STATE OF MICHIGAN
MICHIGAN PUBLIC SERVICE COMMISSION

In the matter, on the Commission’s own motion, to commence a collaborative to consider issues related to implementation of effective new technologies and business models	)))))))))	Case No. U-20898

COMMENTS SUBMITTED BY THE INSTITUTE FOR POLICY INTEGRITY AT NYU SCHOOL OF LAW

June 23, 2023

I. Introduction

Policy Integrity is a nonpartisan think tank dedicated to improving the quality of government decisionmaking through advocacy and scholarship in the fields of administrative law, economics, and public policy. Policy Integrity has extensive experience advising stakeholders and government decisionmakers on the rational, balanced use of economic analysis, both in federal practice and at the state level. Policy Integrity advocates for sound cost-benefit analysis at every level of government and argues for an unbiased approach to measuring the costs and benefits of environmental, public health, and safety policy. Policy Integrity has previously filed public comments and written reports and articles on issues pertaining to economic analysis of grid modernization and distributed energy resources. Policy Integrity seeks to apply its economic, legal, and policy expertise to help advise the Michigan Public Service Commission (the Commission) on how to ensure that the societal cost test adopted to evaluate potential electric utility pilot projects reflects the best available economic analysis.

In October 2019, the Commission established the MI Power Grid Initiative, "a focused, multi-year stakeholder initiative to maximize the benefits of the transition to clean, distributed energy resources (DERs) for Michigan residents and businesses,"[1] with the stated expectation that one of its areas of focus would be "[n]ew technologies and business models, including preparing for the opportunities and challenges associated with the commercialization of new technologies and business models such as electric vehicles, electric storage, and other technologies still under development, both at customer and utility scale."[2] A year later, in October 2020, the New Technologies and Business Models stakeholder group was officially

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[1] MPSC Case No. U-20898, *In the matter, on the Commission's Own Motion, to Commence a Collaborative to Consider Issues Related to Implementation of Effective New Technologies and Business Models*, Order (Oct. 29, 2020) [hereinafter October Order] at 1.
[2] *See Id.* at 2.

launched in furtherance of this effort.[3] On February 1, 2023, as directed in the Commission's Order dated August 23, 2022 (the August Order),[4] DTE Electric Company (DTE) and Consumers Energy (DTE and Consumers Energy, collectively, the Companies) filed in the New Technologies and Business Models docket a proposal (such proposal, the Proposal)[5] for a benefit-cost analysis (BCA) framework for use in evaluating prospective pilot programs. Policy Integrity submits these comments pursuant to the Commission's April 24, 2023 Order (the April Order)[6] inviting the stakeholder community to comment on the Proposal.

As directed by the Commission, the Proposal for a BCA framework is for a jurisdiction-specific test (JST) based on a societal cost test. However, the proposed JST is unlikely to yield a clear understanding of the net benefits associated with proposed pilots in the context of Michigan's regulatory structure and priorities. Policy Integrity recommends several revisions, which will allow any BCA to arrive at more useful figures, better align the BCA methodology with Michigan's regulatory structure and requirements, and more closely follow the recommendations of the National Standard Practice Manual for Benefit-Cost Analysis of Distributed Energy Resources (NSPM) as contemplated in the August Order[7] and an earlier Order filed July 27, 2022 (the July Order).[8] This comment opens with some broad

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[3] *See Id.*, at 2.

[4] MPSC Case No. U-20898, *In the matter, on the Commission's Own Motion, to Commence a Collaborative to Consider Issues Related to Implementation of Effective New Technologies and Business Models*, Order (Aug. 23, 2022) [hereinafter August Order].

[5] MPSC Case No. U-20898, *In the matter, on the Commission's Own Motion, to Commence a Collaborative to Consider Issues Related to Implementation of Effective New Technologies and Business Models,* Proposed Requirements and Further Guidance on Benefit-Cost Analyses for Pilot Initiatives Prepared by DTE Electric Company and Consumers Energy Company (Feb. 1, 2023) [hereinafter Proposal].

[6] MPSC Case No. U-20898, *In the matter, on the Commission's Own Motion, to Commence a Collaborative to Consider Issues Related to Implementation of Effective New Technologies and Business Models*, Order (Apr. 24, 2023) [hereinafter April Order].

