2, Dec. 12, 2015, T.I.A.S. No. 16- 1104.

96 *See* The State Energy & Env't Impact Ctr. at NYU School of Law, Follow the Leaders: States Set Path to Accelerate U.S. Progress on Climate (2021), https://www.law.nyu.edu/sites/default/files/FollowTheLeaders-StateImpactCenter_0.pdf, (listing multiple instances where state emissions reduction or clean energy policies are oriented to the temperature thresholds in the Paris Agreement); *see also, e.g.*, N.Y. City Exec. Order No. 26 § (June 2, 2017) ("New York City will adopt the principles and goals of the Paris Agreement to deliver climate actions that are consistent with or greater than its own commitments to reduce its greenhouse gas emissions 80% by 2050 and that support the critical goal of holding the increase in the global average temperature to below 2° Celsius above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5° Celsius above pre-industrial levels, as set forth in the Paris Agreement. . .").

97 *See* Gundlach & Livermore, *supra* note 93, at 590–94.

98 *See* Ctr. for Climate & Energy Solutions, *State Climate Policy Maps: Greenhouse Gas Emissions Targets* (last updated March 2021), https://www.c2es.org/content/state-climate-policy/.

99 Jamil Farbes et al., Env't Defense Fund, Marginal Abatement Cost Curves for U.S. Net-Zero Energy Systems 17 (2021), https://www.edf.org/sites/default/files/documents/MACC_2.0%20report_Evolved_EDF.pdf.

100 *Id.*

101 *See, e.g.*, Noah Kaufman et al., A Near-Term to Net Zero Alternative to the Social Cost of Carbon for Setting Carbon Prices, 10 Nature Climate Change 1010–11 (2020).

[102] Farbes et al., *supra* note 99, at 4 fig. 1-A.

[103] *Id.* at 18.

[104] *Id.*

[105] *Id.*

[106] White & Niemeier, *supra* note 91.

[107] Saptarshi Das, Eric Wilson & Eric Williams, The Impact of Behavioral and Geographic Heterogeneity on Residential-Sector Carbon Abatement Costs, 231 Energy & Buildings 110611 (2021).

[108] California Global Warming Solutions Act of 2006, Cal. Health & Safety Code §§ 38550, 38551 (West 2022).

[109] The building energy use codes, Title 24, Part 6, of the California Codes and Standards, have been updated every three years since 1978. *See* White & Niemeier, *supra* note 91 at 12121.

[110] *Id.*

[111] *Id.* at 12122–25.

[112] *Id.* at 12125–27

[113] Das et al., *supra* note 107, at 11.

[114] *Id.* at 9.

[115] *Id.* at 10.

[116] *Id.* at 11 figs.10a & 10b.

[117] *Id.* at 11.

[118] 2016 TSD Addendum, *supra* note 29. The estimates for methane and nitrous oxide were developed by Marten et al. using the IWG methodology. *Id.* at 3.

[119] *Id.* at 2.

[120] P.A. Arias et al., *Technical Summary*, in Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 101 (V. Masson-Delmotte et al. eds., 2021), [hereinafter "IPCC AR6 WG1 Tech. Summary"].

[121] Robert L. Kleinberg, Boston Univ. Inst. for Sustainable Energy, The Global Warming Potential Misrepresents the Physics of Global Warming Thereby Misleading Policy Makers 9 (2020), https://hdl.handle.net/2144/41682. fig. 2 (2020).

[122] *Id.* at 10 fig. 3.

[123] *Compare* New York Env't Conserv. L. § 75-0101(2) (requiring state agencies to estimate the GWP of greenhouse gases, including methane, over a 20-year timeframe), *with* IPCC AR6 WG1 Tech. Summary, *supra* note 120, at 101–02.

[124] *E.g.*, the Minnesota Public Utilities Commission only directs utilities to use a social cost value for carbon dioxide. *See* Order Updating Environmental Cost Values, Minn. Pub. Util. Comm'n Docket No. E-999/CI-14-643, at 9–10 (2018).

[125] hasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program Under the American Innovation and Manufacturing Act, 86 Fed. Reg. 55,116 (Oct. 5, 2021).

[126] Env't Prot. Agency, Regulatory Impact Analysis for Phasing Down Production and Consumption of Hydrofluorocarbons (HFCs) at 103 (Sept. 2021), https://www.epa.gov/system/files/documents/2021-09/ria-w-works-cited-for-docket.pdf.

[127] *Id.* at 104.

[128] *See* N.Y.S. Dept. of Env't Conservation., Establishing a Value of Carbon: Guidelines for Use by State Agencies at 37 (rev. May 2022), https://www.dec.ny.gov/docs/administration_pdf/vocguid22.pdf. New York's other SC-GHG values are discussed briefly in the Appendix. *See also id.* at 34-36 for a schedule of New York's estimates for CO_2, methane, and nitrous oxide.

[129] *See* Iain Walker et al., Carbon and Energy Cost Impacts of Electrification of Space Heating with Heat Pumps in the U.S., 259 Energy & Buildings 111910 (2022).

[130] The IPCC defines radiative forcing as "the net change in the energy balance of the Earth system due to some imposed perturbation," and notes that it is "usually expressed in watts per square meter averaged over a particular period of time and quantifies the energy imbalance that occurs when the imposed change takes place." Gunnar Myhre et. Al., *Anthropogenic and Natural Radiative Forcing*, *in* IPCC, 2018: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change 664 (Stocker et al. eds. 2018).

[131] *Id.* at 678 tbl. 8.2.

[132] For example, developing social cost numbers for additional GHGs using the discount rates already in use by the IWG for carbon dioxide, methane, nitrous oxide.

[133] *See* Iliana Paul & Max Sarinsky, Inst. for Pol'y Integrity, *Playing with Fire: Responding to Criticism of the Social Cost of Greenhouse Gases*, (2021), https://policyintegrity.org/publications/detail/playing-with-fire (describing arguments raised in Louisiana v. Biden, 543 F. Supp. 3d 388 (W.D. La. 2022) (stayed pending appeal), as well as responses to those arguments).

[134] 2010 TSD, *supra* note 2, at 1 (2010).

[135] *Id.* at 5. These reduced-form integrated assessment 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).

[136] Working Group, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact

Analysis Under Executive Order 12866, at 5–29 (2016), https://perma.cc/UYX6-2W8M [hereinafter 2016 TSD].

137 2021 TSD, *supra* note 1, at 3.

138 *See* 2016 TSD Addendum, *supra* note 28, at 2–3.

139 *Id.* at 3.

140 U.S. Gov't Accountability Off., GAO 14-663, Regulatory Impact Analysis: Development of Social Cost of Carbon Estimates 12–19 (2014), https://perma.cc/66GM-BW2S.

141 NAS 2017, *supra* note 7, at 3, 33; Nat'l Acads. Scis., Eng'g & Med., Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update 1–2, 46 (2016), https://perma.cc/TJM6-XE65 [hereinafter NAS 2016].

142 *See, e.g.*, sources cited *supra* note 21.

143 Zero Zone, Inc. v. U.S. Dep't of Energy, 832 F.3d 654, 678–79 (7th Cir. 2016).

144 Exec. Order 13,783 § 5(b), 82 Fed. Reg. 16,093, 16,095 (Mar. 28, 2017).

145 *See* California v. Bernhardt, 472 F. Supp. 3d 573, 611-13 (N.D. Cal. 2020) (explaining that Trump administration's methodology "has been soundly rejected by economists as improper and unsupported by science").

146 U.S. Gov't Accountability Off., GAO 20-254, Social Cost of Carbon: Identifying a Federal Entity to Address the National Academies' Recommendations Could Strengthen Regulatory Analysis 24 (2020), https://perma.cc/9J9S-HZH2 ("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.").

147 *See California v. Bernhardt*, 472 F. Supp. 3d at 611–14 (N.D. Cal. 2020).

148 2021 TSD, *supra* note 1, at 4.

149 *Id.* at 11.

150 Paul & Sarinksy, *supra* note 133.

151 Richard L. Revesz & Max Sarinsky, *The Social Cost of Greenhouse Gases: Legal, Economic, and Institutional Perspective*, 39 Yale J. Regul. 855 (2022).

152 Zero Zone, Inc. v. U.S. Dep't of Energy, 832 F.3d 654, 679 (7th Cir. 2016).

153 California v. Bernhardt, 472 F. Supp. 3d 573, 613 (N.D. Cal. 2020) ("[F]ocusing solely on domestic effects has been soundly rejected by economists as improper and unsupported by science.").

154 Indeed, the integrated assessment models used to develop the global SCC estimates largely ignore inter-regional costs entirely, *see* Omitted Damages, *supra* note 18, 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 (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 Colum. L. Rev. 1531 (2009).

155 *See* Freeman & Guzman, *supra* note 154, at 1563–93.

156 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." *California v. Bernhardt*, 472 F. Supp. 3d at 613. 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." *Id.* (internal quotation marks omitted).

157 *See, e.g.*, David A. Dana, *Valuing Foreign Lives and Settlements*, J. Benefit-Cost Analysis, July 14, 2010, at 1, 10 ("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.").

158 *8.7 million Americans (excluding military) live in 160-plus countries*, Assoc. of Ams. Resident Overseas, https://www.aaro.org/about-aaro/8m-americans-abroad (last visited June 21, 2022). Admittedly, 8.7 million is only 0.1% of the total population living outside the United States.

159 *See* Peter Howard & Jason Schwartz, Inst. for Pol'y Integrity, Foreign Action, Domestic Windfall (2015), https://policyintegrity.org/publications/detail/foreign-action-domestic-windfall.

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

161 *See* Howard & Schwartz, *Think Global*, *supra* note 42, at 260.

162 *See Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations*, Regulatory Impact Analysis Statement, SOR/2013-24 (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, 8:00 AM), https://obamawhitehouse.archives.gov/blog/2016/06/29/economic-benefits-50-percent-target-clean-energy-generation-2025 (summarizing the North American Leader's Summit announcement that the United States, Canada, and Mexico would "align" their SCC estimates).

163 *See Program Linkage*, Cal. Air Res. Bd., https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program/program-linkage (last visited June 21, 2022).

164 For example, the U.S. Climate Alliance was created in 2017 as a way to coordinate states' efforts to meet the goals of the Paris Agreement. *See U.S. Climate Alliance Fact Sheet*, U.S. Climate All., http://www.usclimatealliance.org/us-climate-alliance-fact-sheet#:~:text=On%20June%201%2C%202017%2C%20the,U.S.%20from%20this%20international%20accord (last visited June 21, 2022).

165 Matthew J. Kotchen, *Which Social Cost of Carbon? A Theoretical Perspective*, 5 J. Assoc. Env't. & Res. Economists 673, 683 (2018).

166 Strategically Estimating, *supra* note 40.

167 Howard & Schwartz, *Think Global*, *supra* note 42.

168 *See* Howard & Schwartz, *supra* note 160.

169 For examples of these arguments, see Louisiana v. Biden, No. 2:21-CV-01074, 2022 WL 438313, at *4 (W.D. La. Feb. 11, 2022), *stayed pending appeal*, No. 22-30087, 2022 WL 866282 (5th Cir. Mar. 16, 2022) and Benjamin Zycher, *The Social Cost of Carbon, Greenhouse Gas Policies, and Politicized Benefit/Cost Analysis*, 6 Tex. A&M L. Rev. 59 (2018).

170 2021 TSD, *supra* note 1, at 16–22.

171 *Id.* at 17 ("[T]he latest data as well as recent discussion in the economics literature indicates that the 3 percent discount rate used by the IWG to develop its range of discount rates is likely an overestimate of the appropriate discount rate . . . ."). Of particular note, the Working Group highlights a new framework that demonstrates that the consumption discount rate is the solely appropriate rate in inter-generational contexts. *Id.* at 19 (citing Li & A. Pizer, *supra* note 54). Elicitations of experts have also consistently found broad support for lower discount rates when assessing long-term climate damages. *See, e.g.*, Peter Howard & Derek Sylvan, Inst. for Pol'y Integrity, Expert Consensus on the Economics of Climate Change 20 (2015), https://policyintegrity.org/publications/detail/expert-climate-consensus (showing overwhelming support for discount rates between 0-3%); Moritz A. Drupp et al., *Discounting Disentangled*, 10 Am. Econ. J. 109, 109 (2018) (finding "consensus among experts" at a 2% discount rate).

172 *See, e.g.*, Kenneth J. Arrow et al., *Is There a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation?*, 272 Science 221, 222 (1996) (explaining that a consumption-based discount rate is appropriate for climate change); Peter Howard & Derek Sylvan, *Wisdom of the Experts: Using Survey Responses to Address Positive and Normative Uncertainties in Climate-Economic Models*, 162 Climatic Change 213 (2020); Martin L Weitzman, *Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate*, 36 J. Env't Econ. & Mgmt. 201 (1998); Richard G. Newell & William A. Pizer, *Discounting the Distant Future: How Much Do Uncertain Rates Increase Valuations?*, 46 J. Env't Econ. & Mgmt. 52 (2003); Ben Groom et al., *Discounting the Distant Future: How Much Does Model Selection Affect the Certainty Equivalent Rate?*, 22 J. Appl. Econometrics 641 (2007).

173 Council of Econ. Advisers, Discounting for Public Policy: Theory and Recent Evidence on the Merits of Updating the Discount Rate 12 (2017), https://perma.cc/HKY9-DSDE.