[7] *See* August Order at 4.

[8] *See* MPSC Case No. U-20898, *In the matter, on the Commission's Own Motion, to Commence a Collaborative to Consider Issues Related to Implementation of Effective New Technologies and Business Models*, Order (Jul. 27, 2022) [hereinafter July Order].

recommendations that transcend the individual questions posed in the April Order, and then responds to several of the questions (specifically, questions 1-4 and 6).

In summary, these comments recommend that the Commission require: (1) that the JST ultimately adopted articulate Michigan's decarbonization policy goal with greater specificity; (2) the addition of certain elements that will be needed to meaningfully prioritize equity or environmental justice; (3) that the JST recognize the materiality of non-greenhouse gas emissions; (4) that all costs and benefits, especially emissions impacts, be assessed against a clearly articulated baseline; (5) that the JST must account for emissions other than those that are the product of combustion; (6) that the ultimate JST methodology should specify that net benefits are to be maximized; (7) that the JST should require that, wherever possible, impacts be at a minimum quantified and if at all possible monetized; (8) that the JST should require the monetization of greenhouse gas emissions based on the Social Cost of Greenhouse Gases; (9) that the JST require the use of a discount rate that is appropriate for costs and benefits that will accrue to future generations, which is typically lower than a utility's weighted average cost of capital; and (10) that the JST incorporate a defensible methodology for evaluating greenhouse gas emissions associated with natural gas usage where applicable, including where pilot program impacts include increased or decreased use of natural gas-fired electric generation.

In addition, these comments append several relevant Policy Integrity publications, as follows:

<u>Attachment 1.</u> *Valuing Pollution Reductions: How to Monetize Greenhouse Gas and Local Air Pollutant Reductions from Distributed Energy Resources* (2018);[9]

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[9] Jeffrey Shrader et al., Inst. for Pol'y Integrity, *Valuing Pollution Reductions* (2018), https://policyintegrity.org/files/publications/valuing_pollution_reductions2.pdf.

Attachment 2. *Getting the Value of Distributed Energy Resources Right: Using a Societal Value Stack* (2019);[10]

Attachment 3. *Making the Most of Distributed Energy Resources: Subregional Estimates of the Environmental Value of Distributed Energy Resources in the United States* (2020).[11]

Attachment 4. *Making Regulations Fair: How Cost-Benefit Analysis Can Promote Equity and Advance Environmental Justice* (2021).[12]

Attachment 5. *The Social Cost of Greenhouse Gases: A Guide for State Officials* (2022).[13]

II. Responses to Questions

Question 1: *Are there necessary elements that are missing from the BCA proposal? Are there additional impact categories, such as environmental and health effects or equity considerations, which should be considered? If other impacts should be included, how should they be included (monetized, quantitative, or qualitative)?*

A. The decarbonization policy goals should be articulated with greater specificity.

Though the Companies enumerate "decarbonization" as one of the relevant policy goals and objectives,[14] a more precise statement of the decarbonization policy goal would provide a foundation for a stronger the BCA framework. Governor Whitmer's MI Healthy Climate Plan

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[10] Justin Gundlach & Burcin Unel, Inst. for Pol'y Integrity, *Getting the Value of Distributed Energy Resources Right* (2019), https://policyintegrity.org/files/publications/Getting_the_Value_of_Distributed_Energy_Resources_Right.pdf.

[11] 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.

[12] Jack Lienke, et al., Inst. for Pol'y Integrity, *Making Regulations Fair* (2021), https://policyintegrity.org/files/publications/Making_Regulations_Fair_Report_vF_%281%29.pdf.

[13] Justin Gundlach & Iliana Paul, Inst. For Pol'y Integrity, *The Social Cost of Greenhouse Gases: A Guide for State Officials* (2022), https://policyintegrity.org/files/publications/The_Social_Cost_of_Greenhouse_Gases-A_Guide_for_State_Officials_vF.pdf.

[14] Jack Lienke, et al., Inst. for Pol'y Integrity, *supra* note 12.

seeks economy-wide greenhouse gas emissions reductions of 28% by 2025, 52% by 2030, and economy-wide carbon neutrality by 2050.[15] The specificity of the timeline, the scale of the emissions reductions required, and the fact that the stated reductions refer to economy-wide emissions (rather than, e.g., solely emissions from electric generation) are all relevant to the design of a JST. Measures that would move Michigan closer to achieving these goals, or would hinder achievement of these goals, should be readily discernible based on benefit-cost analysis conducted in accordance with the JST.