174 NAS 2017, *supra* note 7, at 181.

175 Circular A-4, *supra* note 52, at 35–36.

176 Howard & Schwartz, *About Time*, *supra* note 74.

177 Nicholas Stern et. al., T*he Economics of Immense Risk, Urgent Action and Radical Change: Towards New Approaches to the Economics of Climate Change*, J. Econ. Methodology (online edition) (Feb. 24, 2022), https://doi.org/10.1080/1350178X.2022.2040740.

178 *Id.* at 1–2, 12.

179 *Id.* at 25–27.

180 Isacs et al., *supra* note 88, at 41–42 ("[T]he uncertainties around [the social cost of carbon] estimations are immense," but "[l]ike for [the social cost of carbon], many of the factors determining a MAC value are highly uncertain."); *see also* Gundlach & Livermore, *supra* note 94 (discussing features, differences, and potential complementarities of SC-GHG and MAC-based approaches to emissions valuation).

181 *See* Justin Gundlach & Peter Howard, Improve the Social Cost of Carbon, Do Not Replace It, Regul. Rev., (Apr. 12, 2021), https://www.theregreview.org/2021/04/12/gundlach-howard-improve-social-cost-carbon-not-replace-it/.

182 2021 TSD, *supra* note 1, at 26–28.

183 *Id.* at 27.

184 *See, e.g.*, Alexander Golub et al., *Uncertainty in Integrated Assessment Models of Climate Change: Alternative Analytical Approaches*, 19 Env't Modeling & Assessment 99, 107 (2014) ("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.").

185 Policy Integrity and other groups have filed comments in numerous regulatory proceedings highlighting the various forms of uncertainty that increase the social cost of greenhouse gases and have provided numerous references. *See, e.g.*, Env't Def. Fund et al., Comments on the Improper Valuation of Climate Effects in the Proposed Revised Cross-State Air Pollution Rule Update for the 2008 Ozone NAAQS, Technical App'x: Uncertainty (Dec. 14, 2020), https://policyintegrity.org/documents/Joint_SCC_comments_EPA_revised_CSAPR_Ozone_NAAQS_2020.12.14.pdf.

186 *See* Howard & Schwartz, *Valuing the Future*, *supra* note 46, at 626.

187 2016 TSD, *supra* note 136, at 21.

188 Pub. Citizen v. Fed. Motor Carrier Safety Admin., 374 F.3d 1209, 1221 (D.C. Cir. 2004).

189 Mont. Wilderness Ass'n v. McAllister, 666 F.3d 549, 559 (9th Cir. 2011).

190 *Id.*

191 *See* Wis. Pub. Power, Inc. v. FERC, 493 F.3d 239, 260 (D.C. Cir. 2007) ("It is well established that an agency's predictive judgments about areas that are within the agency's field of discretion and expertise are entitled to particularly deferential review, as long as they are reasonable.") (internal quotation marks omitted).

192 Robert S. Pindyck, *Pricing Carbon When We Don't Know the Right Price*, REGULATION, Summer 2013, at 43 (2013), https://object.cato.org/sites/cato.org/files/serials/files/cato-video/2013/6/regulation-v36n2-1-2.pdf; Robert Pindyck, *Climate Change Policy: What Do the Models Tell Us?*, 51 J. ECON. LITERATURE 860 (2013) [hereinafter Pindyck, What Do the Models Tell Us?].

193 Robert S. Pindyck, Comments to Ms. Catherine Cook, Bureau of Land Management, on Proposed Rule and Regulatory Impact Analysis on the Delay and Suspension of Certain Requirements for Waste Prevention and Resource Conservation at 3 (Nov. 6, 2017), https://perma.cc/8MY5-58P5 ("[M]y expert opinion about the uncertainty associated with Integrated Assessment Models (IAMs) was used to justify setting the [social cost of methane] 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 . . . Interagency Working Group to compute the [social cost of carbon] and [social cost of methane], I have undertaken two lines of research that do not rely on IAMs. . . . [They lead] me to believe that the [social cost of carbon] is larger than the value estimated by the U.S. Government . . . ."); *see also*, *e.g.*, Robert P. Murphy, *MIT Economist Shows Weakness in "Social Cost of Carbon,"* INST. ENERGY RSCH. (May 19, 2015), https://www.instituteforenergyresearch.org/climate-change/mit-economist-shows-weakness-in-social-cost-of-carbon/ ("The case for aggressive government intervention keeps getting weaker and weaker . . . .").

194 Pindyck, *What Do the Models Tell Us?*, *supra* note 192, at 870.

195 Robert S. Pindyck, *The Social Cost of Carbon Revisited*, 94 J. ENV'T ECON. & MGMT. 140, 142 (2019).

196 *See* Complaint ¶ 68, Louisiana v. Biden, No. 2:21-CV-01074 (W.D. La. Apr. 22, 2021), *stayed pending appeal*, No. 22-30087, 2022 WL 866282 (5th Cir. Mar. 16, 2022) (citing U.S. Chamber of Commerce comments, which in turn quote Pindyck).

197 *Id.* ¶ 103; *accord id.* ¶ 144 (claiming that Working Group's values "ignore important aspects of the problem including the positive externalities of energy production").

198 *See* Omitted Damages, *supra* note 18, at 6.

199 Moore et al., *supra* note 16.

200 Note that the climate cost of this phenomenon is also omitted from IAMs.

201 Revesz et al. (2014), *supra* note 21; Omitted Damages, *supra* note 19.

3. Legal Authority for Applying the SC-GHG

In order to use the SC-GHG in regulatory decisions that directly affect private actors' rights and obligations, state policymakers must first have the legal authority to do so. Determining whether and how policymakers have the authority to apply this metric requires case- and context-specific analyses. Still, some generalizations bear mentioning. This section first discusses legal authority to apply the SC-GHG at a general, abstract level. It then discusses concrete examples at both the federal and state levels. The federal examples provide additional detail for applications not yet explored by many—or any—states.

3.1. Legal Authority Generally

State agencies' authority to apply the SC-GHG most often comes from enabling statutes, though it could, in principle, derive from a state constitution as well.[1] If a law unambiguously indicates that policymakers must or must not use the SC-GHG, the decision is clear. Similarly, a law that explicitly permits—but does not require—a policymaker to consider those costs leaves little ambiguity. Statutes that are silent on the point are harder to interpret.

While policymakers should, of course, assess each statute's unique language and context, several generalizations are possible.

First, if the statute allows policymakers to consider highly general factors like welfare, public health, costs and benefits, or economic impact, when making decisions about how to implement a law, the SC-GHG likely suits those ends. As Section 2.1 of this guidebook explains, the SC-GHG reflects many of the welfare, public-health, and economic harms that greenhouse gas emissions impose. So, language that directs state agencies or courts to consider these factors when making decisions or determinations can provide a basis for applying the SC-GHG.

Second, if the law offers little or no guidance on what factors to consider, then policymakers often can—and should—employ the SC-GHG to help illuminate the climate impacts of their decisions. That is especially true in sectors like transportation, energy, land use, and others that carry strong implications for greenhouse gas emissions, as the SC-GHG can help illustrate and contextualize the associated harms.

Third, if the law lists many factors to consider, and no express reference to climate change or climate impacts is included, then the statute's context would dictate how to interpret that omission. On the one hand, if the statute uses words like "including" or "for example" in introducing its list of factors, then the statute likely allows policymakers to use the SC-GHG. On the other hand, if it lists factors that are unrelated to climate impacts without such qualifiers, then policymakers might have to infer whether the list is intended as exclusive, or whether unlisted factors may also bear on the policy.

Fourth, if policymakers are unable to quantify climate impacts, they would still do well to describe climate impacts qualitatively, using as much quantitative information as the relevant context and available data allow.

3.2. Federal Authority

Federal agencies generally apply the SC-GHG in three broad decisionmaking frameworks: cost-benefit analysis, review of environmental impacts pursuant to the National Environmental Policy Act (NEPA), and procurement and grantmaking decisions.

Federal agencies' authority (and, potentially, obligation) to apply the SC-GHG in regulatory cost-benefit analysis arises from one of two types of sources. One is substantive statutes. The Energy Conservation Policy Act, for instance, directs the Department of Energy to adopt energy efficiency standards for appliances that will achieve maximal energy efficiency within the bounds of what the agency determines to be "technologically feasible and economically justified."[2] When the department weighed its updated energy efficiency standard for commercial refrigerators in 2014 and found that standard to be "economically justified," it used the SC-GHG to help estimate the standard's benefits.[3] In the *Zero Zone* case, the U.S. Court of Appeals for the Seventh Circuit upheld the updated standard as well as the department's reasoning.[4] The other source of authority is the combination of Executive Orders 12,866 and 13,563 and the Administrative Procedure Act. The Executive Orders direct federal agencies to conduct cost-benefit analysis to justify significant rules,[5] and the federal Administrative Procedure Act requires agencies to ground their regulations in sound reasoning and evidence.[6] While courts reviewing an agency decision do not prescribe a particular rationale for arriving at and defending that decision, courts do examine the quality and rationality of the agency's justification.[7] So, when an agency justifies its decision using cost-benefit analysis—as required for significant rules under the Executive Orders—a reviewing court will insist that the analysis be complete and evenhanded.[8] Agency decisions that increase or reduce greenhouse gas emissions are therefore hard to justify without valuing those emissions in a way that enables—as the SC-GHG does—comparison to other effects.

The second type of application, environmental review of agency decisions, is required by NEPA but not consistently undertaken by agencies.[9] NEPA requires agencies to take a "hard look" at how their actions affect the environment,[10] meaning that they must identify environmental impacts, assess alternatives to the proposed action, and consider how to mitigate environmental harms.[11] Operationally, this application looks much like the monetization of benefits (or costs) that informs a cost-benefit analysis, but instead of the resulting monetary value always being netted against others, the monetized value of emissions often merely features in the list of impacts attributable to a given decision or project.[12] Some agencies' applications of the SC-GHG to environmental review more closely resemble cost-benefit analysis than others—the U.S. Postal Service, for instance, recently used the SC-GHG in a final environmental impact assessment to compare different vehicle fleet procurement options.[13]

The third type of application rests on federal laws governing procurement and grantmaking by individual agencies and involves including the SC-GHG among other factors that inform decisions about what to procure or to whom funding should be granted.[14] The particular laws that authorize procurement or grantmaking generally set forth criteria for conducting those activities. The Federal Acquisition Regulation, for instance, directs agencies to prefer the alternative that offers the "best value."[15] Notably, this can include consideration of a range of social consequences and not only effects to which markets have assigned prices. Governments can apply the SC-GHG to the procurement of a wide range of assets, including vehicle fleets, energy, energy efficiency retrofits for buildings, and even the cement and steel used in infrastructure and construction. Although the analyses of each of these differ, in all cases they involve estimating the lifecycle emissions profiles of different procurement options or grant applications and using the SC-GHG to translate avoided emissions into a value comparable to other types of cost savings. Grant awards, similarly, can require applicants to include analyses of emissions impacts (or avoidance) of their proposals so that the awarding agency can weigh that aspect of the program or project against others in comparable terms.

3.3. State Authority

As noted in Section 1.2, states have applied the SC-GHG in several types of decisions and analyses, the clear majority of which have, to date, focused on the power sector. Some of those applications, both in relation to the power sector and others, have an explicit statutory basis. In other instances, an agency's authority to employ the SC-GHG has been inferred from statutory language that does not expressly refer to the metric but also does not proscribe its use.

Two examples of power sector integrated resource planning rules—one from Washington State and one from Georgia—help to illustrate the difference between explicit and implicit authority to apply the SC-GHG. As described more fully in Section 4.1.1.2, electric utilities in many states are required to periodically submit integrated resource plans (IRPs) that present different approaches for how the utility will supply power to their consumers for the next 10 or 20 years. IRPs generally include analyses of expected outcomes related to, among other things, costs and emissions volumes.

In Washington State, provisions of the 2019 Clean Energy Transformation Act expressly require electric utilities to incorporate the SC-GHG into the analyses presented in their biennial IRP of different proposals for capital investments and programs.[16] The Act also requires that utilities disclose greenhouse gas emissions arising from electricity generation and that the power sector, as a whole, complies with an emissions reduction schedule.[17]

In Georgia, state law requires electric utilities to file IRPs,[18] and the implementing regulations adopted by the state's utility commission spell out what utilities must include in those IRPs.[19] Unlike in Washington, however, those regulations do not refer to the SC-GHG, nor do they require expressly that IRPs present a monetized estimate of the climate damage (or its avoidance) arising from investments in particular resources or programs. They do, however, direct utilities to take several analytical steps that can be read to include applying the SC-GHG in the analyses presented in IRPs. Those directions begin with the definitions in the commission's implementing regulations. "Avoided externality costs" are cognizable,[20] and "[e]xternalities should be quantified and expressed in monetary terms where possible."[21] Climate change is, of course, an externality of greenhouse gas emissions, meaning that it is a quantifiable effect of those emission that is not reflected in the price paid by emitters for their emissions. Further, "environmental impacts of air pollutant emissions from power plants" are to be counted as "indirect costs."[22] These definitions suggest that the SC-GHG would be well suited to carrying out commission policy "concerning minimizing customer bills, minimizing overall rates and *maximizing net societal benefit*." [23]

Use of the SC-GHG in the resource planning process is discussed further in Section 4.1.1.2.

3.4. Legal Risks of Applying the SC-GHG

The nature of the legal risks that states face by using the SC-GHG depends on the legal context of the use. Broadly speaking, climate policy at the state level tends to be made in two legally distinct phases. The first is a planning or informational phase in which key facts are established. Plans and analyses conducted in this phase include "scoping plans" and "energy master plans" that map out economy-wide options for emission reducing measures (see Section 4.1.1.4), as well as analyses that focus more narrowly on particular resource types, like studies of the value of distributed solar generation (see Section 4.3.3). The second phase involves decisions with legal force that apply the SC-GHG to help determine the allocation of obligations, resources, costs, or subsidies.

Legal risks generally do not arise in this first phase, which involves the conduct of nonbinding analyses in which a state uses the SC-GHG to plan or estimate the value of particular assets, activities, or interventions.[24] Still, use or non-use of the SC-GHG in such an analysis can plant a seed that grows into potential legal risk later on. For example, if a decisionmaker later relies upon that analysis or planning process to support of justify a decision with direct effects on the rights or obligations of private actors, the plan could become subject to judicial scrutiny. To mitigate this potential risk, state policymakers should consider the end-use of the planning document during its development and appropriately apply the SC-GHG to align with the laws that are likely to govern the decisions that grow from the planning document.

The second phase of policymaking, in which an agency relies on the SC-GHG to make legally binding decisions, can give rise to several kinds of legal risk:

One sort of legal challenge would involve allegations that the agency lacks the authority to rely on the SC-GHG. Whether the statute or executive order on which the agency bases its use of the SC-GHG is the state's version of the federal Administrative Procedure Act or a substantive statute, such a challenge might allege that the SC-GHG is not relevant to the decision or is proscribed from consideration based on the other decisionmaking criteria omitted from or enumerated in the statute. To reduce risk, agencies should carefully explain how the SC-GHG (and the climate damages it estimates) relate to the factors identified by the governing statute or executive order. Agencies may also benefit from explaining why it is not only permissible but *necessary* to apply the SC-GHG in order to make a reasoned decision.

Other challenges might allege that the SC-GHG itself is flawed for one or more of the reasons discussed in Section 2.4. To ward off such challenges, state legislatures and agencies might consider conducting a review that establishes and explains the validity of the Working Group's SC-GHG for the state's own purposes.[25] That review would not substitute for or redo the work of the Working Group, but would provide an independent legal basis for using the SC-GHG—one that does not rely entirely on the continued application of the federal SC-GHG by federal agencies.

A third type of legal risk can arise not from use of the SC-GHG itself, but rather from challenges in fully quantifying or verifying changes in emissions. In general, agencies should try to take symmetrical analytical approaches to estimating both costs and benefits, and to quantify effects to the extent possible. When faced with a decision between using limited or uncertain emissions data to estimate climate impacts or simply omitting any quantified estimate of emission impacts, an agency should strive to include a quantitative estimate. As Montana's Department of Public Service Regulation observed in a decision about whether to value avoided greenhouse gas emissions, "[a]lthough highly uncertain, all parties agreed that future carbon costs should not be considered zero."[26] And, in the event that the available data are simply too poor to support quantification, the agency should instead develop a thorough qualitative description to be considered in the agency's analysis.

1 *See, e.g.*, Pa. Const. art. I § 27 (establishing "a right a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment"); N.Y. Const. art. I § 19 (similar).

2 42 U.S.C. § 6295(o)(2)(A).

3 Energy Conservation Standards for Commercial Refrigeration Equipment, 79 Fed. Reg. 17,726 (Mar. 28, 2014). For another example of a federal agency that is bound to employ cost-benefit analysis by a substantive statutory directive, see Bur. of Ocean Energy Mgmt., Economic Analysis Methodology for the 2017–2022 Outer Continental Shelf Oil and Gas Leasing Program 1-1 to 1-29 (2016); 43 U.S.C. § 1344(a)(1) (requiring Secretary to manage outer continental shelf "in a manner which considers economic, social, and environmental values of the renewable and non-renewable resources contained in the outer Continental Shelf").

4 Zero Zone, Inc. v. Dep't of Energy, 832 F.3d 654 (7th Cir. 2016).

5 Exec. Order 12,866, 58 Fed. Reg. 51,735 (1993); Exec. Order 13,563, 76 Fed. Reg. 3821 (2011).

6 5 U.S.C. § 553(e) (2018); Scenic Hudson Pres. Conf. v. Fed. Power Comm'n, 453 F.2d 463, 468 (2d Cir. 1971) ("Where the Commission has considered all relevant factors, and where the challenged findings, based on such full consideration, are supported by substantial evidence, we will not allow our personal views as to the desirability of the result reached by the Commission to influence us in our decision.").

7 Dep't of Homeland Sec. v. Regents of the Univ. of Cal., 140 S. Ct. 1891, 1907 (2020) ("It is a 'foundational principle of administrative law' that judicial review of agency action" is based on "the grounds that the agency invoked when it took the action." (quoting Michigan v. EPA, 576 U.S. 743, 758 (2015))); *see also* SEC v. Chenery Corp., 318 U.S. 80, 88 (1943); Caroline Cecot & W. Kip Viscusi, *Judicial Review of Agency Benefit-Cost Analysis*, 22 Geo. Mason L. Rev. 575 (2015).

8 *See, e.g.*, Mozilla Corp. v. Fed. Commc'ns Comm'n, 940 F.3d 1, 70–71 (D.C. Cir. 2019) (discussing the consistency of the FCC's approach with instructions in Circular A-4); Cooling Water Intake Structure Coal. v. EPA, 905 F.3d 49, 67 (2d Cir. 2018) ("[A]gencies are ordinarily required to consider the relative costs and benefits of a regulation as part of reasoned decisionmaking."); Nat'l Ass'n of Home Builders v. EPA, 682 F.3d 1032, 1040 (D.C. Cir. 2012) ("[W]hen an agency decides to rely on a cost-benefit analysis as part of its rulemaking, a serious flaw undermining that analysis can render the rule unreasonable."); City of Portland v. EPA, 507 F.3d 706, 713 (D.C. Cir. 2007) ("[W]e will [not] tolerate rules based on arbitrary and capricious cost-benefit analyses.").

9 *See* Zoe Palenik, *The Social Cost of Carbon in the Courts: 2013-2019*, 28 N.Y.U. Env't L.J. 393, 405–10 (2020) (tracing line of recent cases).

10 *See, e.g.*, Vecinos para el Bienestar de la Comunidad Costera v. FERC, 6 F.4th 1321 (D.C. Cir. 2021); High Country Conservation Advoc. v. U.S. Forest Serv., 52 F. Supp. 3d 1174, 1181 (D. Colo. 2014).

11 *See* Baltimore Gas & Elec. Co. v. Natural Res. Def. Council, 462 U.S. 87, 96 (1983); *see also* 40 C.F.R. § 1508.8(b) (2018) (requiring assessment of the "ecological," "economic," "social," and "health" effects).

12 *See, e.g.*, U.S. Forest Serv., Rulemaking for Colorado Roadless Areas: Supplemental Final Environmental Impact Statement 35–46 (2016).

13 U.S. Postal Serv., Record of Decision and Record of Environmental Consideration: Next Generation Delivery Vehicle Acquisitions app. A, 4-18 to -21 (2022), https://cdxapps.epa.gov/cdx-enepa-II/public/action/eis/details?eisId=354079; *see also* Bureau of Ocean & Energy Mgmt., Cook Inlet Planning Area Oil and Gas Lease Sale 244 In the Cook Inlet, Alaska Final Environmental Impact Statement 4-190 to 4-191 (2016) (estimating the social cost of emissions resulting from proposed offshore oil and gas lease sales).

14 *E.g.*, U.S. Gen. Servs. Admin., Fact Sheet: GSA Includes New Environmental Features in Next-Generation Parcel Delivery (undated), https://www.gsa.gov/cdnstatic/DDS3_green_features_fact_sheet.doc (describing application of SCC to procurements); U.S. Department of Transportation, Benefit-Cost Analysis Guidance for Discretionary Grant Programs 34–35 tbl.A-6; 40–41 (2021).

15 41 U.S.C. § 1303(b)(3)(B).

16 Wash. Rev. Code §§ 19.280.030(3)(a) ("An electric utility shall consider the social cost of greenhouse gas emissions . . . when developing integrated resource plans and clean energy action plans.").

17 *Id.* §§ 19.405.060, 19.405.070(1) ("Each electric utility must provide . . . its greenhouse gas content calculation in conformance with this section."); *see also* Elizabeth Hossner & Keith Faretra, Puget Sound Energy, 2021 IRP Webinar #5: Social Cost of Carbon, Planning Assumptions & Resource Alternatives Electric Portfolio Model (July 21, 2020) (describing use of SCC of $75 for 2022 rising to $99 by 2040 in resource planning in compliance with prescriptions of Washington State's Clean Energy Transformation Act).

18 Ga. Code Ann. § 46-3A-2.

19 Ga. Comp. R. & Regs. § 515-3-4.01 et seq.

20 *Id.* § 515-3-4-.02(2)(b).

[21] *Id.* § 515-3-4-.02(21).

[22] *Id.* § 515-3-4-.02(24).

[23] *Id.* § 515-3-4.-05(1)(a) (emphasis added).

[24] A California's court's decision to dismiss a lawsuit that challenged the California Air Resources Board's development of a scoping plan that itself had no regulatory effect illustrates the point. As the court observed, the statutory directives to the board "are exceptionally broad and open-ended. They leave virtually all decisions to the discretion of the Board . . . ." Ass'n of Irritated Residents v. State Air Res. Bd., 206 Cal. App. 4th 1487, 1495 (Cal. Ct. App. 2012).

[25] *See, e.g.*, N.Y.S. Dep't of Env't Conservation, Establishing a Value of Carbon: Guidelines for Use by State Agencies (Rev. June 2021) (describing available options for emissions valuation and endorsing version of SC-GHG for use by New York agencies).

[26] Vote Solar v. Montana Dep't of Pub. Serv. Regul., 473 P.3d 963, 976 (Mont. 2020) (quoting Order No. 7323k, ¶ 81, the utility commission decision below), *as amended on denial of reh'g* (Oct. 6, 2020).

4. Applications of the Social Cost of Greenhouse Gases

The internal workings of the SC-GHG are complex, but its application is straightforward.[1] By assigning a monetary value to the harm caused by greenhouse gas emissions, the SC-GHG enables decisionmakers to make two sorts of comparisons: first, between the climate and non-climate effects of a given policy, activity, or decision; and second, between the climate effects of a policy, activity, or decision and the climate effects of an alternative. By converting climate impacts into dollars, the SC-GHG ensures that both of these comparisons are apples-to-apples, not apples-to-oranges, and that decisionmakers can incorporate climate impacts into a wide variety of applications. For instance, being able to meaningfully compare climate effects and non-climate effects makes it possible to incorporate avoided climate damages along with other sources of value into royalties, fees, procurement decisions, or subsidies. And, making the climate effects of different alternatives readily comparable allows decisionmakers to weigh options on the basis of their relative environmental impacts, whether as part of an environmental impact review, a grant program, or in some other decisionmaking context.

This section describes how using the SC-GHG can make it easier for states to evaluate and weigh climate impacts in the following operational areas:

- Cost-benefit analysis
- Environmental impact review
- Procurement, investments, and grantmaking
- Royalties, penalties, and resource compensation

To illustrate how state agencies' planning and implementation of climate policy might involve each of these different types of decision or analysis, this section draws on examples from different sectors over which agencies have authority—electricity, transportation, oil and gas, gas distribution systems, and land use.

Though a number of states have used the SC-GHG in decisionmaking contexts, states have not, to date, used the SC-GHG for *all* of the types of decisions and analyses discussed below. State agencies have yet to incorporate the SC-GHG into environmental impact review, for instance, so we draw on federal examples for that application. For still others, which neither state nor federal agencies have undertaken, we describe what such an application might involve.

Table 4-1. Case Studies of SC-GHG Use

	Type of Use	Jurisdiction & Agency	Subject
CBA	*Rulemaking*	• U.S. Dep't of Energy • Colorado Dep't of Transportation • New York Dep't of Environmental Conservation	• Energy efficiency standards for manufactured housing • Rules for transportation-related capital spending • Regulations of emissions from the oil and gas industry and vehicles.
CBA	*Electric Utility IRPs*	Colorado Pub. Utilities Comm'n	Inform electricity resource planning
CBA	*Gas Distribution System*	New York Pub. Service Comm'n	Utilities' have developed Gas BCA Handbooks based on BCA Framework
CBA	*Planning Info.*	• California Air Resources Board • New Jersey Governor's Office	Demonstrate benefits of different components of climate change scoping plan (CA) and Energy Master Plan (NJ)
CBA	Land Use	--	--
	Grants & Investments	• Colorado, all agencies • California Dep't of Transportation • U.S. Dep't of Transportation	• Assessment of energy efficiency measures in capital spending projects • Evaluation of potential capital spending projects • Invites grant applicants to use the SC-GHG to characterize project benefits
	Procurement	U.S. Postal Service	Environmental impact statement of planned procurement of mail delivery vehicle fleet
	Penalties	--	--
	Royalties	--	--
	Resource Compensation	• Illinois Commerce Comm'n • New Jersey Board of Pub. Utilities • New York Pub. Service Comm'n • Maine Pub. Utilities Comm'n	• Inform or delimit the value of a zero emission credit/certificate (IL, NY / NJ) to compensate nuclear generators • Study the value of distributed (rooftop) solar to determine the benefits of solar from reducing/avoiding emissions

4.1. Cost-Benefit Analysis

Cost-benefit analysis requires a decisionmaker to weigh the positive and negative effects of an action. A decisionmaker can easily determine the monetary value of some effects, whether because markets assign them a price or, for instance, because regulated entities estimate their monetary value as a matter of course, such as the cost of capital investments. However, for other effects, like the harms done to human health by local air pollution or to the economy by contributing to the greenhouse gas emissions that cause climate change, a decisionmaker must look to tools that translate findings from scientific, medical, or economic literature into quantities and monetary values. Cost-benefit analysis is a way to identify and weigh all relevant considerations—even those that are difficult to measure—in a manner that enables the comparison of costs and benefits and thereby supports transparent and rigorous decisionmaking.

Federal and state agencies—and sometimes entities they regulate—apply the SC-GHG when they compare the costs and benefits of various decisions. Those comparisons can take several forms, some more rigorous and standardized than others. Notably, the SC-GHG was originally developed for use in the sort of cost-benefit analysis required of federal agencies when they conduct rulemakings.[2] It is no surprise, then, that federal agencies, which make routine use of highly standardized cost-benefit analysis, generally incorporate the SC-GHG into that analysis if the decision at issue has implications for greenhouse gas emissions. State agencies, by contrast, are not necessarily subject to the same cost-benefit analysis standards as federal agencies, and so may have varying approaches to how they examine and weigh decisions.

Box 4-1: Simplified Steps for Applying the SC-GHG in CBA

The following, generic steps are very likely to feature in any cost-benefit analysis that makes use of the SC-GHG to estimate the value of a given decision's effects on greenhouse gas emissions.

1. Convert the SC-GHG values from the dollar year used for the SC-GHG estimates (the 2021 estimates use 2020 dollars), to the dollar year used in the rest of the analysis, if the values have not already been converted.
2. Determine the avoided emissions for each year between the effective date and the end date of the policy;
3. Multiply the quantity of avoided emissions in each year by the corresponding SC-GHG for that year, to calculate the monetary value of damages avoided by avoiding emissions in that year;[3]
4. Apply the same discount rate used to calculate the SC-GHG to calculate the present value of future effects of emissions from that future year;[4]

   The present value of future money formula is: $PV = FV/(1+i)^n$ where PV is present value, FV is future value (i.e., the SC-GHG value for year 2025 emissions multiplied by the volume of emissions), i is the discount rate expressed as a decimal (e.g., 0.025 for 2.5%), and n is the number of years between the year of analysis and the future value.
5. Sum these present values for all relevant years (e.g., 2022, 2023, etc. through the end date) between the effective date and the end date to arrive at the total monetized climate benefits of the plan's avoided emissions;[5] and
6. Describe qualitatively damages that have been omitted from the SC-GHG, and consider those benefits in any final assessments.[6]

For analyses covering multiple greenhouse gases, officials should use the appropriate social cost value for each gas; they should not simply rely on global warming potential coefficients to translate between social cost values. For example, if a state is assessing a policy that would affect carbon dioxide and methane emissions, the analysis should include the SC-CO_2 and the SC-CH_4. Schedules of the annual values for all gases are included in Appendix A.

Step 4 of this analysis requires selection of a discount rate—or, potentially, a few. How to choose the proper discount rate (or rates) requires further explanation. That explanation is drawn from several resources, which explain the theoretical underpinnings and recent research in greater depth, which users of this guide may wish to consult separately.[7]

Why use a discount rate? For several reasons, people prefer having a dollar now to having one in the future.[8] Recognizing this relationship between time and value, governments and private entities use discount rates (discussed in more depth in Section 2.1.4) when making comparisons of value across time. For instance, if a policy measure or private investment will incur costs over the next two years and yield benefits over the subsequent 25 years, discounting is needed to enable the comparison of those costs and benefits on an apples-to-apples basis.

Importantly, however, discount rates depend on whether the perspective is that of society or of a private entity. Consumption-based discount rates reflect a public or societal perspective, and are lower than rates that reflect a private investor's perspective. A private investor, by contrast, uses a higher capital-based discount rate, which reflects the opportunity cost of making a private investment instead of having money available to purchase or invest in something else in near future. The time horizon for an analysis is also important when deciding on a discount rate. For analyses of less than several decades, it is appropriate for an agency to apply an *intra*-generational discount rate;[9] for longer durations, the agency should use an *inter*-generational rate.[10] Intergeneration rates tend to be lower and to have a smaller range.[11]

Understanding what discount rate a state agency should use is important, but there are two more questions that state agencies must answer when they incorporate monetized emissions effects into their valuation of certain decisions or investments. First, how should they align the consumption-based discount rate they apply to policy decisions with the SC-GHG? And second, how should they deal with policy measures that involve both public and private intra-generational investments?

The first of these questions is easier to answer. As indicated in Step 4 above, an analysis should apply a consistent discount rate to both climate impacts *and* the net present valuation of those impacts. So, if an agency applies a 2.5% discount to get its estimate of the climate damage avoided from lower greenhouse gas emissions, it should also use a 2.5% rate for the net present value calculation that indicates what an investment's value is today. Note, however, that using a consistent rate does not necessarily mean using only one rate: an analysis can be run multiple times with different rates, so that the agency can see the full spectrum of values revealed by different degrees of discounting. Supplemental analyses using different parameters, like a different discount rate, are called sensitivity analyses.

The second question is harder to answer—and is arising more often as more state agencies direct regulated entities to incorporate emissions impacts into their valuations of proposed investments. The most frequent example of this involves a utility or renewable project developer being asked to present a utility commission with an analysis of what a proposed project is worth. Calculating that worth means integrating the monetary values of capital assets and emissions (or avoided emissions), which in turn means deciding how to reconcile different discount rates. At present, the latest research does not point to a tidy solution. So, as with the answer to the first question, the best available approach seems to be to generate a range or matrix showing the results of applying all potentially appropriate discount rates and possibly selecting one iteration as "central." This could look like the U.S. Department of Energy cost-benefit analysis presented in Section 4.1.1.1.

We recognize that in some situations faced by regulators this recommendation amounts to incomplete guidance.[12] As this is a subject of intense interest to governments around the world,[13] research is likely to illuminate more about how best to deal with this circumstance. **In the meantime, we note that this recommendation goes against using an averaged or otherwise homogenized rate and instead calls for being forthright about the analytical dissonance that comes with applying several different rates.**

For a fuller discussion of discounting and the basis for these recommendations, see *Valuing the Future: Legal and Economic Considerations for Updating Discount Rates.*[14]

4.1.1. Case Studies of the SC-GHG Used in Cost-Benefit Analysis

The rest of this section presents examples of how federal and state agencies have incorporated—or could incorporate—the SC-GHG into several forms of cost-benefit analysis. These analyses pertain to different sectors and have different aims. The first was conducted by the U.S. Department of Energy to support its adoption of energy efficiency standards for manufactured housing. The second was conducted by regulated electric utilities in Colorado as part of their triennial energy master planning obligation. And the third is a pair of informal cost-benefit analyses undertaken by the governments of California and New Jersey.

4.1.1.1. SC-GHG in Rulemaking Cost-Benefit Analysis

In 2021, the Department of Energy (DOE) conducted a cost-benefit analysis of its proposed energy efficiency standards for manufactured housing,[15] as required by federal law (see Section 3.2). In that analysis, DOE considered "the effect of potential energy conservation standards on power sector and site combustion emissions," as well as emissions from "upstream" fuel development and production.[16] The figure below breaks out benefits from avoided greenhouse gas emissions for each alternative, and includes the whole range of Working Group estimates.[17] These benefits are then tallied along with other benefits and costs to consumers. Note that DOE explored both tiered and untiered standards. In the tiered approach, certain units would be subject to less stringent energy conservation standards in light of "cost-effectiveness considerations required by statute and affordability concerns."[18] The untiered standard applies the 2021 International Energy Conservation Code uniformly.[19]

Table 4-2. Summary of Economic Benefits and Costs to Manufactured Home Homeowners under the Proposed Standards[20]

	Net present value (billion 2020$)		Discount rate (%)
	Tiered	Untiered	
Benefits:			
Consumer Operating Cost Savings	5.5	6.1	7.
	14.3	15.9	3.
GHG Reduction (using avg. social costs at 5% discount rate) *	1.1	1.2	5.
GHG Reduction (using avg. social costs at 3% discount rate) *	4.5	5.0	3.
GHG Reduction (using avg. social costs at 2.5% discount rate) *	7.4	8.2	2.5.
GHG Reduction (using 95th percentile social costs at 3% discount rate) *	13.6	15.0	3
NO_X Reduction	0.2	0.2	7.
	0.4	0.5	3.
SO_2 Reduction	0.3	0.3	7.
	0.7	0.8	3.
Total Benefits	7 to 19.5	7.8 to 21.6	7 plus GHG range.
	10.5	11.6	7.
	20.0	22.2	3.
	16.6 to 29.1	18.4 to 32.2	3 plus GHG range.
Costs:			
Consumer Incremental Product Costs †	3.9	4.7	7.
	7.9	9.6	3.
Total Net Benefits:			
Including GHG and Emissions Reduction Monetized Value	3.1 to 15.6	3 to 16.9	7 plus GHG range.
	6.6	6.9	7.
	12.1	12.6	3.
	8.7 to 21.2	8.7 to 22.6	3 plus GHG range.

Note: This table presents the costs and benefits associated with manufactured homes shipped in 2023–2052.

* The benefits from GHG reduction were calculated using global benefit-per-ton values. See section IV.D.2 of this document for more details.

** Total Benefits for both the 3-percent and 7-percent cases are presented using the average GHG social costs with 3-percent discount rate. In the rows labeled "7% plus GHG range" and "3% plus GHG range," the consumer benefits and NOX and SO2 benefits are calculated using the labeled discount rate, and those values are added to the GHG reduction using each of the four GHG social cost cases.

† The incremental costs include incremental costs associated with principal and interest, mortgage and property tax for the analyzed loan types.

This table shows the discount rates used to calculate the net present value of the proposals' costs and benefits. It also gives a range of net benefits depending on the SC-GHG estimates used and the overall cost-benefit analysis discount rate.

Colorado has also recently used the SC-GHG in the rulemaking context. The Colorado Department of Transportation (CO DOT) is developing regulations that will change how the state approaches transportation-related capital spending. Draft rules issued in September 2021 propose a greenhouse gas emissions standard for state and regional transportation plans that would align with the state's goal of reducing transportation-sector emissions.[21] The CO DOT prepared a cost-benefit analysis of the proposed rules and included the SC-GHG in its calculation of the rules' economic benefits.[22] That cost-benefit analysis captures several factors. Benefits include vehicle operating costs, local air pollution, safety, and climate impacts,[23] which are weighed against the costs of program administration and infrastructure.[24] The CO DOT uses the Working Group's social cost estimate at a 2.5% discount rate to estimate the new rules' avoided climate damages. Notably, this analysis is programmatic and does not examine individual transportation projects.

New York has also used the SC-GHG to estimate the net benefits of new regulations. In 2021, the state's Department of Environmental Conservation adopted a rule copying California's Advanced Clean Truck zero emission vehicle standards,[25] and another that regulates emissions from oil and natural gas.[26] The department's analysis of the first rule, as shown in Figure 4-1, values carbon dioxide emissions at 1%, 2%, and 3% discount rates for the emissions modeled using two analytical approaches ("scenarios").

Table 4-3. Estimated Avoided Social Cost of Carbon from 2025-2040[27]

Scenario	Avoided SC-CO_2 3% Discount Rate (2018$ millions)	Avoided SC-CO_2 2% Discount Rate (2018$ millions)	Avoided SC-CO_2 1% Discount Rate (2018$ millions)
CA Scaled	263	632	2,127
MOVES3	860	2,057	6,918

The analysis of the second rule, as shown in Figure 4-2, quantifies (first row) and values (second row) methane emissions reductions from the rule's required changes to the production, refining, storage, gathering, and transmission of oil and gas. The valuation step applies the social cost of methane at 1%, 2%, and 3% discount rates.

Table 4-4. Potential Methane Emissions Reductions and Costs of Failing to Achieve Them[28]

Annual Cost of Methane			
Total Potential Emissions Reductions ($MTCH_4$)	14,643 – 52,534		
Social Cost if Reductions are not achieved (2020 dollars)	\$96,321,654 - \$345,568,652	\$40,736,826 - \$146,149,588	\$22,359,861 - \$80,219,418
	1% Discount Rate (\$6,578/metric ton)	**2% Discount Rate (\$2,782/metric ton)**	**3% Discount Rate (\$1,527/metric ton)**

4.1.1.2. SC-GHG in Cost-Benefit Analysis for Electric Utility Planning

In many states, utility commissions use an integrated resource planning process to assess utilities' proposed investments and programs. Colorado,[29] Minnesota, Nevada, and Washington State require utilities to use a version of the SC-GHG in the integrated resource plans they submit to utility commissions to propose investments and request authorization to recover the cost of those investments from ratepayers.

Requiring utilities to incorporate climate damages into their analysis of possible investments enables utilities and regulators to see more plainly the full costs of polluting generation options and the benefits of clean generation. Utilities often conduct a cost-benefit analysis for each portfolio of investments they propose. An example from Colorado illustrates how this can incorporate the SC-GHG.

In 2017, the Colorado Public Utilities Commission (CO PUC) ordered the Public Service Company of Colorado (a.k.a. Xcel Energy) to consider the social cost of carbon in its Electric Resource Plan.[30] The CO PUC noted that, by modeling these climate impacts, "we can test the robustness of the portfolios and assess the impact to customers of a broader range of costs from carbon emissions."[31] The Commission also found that the Working Group estimate "is a reasonable quantification of the potential cost of externalities for the purpose of [resource plan] model portfolios."[32] Two years later, in early 2019, the Colorado State Legislature codified into law the CO PUC's decision to require utilities to use the SC-GHG in their Electric Resource Plans. Specifically, the legislature required the utilities commission to evaluate "the cost of carbon dioxide emissions" in resource planning, with the condition that the SC-GHG must be calculated using a 2.5% discount rate or lower and should be no less than $68 per ton of carbon dioxide.[33]

In accordance with this new law, Xcel Energy used the SC-GHG in its 2021 Electric Resource Plan and Clean Energy Plan.[34] Xcel's plan aims to reduce greenhouse gas emissions by 85% from 2005 levels and provide 80% of its energy from clean generators.[35] The analysis in Xcel's plan used the SC-GHG as a shadow price, meaning that the utility modeled outcomes as though the Xcel would pay a price equal to the SC-GHG for emitting each ton of greenhouse gases.[36] Consequently, the benefits and costs of the scenarios Xcel valued included the climate damages that would be caused by emitting resources or avoided by clean ones.

4.1.1.3. SC-GHG in Cost-Benefit Analysis for Gas Distribution System Planning

States that have adopted economy-wide emissions reduction commitments must confront the tensions—or outright incompatibilities—between those commitments and existing approaches to the delivery and use of fossil methane gas in commercial and residential buildings. That sector's use of gas on-site was responsible for about 13% of U.S. greenhouse gas emissions in 2019—the year of EPA's most recent inventory.[37] The gas was delivered through about 1.3 million miles of gas mains and just under a million miles of gas service lines.[38] These distribution systems tend to grow when demand for gas has grown, but do not necessarily shrink when demand has fallen.[39] Recognizing the need to harmonize the governance of gas distribution systems and utilities (usually called "local distribution companies" or LDCs) with statewide greenhouse gas emissions reduction goals, utility commissions in several states have initiated gas system planning proceedings.[40] This marks a notable change from the longstanding reliance on periodic "rate cases" to review the prudence of investments in the gas distribution system and the rates charged by utilities to recover the costs of those investments.

The SC-GHG can help inform planning and decisionmaking in the states that have initiated gas planning proceedings and in others that seek to better align gas distribution systems and LDC investments and operations with climate goals. Similar to how electric utilities use the SC-GHG to compare different generation portfolios, the SC-GHG can also be used to help compare alternative investments proposed by LDCs and others in terms of their emissions impacts. Examples of what might be compared include: conventional investments in gas distribution infrastructure, improvements to gas distribution system efficiency, the development and operation of gas demand response programs, and electrification projects or project portfolios that help gas customers replace gas-reliant equipment and appliances with electric ones. In principle, the SC-GHG can be applied in comparisons made in a planning proceeding on the programmatic level, or the project or project portfolio level in a rate case.

To date, the SC-GHG has not been used in exactly this way, but it has been used in New York in an analogous fashion by utilities implementing the Public Service Commission's Benefit Cost Analysis (BCA) Framework.[41] That Framework was initially implemented to enable comparisons of conventional electricity infrastructure investments and non-wire alternatives,[42] but has since provided the basis for analyzing non-pipes alternatives as well.[43] The basic purpose of the Framework is, simply stated: to enable rigorous comparison of supply and demand-side solutions that can provide similar services but are highly dissimilar in their capital structure and operation. The SC-GHG is an important element of the Framework and enables the estimation in monetary terms of how much a project or project portfolio contributes—whether positive or negative—to greenhouse gas emissions.

Of course, the availability of analytical tools like New York's BCA Framework and the SC-GHG do not on their own empower utility commissions to give legal effect to the analytical conclusion that further investments in gas distribution infrastructure are less cost-effective for consumers than electrification.

4.1.1.4. SC-GHG in Informational Cost-Benefit Analysis for Multisector Planning

Some states also use the SC-GHG for information purposes in a simplified cost-benefit analysis to show how climate benefits help to justify clean energy transition and emissions reduction measures over the medium and long-term. California's 2022 Climate Change Scoping Plan is one such example.[44] Figures 4-4 and 4-5 shows each element of the plan and the range of its expected climate benefits.[45]

Table 4-5. Estimated Social Cost (Avoided Economic Damages) of Measures Considered in the Proposed Scenario (AB 32 GHG Inventory Sectors)[46]

Measure	Social Cost of Carbon in 2035, 5%–2.5% discount rate billion USD (2021 dollars)	Social Cost of Carbon in 2045, 5%–2.5% discount rate billion USD (2021 dollars)
Deploy ZEVs and reduce driving demand	1.03–4.50	2.46–9.53
Coordinate supply of liquid fossil fuels with declining California fuel demand	0.64–2.78	0.99–3.84
Generate clean electricity	N/A[a]	0.20–0.79
Decarbonize industrial energy supply	0.18–0.78	0.49–1.89
Decarbonize buildings	0.35–1.50	0.91–3.52
Reduce non-combustion emissions	0.49–1.26 (SC-CH_4)	0.85–1.98 (SC-CH_4)
Compensate for remaining emissions	0.41–1.76	2.50–9.68
Proposed Scenario SC-CO_2	2.2–9.7	2.0–7.9
Proposed Scenario SC-CH_4	0.49–1.3	0.85–2.0
Proposed Scenario (Total)[b]	2.7–11.0	2.8–9.9

[a] SB100 does not lead to further GHG emissions reductions than the Reference Scenario until after 2035.

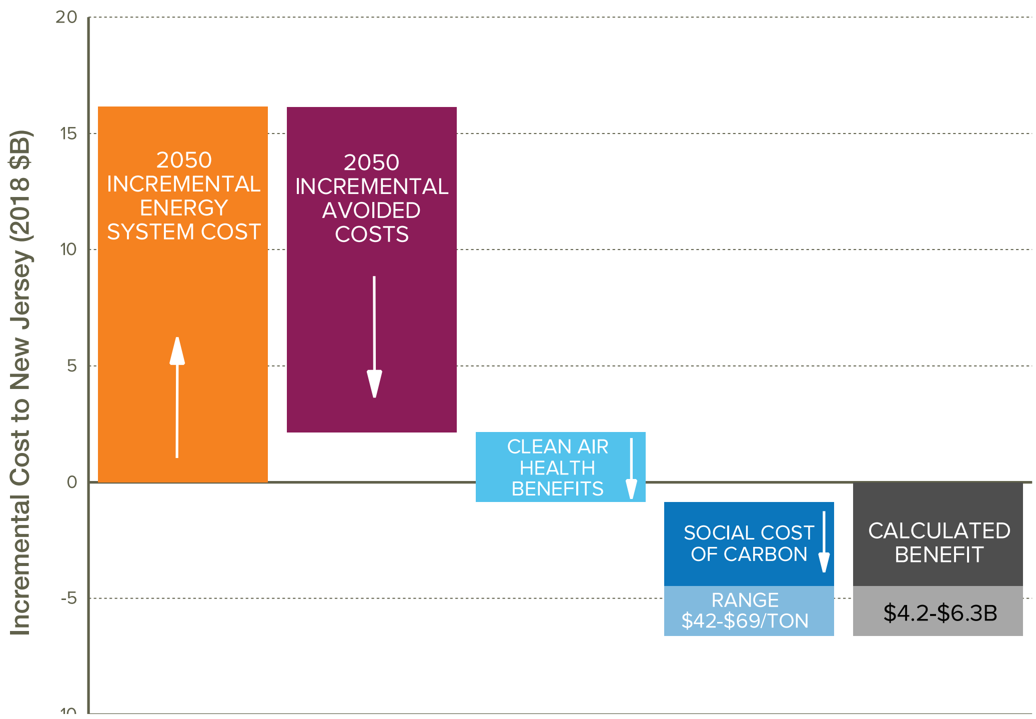
Table 4-6. Estimated Social Cost (Avoided Economic Damages) of Measures Considered in the Proposed Scenario (Natural and Working Lands)[47]

Measure	Social Cost of Carbon in 2035, 5%–2.5% discount rate Billion USD (2021 dollars)	Social Cost of Carbon in 2045, 5%–2.5% discount rate Billion USD (2021 dollars)
Forests/Shrublands/Grasslands	0.003–0.012	0.004–0.014
Annual Croplands	0.006–0.025	0.007–0.028
Perennial Croplands	<0.001–0.001	0.000–0.001
Urban Forest	0.012–0.055	0.016–0.063
Wildland Urban Interface (WUI)	(0.018) – (0.080)	(0.023) – (0.090)
Wetlands	0.011–0.046	0.014–0.053
Sparsely Vegetated Lands	<0.001	<0.001

The Scoping Plan draws on several emissions reduction scenarios, covering California's signature cap-and-trade program, as well as a renewable portfolio standard for the electric power sector, controls on mobile sources and freight, regulation of short-lived climate pollutants like HFCs, and energy efficiency measures.[48] Because the Plan provides monetary values of the emissions as a reference, it allows Californians to more easily understand and assess the Plan than if it simply laid out quantities of emissions.

New Jersey's 2019 Energy Master Plan similarly employs the SC-GHG to show the benefits of the emissions reduction measures it proposes for transportation, the electric power sector, buildings, and other sectors that the state aims to target to meet its goal of 100% clean energy by 2050.[49] Using the SC-GHG, New Jersey estimates that the plan would yield between $4 billion to $6 billion annually in avoided climate damages.[50] As the figure below shows, the Energy Master Plan uses the SC-GHG to weigh the benefits of avoiding greenhouse gas emissions against the costs of doing so, and presents the results in a way that is easily understood.

Figure 4-1. Benefits and Incremental Costs of New Jersey in the Least-Cost Scenario[51]



In the planning documents issued by California and New Jersey, the SC-GHG improves the accessibility of the states' climate benefit analysis, clarifying for the public and decisionmakers that the complex and ambitious program proposals are cost-justified and worthwhile.

4.1.1.5. SC-GHG in Cost-Benefit Analysis for State (and Local) Land Use Planning

"Land use" refers to efforts by states and localities to use legal mandates, prohibitions, and procedural rules to influence the form and modalities of the built environment. This includes, for instance, decisions about what structures or uses to allow. The SC-GHG can be useful for informing these types of land use decisions and for assessing how they are likely to contribute more or less to the emission of greenhouse gases.

States' and localities' land use decisions contribute to greenhouse gas emissions in a number of ways. Zoning is the most commonly understood form of land use. While zoning decisions often contribute to greenhouse gas emissions (or reductions), other forms of land use decisionmaking similarly affect emissions-intensive decisions like whether and where to develop infrastructure and buildings. A 2019 analysis identifies six forms of land use planning that affect greenhouse gas emissions from the transportation sector:

- **Local general plans** (also known as comprehensive plans) guide infrastructure investments and zoning. They may be required to be consistent with state policy goals or coordinated with neighboring local governments. States may also require that local zoning ordinances be consistent with the local general plan.
- **State and regional transportation plans** are required in order to receive federal transportation funds.
- **Long-range transportation plans** have a 20-plus-year horizon and identify broad funding priorities and policy goals.
- **Transportation improvement programs** have a four-year horizon and specify individual projects to be financed with federal transportation funds.
- **Climate action plans** can cover a wide range of policy domains, unified only by the goals of reducing GHG emissions and adapting to the effects of climate change.
- **Scenario plans** use predictive modeling to structure policy in light of specified outcomes and/or to explore policy options for addressing foreseeable contingencies. They may be undertaken as part of one of the above planning processes, or independently.[52]

Insofar as these sorts of land use decisions' emissions impacts are quantifiable, then the SC-GHG can help inform relevant decisionmakers. Monetizing those emissions' harms using the SC-GHG renders the harms comparable to other impacts that bear on the decision, like the degree of economic stimulation, consumer benefit, or tax revenue a decision would generate. In that sense, the SC-GHG can help enable apples-to-apples comparisons of a decision's harms and benefits.

4.2. Procurement, Grantmaking, and Capital Spending

States can work towards their climate goals by directing state dollars to goods, services, and programs that result in fewer greenhouse gas emissions—or none at all—compared to alternatives. Although procurement, grantmaking, and investing are distinct in important ways, they are similar in several respects, and can all be undertaken in ways that consider climate impacts by incorporating the SC-GHG.

4.2.1. SC-GHG in State and Federal Agency Procurement

Agencies with broad discretion to consider environmental or climate impacts in their procurement decisions can use the SC-GHG to weigh monetized climate damages (or avoided climate damages) against other factors they consider in their procurement processes.[53] For example, the laws that govern state procurement in Maryland include a section on "environmentally preferable purchasing," which lists "climate change" and "fossil fuel" among the factors that are relevant to procurement decisions.[54] The Buy Clean California Act is similar. The legislative findings section of the act explains that "California . . . can improve environmental outcomes and accelerate necessary greenhouse gas reductions to protect public health, the environment, and conserve a livable climate by incorporating emissions information from throughout the supply chain and product life cycle into procurement decisions."[55] California also has specific statutes that cover vehicle procurement which defines "best value procurement" to include environmental benefits, such as "reduction of greenhouse gas emissions."[56]

Even if state agencies do not have *explicit* discretion to consider their spending choices' climate or environmental effects, agencies may still have the authority to consider climate impacts and to incorporate the SC-GHG into procurement decisions. Consider the example of the federal-government-wide Federal Acquisition Regulation (FAR), which prescribes parameters of federal agency procurement. Many sections of the FAR permit agencies to use the SC-GHG in procurement even though they do not refer to that tool, climate change, or greenhouse gas emissions.[57] In particular, the FAR regulations dictate that agencies prioritize "best value," which is defined as "the expected outcome of an acquisition . . . that provides the greatest overall benefits."[58] And the Federal Regulatory Acquisition Council, made up of the General Services Administration, Department of Defense, and the National Aeronautics and Space Administration recently issued a call for comments about how to incorporate the SC-GHG into federal procurement decisions.[59]

Some states have coupled permissive rather than prescriptive statutory provisions with one or more executive orders that expressly direct agencies to consider climate change when making procurement decisions. New York's legislature determined that goods and services "be procured [by political subdivisions] in a manner so as to assure the prudent and economical use of public moneys in the best interest of the taxpayers" and "to facilitate the acquisition of goods and services of maximum quality at the lowest possible cost under the circumstances."[60] And New York's 2008 Executive Order 4 establishes the Interagency Committee on Sustainability and Green Procurement and directs that committee to develop specifications and "green" procurement lists for use by agencies—those lists and specifications are to consider, among other things, "reduction of greenhouse gases."[61] Thus, New York's agencies are authorized and directed to consider climate change in the context of procurement, and can employ the SC-GHG to help strike a balance between quality and cost.

There are many generic tools available to support government entities seeking to incorporate environmental and climate impacts into their procurement decisions (see Box 4-2), but different governments have taken different approaches to weighing emissions in procurement decisions. Washington State and the U.S. Postal Service have both recently examined the effects of public vehicle fleet procurement options on greenhouse gas emissions.

Box 4-2: Atlas Fleet Procurement Analysis Tool

Atlas Public Policy, a consulting group, has developed a Fleet Procurement Analysis Tool that gives users information on "the financial viability and environmental impact" of different types of vehicles.[62] An example graph and table included in the tool's user guide provides a breakdown of the cost categories that make up the total vehicle costs per mile, including a carbon cost based on the SC-GHG.[63]

The tool treats the SC-GHG as just another cost like those accruing from taxes and fees, insurance, and assorted others.[64] In the example shown above, the expected lifetime cost profile of an electric vehicle (2019 Hyundai Ioniq) is lower than that of an internal combustion engine vehicle (2019 Chevrolet Cruze).[65]

In 2020, Washington State published a study of options for electrifying its public vehicle fleets, which included over 56,000 vehicles.[66] A key objective of the study was to help the state specify criteria for when electrification of a subset of publicly owned fleets would be cost-effective. The study found—unsurprisingly—that assigning a price to carbon dioxide emissions based on the SC-GHG at a 2.5% discount rate ($74/ton in 2020) would make a big difference. Specifically, it would boost by a factor of three the number of vehicles for which electric replacement would be cost-effective.

The U.S. Postal Service began procuring a new fleet of "next generation" delivery vehicles in 2022.[67] It conducted an environmental impact assessment of its procurement plan, which would purchase a fleet of vehicles intended to operate for 30 years.[68] That assessment considered two options: a fleet made up of 90% internal combustion engine vehicles and 10% battery electric vehicles, or a fleet composed of only battery electric vehicles.[69] It used three different models to quantify emissions impacts of those options: GREET (Greenhouse Gases, Emissions, and Energy use in Technologies from the U.S. Department of Energy;[70] eGRID (Emissions & Generation Resource Integrated Database from U.S. EPA;[71] and MOVES (MOtor Vehicle Emissions Simulator) from U.S. EPA.[72] The assessment found that the mixed fleet would reduce greenhouse gas emissions relative to a "no action" alternative in which the existing fleet continued operating,[73] but the all-electric fleet would reduce emissions by two to three times more.[74] Monetizing those amounts yielded the values shown in Figures 4-6 and 4-7 below.[75]

Table 4-7. Calculated SC-GHG (90% ICE NGDV and 10% BEV NGDV)[76]

Operational Year	5% Discount Rate ($, US Dollars)	3% Discount Rate ($, US Dollars)	2.5% Discount Rate ($, US Dollars)	3% 95th Percentile Discount Rate ($, US Dollars)
2030	-5,498,055	-17,618,744	-25,236,314	-52,381,640
2035	-6,365,706	-19,055,123	-27,263,765	-57,804,880
2040	-7,225,573	-20,828,337	-29,291,215	-63,213,561
2045	-8,153,479	-22,533,511	-31,333,225	-68,128,329
2050	-9,267,583	-24,306,725	-33,106,439	-73,282,774

Notes:

1 Social Cost of GHG was estimated based on ten-year total emissions in GHG after completion of the project as the basis (from Table 4-6.2) to forecast lifespan Social Cost of GHG in five-year intervals. This approach likely provides higher Social Cost of GHG benefits than an approach using every intermediate year of emissions before completion of the project in year 2032. The Social Cost of GHG would be the same after completion of the project (2033 and beyond) under either approach.

2 The aggregated emission changes from the Proposed Action are shown to decrease; resulting in negative values for the corresponding social cost, which represents savings of the anticipated social cost in the future.

Table 4-8. Calculated SC-GHG (Alternative 1.2 - 100% LHD COTS BEVs)[77]

Operational Year	5% Discount Rate ($, US Dollars)	3% Discount Rate ($, US Dollars)	2.5% Discount Rate ($, US Dollars)	3% 95th Percentile Discount Rate ($, US Dollars)
2030	-20,859,908	-65,488,599	-93,480,934	-192,210,077
2035	-24,155,829	-70,888,396	-101,157,155	-212,519,895
2040	-27,419,310	-77,717,670	-108,833,377	-232,689,604
2045	-31,125,212	-84,104,523	-116,649,707	-251,305,528
2050	-35,235,640	-90,933,797	-123,478,982	-270,628,290

Notes:

1 Social Cost of GHG was estimated based on ten-year total emissions in GHG after completion of the project as the basis (from Table 4-6.11) to forecast lifespan Social Cost of GHG in five-year intervals. This approach likely provides higher Social Cost of GHG benefits than an approach using every intermediate year of emissions before completion of the project in year 2032. The Social Cost of GHG would be the same after completion of the project (2033 and beyond) under either approach.

2 The aggregated emission changes from the Alternative 1.2 are shown in decrease; resulting negative values for the corresponding social cost, which represents savings of the anticipated social cost in the future.

The SC-GHG has not been used extensively in procurement decisions at the federal or state levels, but the metric is ripe for such application. As shown by the examples from Washington State and the U.S. Postal Service, the SC-GHG can be used in multiple ways to facilitate procurement decisions, including by modeling outcomes of long-term procurement plans and by comparing the monetized climate effects of alternative procurement options.

4.2.2. Grants and Capital Spending

As with procurement, states can incorporate the SC-GHG into the criteria they use when awarding discretionary grants or using state funds to make capital expenditures. Doing so can help reveal competing proposals' implications for the climate and make those implications comparable to costs and other features.

The SC-GHG can be useful at multiple decision points in the grants and capital spending process. The examples below relate to building energy efficiency measures and approaches taken by federal and state departments of transportation in this process. Build energy use and transportation account for 13% and 29% of American greenhouse gas emissions, respectively[78]—transportation alone causing more emissions than any other single sector—and states have many options to cut these emissions through the policies they set and the projects they fund. Choosing among, implementing, and optimizing these options demands rigorous scrutiny and is compatible with use of the SC-GHG. The following examples show how the SC-GHG can be used at the project-level and when applicants bid for projects.

Spending Guidelines: In 2022, Colorado Governor Jared Polis signed an executive order aimed at reducing emissions from state operations, including through building energy use.[79] The order directs agencies to "[i]dentify and pursue energy efficiency improvements for State buildings that are cost effective when comparing the net-present value energy costs and the costs of greenhouse gas emissions. . . ."[80] The order directs agencies to assess cost-effectiveness using the SC-GHG (as prescribed by Colorado law).[81]

Project Level Evaluation: California's Department of Transportation (CalDOT) also uses the SC-GHG when making decisions about transportation-related capital spending, but examines project-level proposals—interstate highway expansions, state highway extensions, and public transit investments—rather than programmatic ones.[82] CalDOT applies the Working Group's social cost values at both a 3% discount rate and a 2% rate to reflect the Working Group's conclusion that "future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed."[83]

Applicant Evaluation: The U.S. Department of Transportation's (U.S. DOT) Better Utilizing Investments to Leverage Development (BUILD) and Infrastructure for Rebuilding America (INFRA) programs, for instance, direct applicants seeking discretionary grants to prepare a cost-benefit analysis that assesses their proposals' climate impacts.[84] Although applicants are not required to do so, the agency's guidance encourages them to use the Working Group's SC-GHG estimates to calculate those impacts.[85]

In these examples, cost-benefit analysis (discussed at length in Section 4.1) is embedded within the grantmaking process. Some agencies may use different analytical tools to assess the comparative merits of proposals, but the SC-GHG can fit into any decisionmaking framework where monetary values are useful or required.

4.3. Penalties, Royalties, and Resource Compensation

The SC-GHG can be used to specify what level of payments would be required for a particular decision or process to reflect—or "internalize"—the climate-related costs (or benefits) of emitting (or avoiding) greenhouse gases. Such payments, whether in the form of penalties, royalties, subsidies, or some other form of resource compensation, could promote activities or technologies that do less climate damage, and discourage those that do more. Notably, a scheme that imposes or provides payments does not need to be designed from scratch to usefully apply the SC-GHG in this way; existing programs can incorporate it. Below we describe examples of agencies that apply the SC-GHG when imposing administrative penalties, collecting royalties for extracted fossil fuels, and compensating clean energy sources.

4.3.1. Penalties

Incorporating climate costs into administrative penalties is appropriate when noncompliance with a particular policy or program results in the emissions of a greater volume of greenhouse gases than would otherwise have been released. Penalties are assessed against entities that violate regulatory standards in order to deter noncompliance and to repay society for the harms imposed. Volkswagen, for instance, famously paid large penalties after being caught in a scheme to defeat the mechanism used to assess its diesel passenger vehicles' compliance with emissions standards.[86] Where the costs of noncompliance include heightened greenhouse gas emissions, making the SC-GHG part of the formula for penalties like those imposed on Volkswagen would be logically consistent with a goal of restitution and offer a ready-made answer to the difficult question of what such conduct costs society in terms of climate damage.

Many of the federal laws that establish penalties give agencies broad discretion over how much to demand for a violation.[87] For example, in addition to inflation adjustments, the National Highway Traffic Safety Administration (NHTSA) is authorized to increase the penalties for automakers that violate the fuel-efficiency standards if doing so "will result in, or substantially further, substantial energy conservation for automobiles."[88] This authorization does not appear to bar a penalty that incorporates the SC-GHG, which would serve as an approximation of the avoidable climate damage arising from noncompliance.

States could likewise apply the SC-GHG when imposing penalties on violations that have clear and measurable—even hard-to-measure—emissions implications. Such an application would be logically consistent for violations by an entity in any industry that must comply with air pollution regulations and emits greenhouse gases, like a power plant, or causes greenhouse gases to be emitted, such as automobile manufacturers.[89]

4.3.2. Royalties

Both state and federal governments charge royalties for resource extraction, but current prices do not represent the full costs of extraction.[90] Fossil fuel extraction on federal lands currently accounts for an enormous share of domestic greenhouse gas emissions.[91] However, the federal government does not require producers to internalize the full societal cost of greenhouse gas pollution arising from extraction activities or the downstream emissions that ultimately result from consumption of what is extracted. This results in an overproduction—from the standpoint of society—of fossil fuels. Along with the federal Department of the Interior (Interior), state regulators that set royalty rates for mineral extraction can correct this market failure. Imposing an "adder" to royalties based on the SC-GHG would directly internalize the climate costs of fossil-fuel extraction onto the producer. This in turn better aligns the incentives of producers with the public interest—to avoid damages from climate change—while ensuring that taxpayers receive fairer values for the use of public land.[92]

Royalties are typically set at a specific rate. For example, the Mineral Leasing Act of 1920 set the minimum federal onshore royalty rate at 12.5% of the value of the resource extracted.[93] Recently, BLM used a rate of 18.75%[94] following a recommendation from Interior.[95] Many states have rates that are significantly higher than the rate historically used by the federal government: California imposes a minimum royalty of 16.67% and Colorado imposes one of 20%.[96] But, in general, these minimum rates do not reflect the harms done by combusting fossil fuels and so are set too low. A recent study found that including a royalty rate surcharge, or adder, that reflects the SC-GHG could generate billions in additional revenue while reducing millions of tons of emissions.[97] The study concludes that an additional 36% adder would sufficiently capture climate damages, so a more socially optimal royalty rate would be nearly 50%.[98]

Interior has broad latitude under federal law to set royalty rates for federal lands.[99] This owes in large part to the Mineral Leasing Act's use of the term "fair market value," which allows Interior to consider a wide array of issues when setting royalty rates.[100] Interior's overall mandate and the Mineral Leasing Act's concern for the environmental impacts of natural resource extraction make it reasonable to read "fair market value" as including climate costs.[101]

States may have similar leeway in setting royalty rates. Consider the following examples of Colorado, Nevada, and New Mexico. Article IX of the Colorado State Constitution authorizes the State Land Board, which sets royalty rates, to manage lands in a manner that "preserve[s] long-term benefits and returns to the state," "maximize[s] options for continued stewardship, public use, or future disposition," and "protect[s] and enhance[s] the beauty, natural values, open space, and wildlife habitat."[102] Applying the SC-GHG arguably would allow the Colorado State Land Board to "preserve long-term benefits" to the state and "protect . . . natural values" by internalizing climate externalities, which could drive down fossil fuel development and concomitant environmental harms.

Fossil fuel leasing provisions in Nevada offer similarly broad discretion. The Nevada State Land Office must make leases in accordance with the statutory purpose of state lands: their use must be "in the best interest of the residents of this State" and give "primary consideration to the principles of multiple use and sustained yield as the status and the resources of the lands permit."[103] Because all residents of Nevada will be affected by climate change, it is arguably in their best interest to that oil and gas operations in their state properly account for climate damages.

And in New Mexico, the State Lands Trust Advisory Board, which supports the Commissioner of Public Lands, has a duty to "provide a continuity for resource management," "maximiz[e] the income from the trust assets," and "protect and maintain the assets and resources of the trust."[104] This duty may guide how the Commissioner exercises their discretion in setting royalty rates.

Reflecting climate costs in royalty rates can raise revenue in addition to addressing climate change and the overproduction of fossil fuels that contributes to it. States that have royalty rates below the social cost of natural resource extraction should consider how incorporating the SC-GHG can better align their oil and gas sector's operation with their climate goals.

4.3.3. Resource Compensation

Several states also use the SC-GHG to determine at what level a nonpolluting resource such as solar, wind, or nuclear should be compensated for the emissions it avoids when it generates electricity. State agencies in Maine, Maryland, and Minnesota have all used a form of the SC-GHG in "value of solar" studies that were commissioned to inform how rooftop solar owners should be compensated when they generate enough electricity to send some of it to the electric grid.[105] And in Illinois, New York, and New Jersey, state agencies use forms of the SC-GHG to inform the level of compensation to be paid to nuclear generators for "zero emissions credits" or ZECs—a proxy for the clean attribute of generating electricity without polluting.[106] Notably, the value of solar studies commissioned by state agencies do not themselves determine or effectuate compensation for distributed solar power; they are a policy planning tool. ZECs, by contrast, are purchased from nuclear generators for each megawatt hour they supply to the grid. The role of the SC-GHG in each is explained below, using examples from Maine and New York.

In 2015, the Maine Public Utilities Commission published the Maine Distributed Solar Valuation Study,[107] as directed by the state legislature.[108] That study included a methodology for determining the value of distributed solar energy generation in Maine and estimated the costs and benefits of a kilowatt-hour generated by distributed solar (see Figure 4-4). The study used a form of the SC-GHG to estimate the benefit of avoiding emissions that would be generated by emitting resources in the absence of solar.

Table 4-9. Components of Value of Distributed Solar in Maine ($/kilowatt-hour).[109]

First Year		Distributed Value ($/kWh)	
Energy Supply	Avoided Energy Cost	$0.061	Avoided Market Costs $0.090
	Avoided Gen. Capacity Cost	$0.015	
	Avoided Res. Gen. Capacity Cost	$0.002	
	Avoided NG Pipeline Cost		
	Solar Integration Cost	- $0.002	
Transmission Delivery	Avoided Trans. Capacity Cost	$0.014	
Distribution Delivery	Avoided Dist. Capacity Cost		
	Voltage Regulation		
Environmental	Net Social Cost of Carbon	$0.021	Societal Benefits $0.092
	Net Social Cost of SO_2	$0.051	
	Net Social Cost of NO_x	$0.011	
Other	Market Price Response	$0.009	
	Avoided Fuel Price Uncertainty	$0.000	
		$0.182	

Although the program subsequently adopted by the Maine Public Utility Commission did not incorporate avoided greenhouse gas emissions into compensation for distributed solar,[110] that program was informed by the value of solar study. The study was also influential beyond Maine, bolstering arguments made to utility commissions and legislatures not to reduce compensation paid for electricity from rooftop solar installations.[111]

New York's Clean Energy Standard, adopted by the state's Public Service Commission in 2016 in pursuit of the state's clean energy goals, established a program designed to compensate nuclear electricity generators for the clean attribute of the power they supply.[112] That program awards Zero Emission Credits (ZECs) to nuclear generators in return for their generation of emission-free electricity, and commits to purchasing a ZEC for each megawatt-hour of electricity supplied. The value of a ZEC is based in part on the social cost of carbon dioxide.[113] New York's program inspired other similar programs in Illinois and New Jersey.

4.4. SC-GHG in Environmental Impact Review

A wide range of actions, authorizations, and programs undertaken by government agencies trigger an obligation to conduct an environmental impact review. The SC-GHG can help agencies easily compare environmental benefits (and costs) of different proposed projects or programs in the environmental impact review process. Indeed, federal agencies have already used the SC-GHG to disclose the climate impacts of a variety of actions in the context of environmental review,[114] always noting that such data is provided for informational purposes only. State agencies have generally not done so, even when their environmental reviews have tallied the volume of greenhouse gas emissions attributable to a project. Minnesota, for instance, is currently conducting a pilot program to explore full incorporation of climate change considerations into environmental review under the Minnesota Environmental Policy Act, but even that pilot program does not involve monetizing estimated emissions arising from proposed projects.[115] States may benefit from examining how some federal agencies have incorporated SC-GHG into their NEPA analyses, in order to determine whether it may be a useful metric for them as well.

As an illustrative example, consider the environmental review of a proposed quarterly lease sale by the Bureau of Land Management (BLM).[116] That proposed sale covered resources located on federal lands in Wyoming. The tables below estimate the greenhouse gas emissions impacts of the sale.[117] The upper table is for the proposed action and the lower table is for an alternative proposal. Each table shows the social cost of emissions from the construction and operation of extraction facilities, as well as the social cost of the estimated end-use (downstream) emissions. The downstream emissions are calculated assuming all recoverable oil or gas is extracted and ultimately combusted. As shown in the figure below, BLM uses the full range of SC-GHG estimates in these tables, including the 95th percentile of the 3% discount rate value to capture high-impact, low-probability outcomes.

4-10. BLM Estimates of Emissions Impacts of Procurement Alternatives 2 and 3[118]

Alternative 2 (Proposed Action) SC-GHGs Associated with Future Potential Development

	Social Cost of GHG (2020$)			
	Average Value, 5% discount rate	Average Value, 3% discount rate	Average Value, 2.5% discount rate	95th Percentile Value, 3% discount rate
Development and Operations	$ 206,134,000	$ 751,671,000	$ 1,124,671,000	$ 2,203,904,000
End-Use	$ 632,572,000	$ 2,457,965,000	$ 3,744,259,000	$ 7,450,189,000
Total	$ 838,706,000	$ 3,209,636,000	$ 4,868,930,000	$ 9,654,093,000

Alternative 3 (Modified Proposed Action) SC-GHGs Associated with Future Potential Development

	Social Cost of GHG (2020$)			
	Average Value, 5% discount rate	Average Value, 3% discount rate	Average Value, 2.5% discount rate	95th Percentile Value, 3% discount rate
Development and Operations	$ 87,890,000	$ 320,493,000	$ 479,530,000	$ 939,687,000
End-Use	$ 269,712,000	$1,048,012,000	$ 1,596,453,000	$ 3,176,564,000
Total	$ 357,602,000	$ 1,368,505,000	$ 2,075,983,000	$ 4,116,251,000

Although this analysis did not determine whether BLM would move forward with the lease sales, its inclusion complied with NEPA's "hard look" requirement and demonstrated to the public the high cost imposed by resource extraction in this instance. Although this sort of use of the SC-GHG for NEPA compliance is still rare, a growing body of federal case law suggests that federal agencies should do so, as the SC-GHG values provide the best method for agencies to assess the climate change impacts of federal land-use actions.[119]

State regulators sometimes participate in NEPA reviews led by federal agencies and many states have "mini-NEPA" laws that impose similar environmental review requirements.[120] For example, the Massachusetts Environmental Policy Act requires state agencies to "determine the impact on the natural environment of all works, projects or activities" and use "all practicable means and measures to minimize damage to the environment."[121] Since 2013, the act's implementing regulations have expressly required agencies conducting an environmental impact review to consider "the reasonably foreseeable impacts of a project, including its additional [greenhouse gas] emissions, and effects, such as predicted sea level rise."[122] This makes it reasonable and, arguably, obligatory for Massachusetts agencies conducting an environmental impact review to incorporate the SC-GHG into their analyses. States may be able—or even obligated—to apply the SC-GHG to environmental impact reviews as a way to assess environmental effects of proposed actions that will increase or reduce greenhouse gas emissions.

1 The SC-GHG can inform the price level of a tax on greenhouse gas emissions. We do not discuss that application here, as this document focuses on the work of government agencies rather than legislatures.

2 Under Executive Order 12,866, rules considered to be "significant" must include a regulatory impact analysis that includes a cost-benefit analysis. Exec. Order 12,866 § 6(a)(3)(B), 58 Fed. Reg. 51735, 51740 (Sept. 30, 1993). The social cost of greenhouse gases protocol was designed for use in the cost-benefit analysis of any rules that had greenhouse gas effects. As the Working Group explains, the social cost metric "allow[s] agencies to understand the social benefits of reducing [greenhouse gas] emissions . . . , or the social cost of increasing such emissions, in the policy making process." Interagency Working Group on the Social Cost of Greenhouse Gases, Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide, Interim Estimates under Executive Order 13,990, at 2 (2021) [hereinafter "2021 TSD"].

3 In general, the SC-GHG goes up over time because greenhouse gases accumulate, exacerbating the effects of climate change—and therefore the harm from each additional unit of emissions—over time. Interagency Working Group on the Social Cost of Carbon, Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, at 28 (2010) [hereinafter "2010 TSD"], https://perma.cc/VTD5-VBL3.

4 Using a consistent discount rate for both the SC-GHG (assessed from the perspective of the actors in the year of emission) and the net present value calculation (assessed from the perspective of the decisionmaker) is important to ensure that the decisionmaker is treating emissions in each time frame similarly. The decisionmaker should not overvalue or undervalue emissions in the present as compared to emissions in the future. *See* Nat'l Acad. Scis., Eng'g & Med., Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update 1–2 (2016) [hereinafter "NAS 2016"], https://perma.cc/TJM6-XE65.

5 Steps 4 and 5 combined are equivalent to calculating the present value of the stream of future monetary values using the same discount rate as the SC-GHG discount rate.

6 For a thorough description of net present value calculations for agencies, complete with equations and explanations of rationales for particular elements of the calculation, see chapter 6 of EPA's Guidelines for Preparing Economic Analysis. U.S. EPA, Guidelines for Preparing Economic Analysis 6-1 to 6-20 (2010), https://www.epa.gov/sites/default/files/2017-09/documents/ee-0568-06.pdf. That chapter describes discounting using intragenerational, consumption-based discount rates, not discounting from a private point of view, nor discounting using over an intergenerational time horizon.

7 NAS 2016, *supra* note 4; Peter Howard & Jason A. Schwartz, *Valuing the Future: Legal and Economic Considertations for Updating Discount Rates*, 39 Yale J. Regul. (forthcoming 2022).

8 *See* Qingran Li & William A. Pizer, Resources for the Future Discounting for Public Benefit-Cost Analysis 1 (June 2021); EPA, Guidelines for Preparing Economic Analysis, *supra* note 6, at 6-1; Richard L. Revesz & Mathew R. Shahabian, *Climate Change and Future Generations*, 84 S. Cal. L. Rev. 1097 (2010-2011) (discussing reasons for and theoretical principles underlying the specification and use of discount rates).

9 EPA, Guidelines for Preparing Economic Analysis, *supra* note 6, at 6-16 to 6-17; Joseph Lowe, UK Treasury, Intergenerational Wealth Transfers and Social Discounting: Supplementary Green Book Guidance 4 (2008).

10 *See, e.g.*, Li & Pizer, *supra* note 8; Qingran Li & William Pizer, *The Discount Rate for Public Policy Over the Distant Future* (NBER Working Paper 25413, rev. Dec. 2019), http://www.nber.org/papers/w25413.

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12 *See, e.g.*, Petition of Clean Energy Parties, N.Y. Pub. Serv. Comm'n Case 15-E-0751 (Oct. 16, 2018). https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B4F3B7376-B7D3-4A8A-907E-52F0DD0C6C9B%7D (seeking calculation of avoided emissions that did not combine a capital-based discount rate and a form of the SC-GHG).

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14 Howard & Schwartz, *supra* note 7.

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21 Colo. Dep't of Transp., Cost-Benefit Analysis for Rules Governing Statewide Transportation Planning (Sept. 2021), https://www.codot.gov/business/rules/documents/cdot-cost-benefit-analysis-for-ghg-rule-sept-2021.pdf.

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23 *Id.* at 3–4.

24 *Id.* at 12–13.

25 6 NYCRR pt. 218 (2021), https://www.dec.ny.gov/docs/air_pdf/adopted218.pdf.

26 6 NYCRR pt. 203 (2021) https://www.dec.ny.gov/docs/air_pdf/adopted203.pdf.

27 6 NYCRR pt. 218, Regulatory Impact Statement Summary at 39.

28 6 NYCRR pt. 203, Regulatory Impact Statement Summary at 8.

29 In addition to applying the SC-CO_2 (and, arguably, SC-CH_4) when developing energy resource plans, Colorado utilities must apply those metrics when conducting cost-benefit analyses of beneficial electrification and demand-side management programs. Colo. Rev. Stat. § 40-3.2-107(1).

30 Colo. Pub. Utils. Comm'n, Decision No. C17-0316, In the Matter of the Application of Public Service Company of Colorado for Approval of its 2016 Electric Resource Plan (Mar. 23, 2017).

31 *Id.*

32 *Id.*

33 Colo. Rev. Stat. § 40-3.2-106(2).

34 Public Service Company of Colorado, Our Energy Future: Destination 2030 (2021).

35 *Id.* at 4.

36 *Id.* at 24.

37 U.S. EPA, *Sources of Greenhouse Gas Emissions*, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions (last visited Mar. 20, 2022).

38 U.S. Pipeline & Hazardous Materials Safety Admin., *Pipeline Miles and Facilities 2010+*, https://portal.phmsa.dot.gov/analytics/saw.dll?Portalpages&PortalPath=%2Fshared%2FPDM%20Public%20Website%2F_portal%2FPublic%20Reports&Page=Infrastructure (last visited Mar. 20, 2022).

39 Lucas W. Davis & Catherine Hausman, *Who Will Pay for Legacy Utility Costs?* (NBER Working Paper 28955 Mar. 2022).

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41 Order Establishing the Benefit Cost Analysis Framework, New York Pub. Serv. Comm'n Case No. 14-M-0101 (Jan. 21, 2016).

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43 *See, e.g.*, ConEdison, Gas Benefit Cost Analysis Handbook, at i (2020), http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B2CCB0D2A-183A-483B-9F56-87878E0471FA%7D ("The Gas Benefit-Cost Analysis (BCA) approach included herein is modeled on the [ConEd] Electric BCA Handbook, which was developed by [ConEd] in collaboration with the New York Joint Utilities to provide consistent and transparent statewide methodologies for electric non-wires solutions and other electric demand-side measures.").

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45 *Id.* at 121-122 .

46 *Id.* at 121 tbl 3-8.

47 *Id.* at 122 tbl. 3-9.

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50 *Id.* at 52 fig. 10.

51 *Id.*

52 Alejandro E. Camacho et al., *Mitigating Climate Change Through Transportation and Land Use Policy*, 49 Env't L. Rep. News & Analysis 10,473, 10,477 (2019) (emphasis added) (citations omitted).

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73 USPS FEIS, *supra* note 68, at 4-22 to 4-23.

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76 *Id.* at 4-23.

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78 U.S. EPA, *Fast Facts on Transportation Greenhouse Gas Emissions*, https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions (last visited Mar. 22, 2022).

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80 *Id.* § III(A)(2).

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92 Sarinksy et al., *supra* note 53, at 22.

93 *See* 30 U.S.C. § 226(b)(1)(A) (setting minimum royalty rate of 12.5 percent of onshore oil and gas revenues); *id.* § 207(a) (setting minimum royalty rate of 12.5 percent of surface coal revenues); 43 U.S.C. § 1337 (a)(1) (setting minimum royalty rate of 12.5 percent of offshore oil and gas revenues).

94 *See, e.g.*, Bureau of Land Mgmt., Environmental Assessment 2022 Second Quarter Competitive Lease Sale (DOI-BLM-WY-0000-2021-0003-EA) at 12 (Apr. 18, 2022).

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99 *Id.*

100 43 U.S.C. § 1344(a)(4) (offshore); *id.* § 1701(a)(9) (onshore). Federal statutes provide minimum royalty rates for extraction on public lands, but do not impose maximum rates. *See* 30 U.S.C. § 226(b)(1)(A) (setting minimum royalty rate of 12.5 percent of onshore oil and gas revenues); *id.* § 207(a) (setting minimum royalty rate of 12.5 percent of surface coal revenues); 43 U.S.C. § 1337 (a)(1) (setting minimum royalty rate of 12.5 percent of offshore oil and gas revenues).

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102 Colo. Const. Art. IX, § 10.

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104 N.M. Stat. Ann. § 19-1-1.4; *see also* N.M. Const. Art. XIII, § 2 (describing the duties of the Commissioner of Public Lands and granting power to Congress to further characterize the Commissioner's role).

105 To access these studies, see the Maine, Maryland, and Minnesota webpages of *The Cost of Climate Pollution*, costofcarbon.org/states/Maine, costofcarbon.org/states/Maryland, costofcarbon.org/states/Minnesota.

106 *See* Peter S. Ross, *Zero-Emission Credits and the Threat to Optimal State Incentives*, 39 Energy L.J. 427 (2018) (describing ZEC programs in each state).

107 Benjamin Norris et al., Maine Distributed Solar Valuation Study (2015) (prepared for Maine Public Utilities Commission), https://energynews.us/wp-content/uploads/2018/07/26.-C-MPUC_Value_of_Solar_Report_final-11216.pdf.

108 Me. Laws of 2013, Pub. L. ch. 562, codified at Me. Rev. Stat. tit. 35-A, §§ 3471–3473.

109 Norris et al., *supra* note 107, at 5.

110 *See* 65-407-313 Me. Code R. § 2 (net energy billing).

111 *See* ICF, Review of Recent Cost-Benefit Studies Related to Net Metering and Distributed Solar (2018) (prepared for U.S. Dep't of Energy) (discussing the Maine study's use of SC-GHG).

112 Order Adopting a Clean Energy Standard, N.Y. Pub. Serv. Comm'n Case 15-E-0302, at 45 (Aug. 1, 2016) ("The closure of upstate nuclear plants would have a tremendous negative impact on the State's ability to meet the greenhouse gas reduction goal in the State Energy Plan.").

113 The formula subtracts two values from the SC-GHG: the price assigned to carbon dioxide emissions by the Regional Greenhouse Gas Initiative and a further amount at times when wholesale electricity prices rise above a threshold amount. *Id.* at 51.

114 For a list of examples, see Inst. for Pol'y Integrity, *Federal Agencies Use of the Social Costs of Greenhouse Gases in NEPA Analysis*, Cost of Climate Pollution Project, https://costofcarbon.org/scc-use-under-nepa (last updated Apr. 5, 2021).

115 *See* Technical Memorandum from Barr Eng'g Co. Project Team to Denise Wilson, Env't Quality Rev. Bd. 4–5 (May 18, 2021) (estimating greenhouse gas emissions arising from hospital redevelopment project but not applying SC-GHG to estimate those emissions monetary value).

116 E.g., Bureau of Land Mgmt., Environmental Assessment 2022 First Quarter Wyoming Lease Sale EA (DOI-BLM-WY-0000-2021-0003-EA) at 36 (2021) [hereinafter "Wyoming Q1 2022 EA"]; Bureau of Ocean Energy Mgmt., Revised Draft Environmental Impact Statement for Cook Inlet Lease Sale 258 (BOEM 2020-063) (Oct. 2021).

117 Wyoming Q1 2022 EA, *supra* note 116, at 36 tbls. 3.21 & 3.22.

118 *Id.*

119 Sarinksy et al., *supra* note 53, at 4.

120 *See* White House Council on Env't Quality, *States and Local Jurisdictions with NEPA-like Environmental Planning Requirements*, https://ceq.doe.gov/laws-regulations/states.html (last visited Mar. 21, 2022) (listing "mini-NEPA" statutes and local laws for 20 jurisdictions).

121 Mass. Gen. Laws Ann. ch. 30, § 61.

122 301 Mass. Code Regs § 11.12(5)(a).

Appendix

SC-GHG Estimates (Annual, Unrounded)

The Interagency Working Group adopted social cost estimates for carbon dioxide, methane, and nitrous oxide in February 2021 that are identical to those adopted in 2016, adjusted for inflation from 2007 dollars to 2020 dollars. The tables on the pages below show the Working Group's unrounded estimates for each of those greenhouse gases.[1]

New York Department of Environmental Conservation (DEC) also published its own set of social cost values for use by New York State agencies, which include social cost estimates for carbon dioxide, methane, and nitrous oxide at 1% and 2% discount rates.[2]

In 2021, EPA released social cost of hydrofluorocarbons (HFCs) estimates in connection with its rule regulating this potent class of greenhouse gases. EPA derived these estimates using the Working Group's social cost methodology. These can be found beginning on page 111 of EPA's Regulatory Impact Analysis for Phasing Down Production and Consumption of Hydrofluorocarbons (HFCs).[3]

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1 Office of Mgmt. & Budget, Regulatory Matters, Social Cost of Greenhouse Gases (last visited Mar. 22, 2022), https://www.whitehouse.gov/omb/information-regulatory-affairs/regulatory-matters/#scghgs. This webpage also includes data files from the Working Group (Social Cost of Greenhouse Gases Complete Data Runs), which contains the simulated frequency distributions of the social cost for each.

2 *See* N.Y.S. Dept. of Env't Conservation., Establishing a Value of Carbon: Guidelines for Use by State Agencies at 34-37 (rev. May 2022), https://www.dec.ny.gov/docs/administration_pdf/vocguid22.pdf.

3 U.S. EPA, Regulatory Impact Analysis for Phasing Down Production and Consumption of Hydrofluorocarbons (HFCs) at 111–13 (Sept. 2021), https://www.epa.gov/system/files/documents/2021-09/ria-w-works-cited-for-docket.pdf.

Social Cost of Carbon
Climate Damages per Ton of Carbon Dioxide in 2020 USD

Year	5.0%	3.0%	2.5%	3% 95th Pct.
2020	14.476	51.082	76.421	151.608
2021	14.964	52.15	77.727	155.119
2022	15.453	53.219	79.033	158.629
2023	15.942	54.287	80.339	162.139
2024	16.431	55.355	81.645	165.65
2025	16.919	56.423	82.951	169.16
2026	17.408	57.491	84.257	172.67
2027	17.897	58.56	85.563	176.181
2028	18.386	59.628	86.869	179.691
2029	18.874	60.696	88.175	183.201
2030	19.363	61.764	89.481	186.712
2031	19.947	62.908	90.844	190.535
2032	20.53	64.052	92.207	194.359
2033	21.114	65.196	93.57	198.183
2034	21.697	66.34	94.934	202.006
2035	22.281	67.484	96.297	205.83
2036	22.864	68.628	97.66	209.654
2037	23.448	69.772	99.023	213.477
2038	24.031	70.916	100.387	217.301
2039	24.615	72.06	101.75	221.124
2040	25.199	73.204	103.113	224.948
2041	25.845	74.35	104.449	228.448
2042	26.491	75.496	105.785	231.947
2043	27.137	76.642	107.12	235.447
2044	27.783	77.788	108.456	238.947
2045	28.429	78.933	109.792	242.447
2046	29.076	80.079	111.128	245.946
2047	29.722	81.225	112.464	249.446
2048	30.368	82.371	113.799	252.946
2049	31.014	83.516	115.135	256.445
2050	31.66	84.662	116.471	259.945

Social Cost of Methane
Climate Damages per Ton of Methane in 2020 USD

Year	5.0%	3.0%	2.5%	3% 95th Pct.
2020	665.688	1485.078	1953.209	3906.371
2021	692.917	1532.015	2008.649	4034.779
2022	720.147	1578.952	2064.09	4163.187
2023	747.376	1625.89	2119.53	4291.595
2024	774.605	1672.827	2174.97	4420.003
2025	801.834	1719.764	2230.41	4548.41
2026	829.063	1766.701	2285.851	4676.818
2027	856.292	1813.639	2341.291	4805.226
2028	883.521	1860.576	2396.731	4933.634
2029	910.75	1907.513	2452.171	5062.042
2030	937.979	1954.45	2507.612	5190.45
2031	972.355	2009.824	2571.507	5344.225
2032	1006.731	2065.198	2635.403	5498.001
2033	1041.107	2120.572	2699.299	5651.776
2034	1075.483	2175.946	2763.195	5805.552
2035	1109.859	2231.32	2827.091	5959.327
2036	1144.235	2286.694	2890.986	6113.103
2037	1178.611	2342.068	2954.882	6266.878
2038	1212.987	2397.441	3018.778	6420.653
2039	1247.363	2452.815	3082.674	6574.429
2040	1281.739	2508.189	3146.569	6728.204
2041	1319.241	2564.102	3209.556	6872.909
2042	1356.743	2620.014	3272.542	7017.614
2043	1394.244	2675.927	3335.528	7162.319
2044	1431.746	2731.839	3398.515	7307.023
2045	1469.247	2787.751	3461.501	7451.728
2046	1506.749	2843.664	3524.487	7596.433
2047	1544.25	2899.576	3587.474	7741.138
2048	1581.752	2955.489	3650.46	7885.842
2049	1619.253	3011.401	3713.446	8030.547
2050	1656.755	3067.314	3776.432	8175.252

Social Cost of Nitrous Oxide
Climate Damages per Ton of Nitrous Oxide in 2020 USD

Year	5.0%	3.0%	2.5%	3% 95th Pct.
2020	5779.426	18405.298	27130.806	48255.974
2021	5981.4	18842.379	27687.532	49463.691
2022	6183.373	19279.46	28244.259	50671.409
2023	6385.347	19716.542	28800.985	51879.127
2024	6587.321	20153.623	29357.712	53086.844
2025	6789.294	20590.704	29914.439	54294.562
2026	6991.268	21027.785	30471.165	55502.279
2027	7193.242	21464.867	31027.892	56709.997
2028	7395.215	21901.948	31584.618	57917.715
2029	7597.189	22339.029	32141.345	59125.432
2030	7799.163	22776.11	32698.071	60333.15
2031	8046.879	23268.02	33309.463	61692.265
2032	8294.595	23759.929	33920.854	63051.381
2033	8542.311	24251.838	34532.245	64410.496
2034	8790.027	24743.748	35143.636	65769.611
2035	9037.743	25235.657	35755.028	67128.727
2036	9285.459	25727.567	36366.419	68487.842
2037	9533.175	26219.476	36977.81	69846.958
2038	9780.891	26711.385	37589.202	71206.073
2039	10028.607	27203.295	38200.593	72565.188
2040	10276.323	27695.204	38811.984	73924.304
2041	10566.545	28224.594	39456.17	75348.507
2042	10856.768	28753.983	40100.356	76772.71
2043	11146.991	29283.373	40744.542	78196.914
2044	11437.213	29812.763	41388.727	79621.117
2045	11727.436	30342.152	42032.913	81045.32
2046	12017.659	30871.542	42677.099	82469.524
2047	12307.881	31400.932	43321.285	83893.727
2048	12598.104	31930.321	43965.471	85317.93
2049	12888.327	32459.711	44609.656	86742.134
2050	13178.549	32989.101	45253.842	88166.337

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