B. Additional elements will be needed to meaningfully prioritize equity or environmental justice.

The Proposal includes equity and environmental justice in its list of "policy goals and objectives… relevant to Michigan utility pilots."[16] The actual methodology spelled out in the Proposal, however, does not clearly provide for utilities to incorporate equity or environmental justice into its analysis.[17] For example, the fact that environmental justice is a policy goal means that the BCA must consider not just overall public-health impacts, but *who* experiences them,[18] yet there is no requirement that any such analysis be performed. The need to be on the lookout for – and to attempt to rectify – potential distributional inequities is not limited to public health; committing to equity means being attentive to disparate impacts wherever they arise. Policy

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[15] Michigan Department of Environment, Great Lakes, and Energy, *MI Healthy Climate Plan* (Apr. 2021), https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Offices/OCE/MI-Healthy-Climate-Plan.pdf?rev=d13f4adc2b1d45909bd708cafccbfffa&hash=99437BF2709B9B3471D16FC1EC692588 [hereinafter MI Healthy Climate Plan] at 4.

[16] Proposal at 18.

[17] At least one Commission Order in the proceeding suggests that the decisionmaking based on the BCA would take at least some aspects of equity into account; for example, it appears that pilots aimed at improving low-income access to affordable energy may be permitted to proceed despite apparently negative net benefits at scale. MPSC Case No. U-20898, *In the matter, on the Commission's Own Motion, to Commence a Collaborative to Consider Issues Related to Implementation of Effective New Technologies and Business Models*, Order (Feb. 23, 2023) at 13-14. However, the proposed JST itself lacks mechanisms for assessing equities and inequities in outcomes.

[18] *See, e.g.*, American Lung Association, *Disparities in the Impact of Air Pollution*, https://perma.cc/EZZ9-2EWG.

Integrity's report, *Making Regulations Fair*, provides actionable guidance on incorporating distributional analysis into benefit-cost analysis.[19]

C. Non-Greenhouse Gas emissions are likely material, and should be at a minimum quantified and preferably monetized.

The Proposal would have the JST omit any consideration of emissions other than greenhouse gas emissions.[20] The NSPM places other air emissions in the "other environmental" category,[21] which the Proposal has deemed not material.[22] The Proposal does not include evidence for its assertions that various types of impacts are "not material." In the case of air emissions other than greenhouse gas emissions, this omission is doubly concerning as such emissions can have a significant impact *and* that impact can fall disproportionately on certain communities that also face other burdens – making these impacts relevant to the stated policy priority of environmental justice.

Reductions in local pollutants such as sulfur dioxide, nitrogen oxides, and fine particulate matter provide external health benefits such as reduced morbidity and reduced risk of premature mortality.[23] The Companies should, therefore, either include non-greenhouse gas emissions in the JST, or provide evidence of their purported non-materiality for all possible pilot programs. Based on the basic orientation of this proceeding – an exploration of "[n]ew technologies and business models, including preparing for the opportunities and challenges associated with the commercialization of new technologies and business models such as electric vehicles, electric storage, and other technologies still under development, both at customer and

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[19] S*ee* Jack Lienke, et al., Inst. for Pol'y Integrity, *supra* note 12.
[20] Proposal at 25.
[21] Proposal at 25.
[22] Proposal at 33.
[23] Nicholas Z. Muller et. al., *Measuring the damages of air pollution in the US*, 54 J. OF ENVTL. ECON. AND MGMT. 1, 8-13 (2007); Dallas Burtraw et al., *Costs and Benefits of Reducing Air Pollutants Related to Acid Rain*, 16 CONTEMP. ECON. POL'Y 379, 397-399 (1998).

utility scale"[24] in conjunction with "a focused, multi-year stakeholder initiative to maximize the benefits of the transition to clean, distributed energy resources (DERs) for Michigan residents and businesses,"[25] – it is inconceivable that a well formulated portfolio of pilot programs would include none with a material impact on non-greenhouse gas emissions.[26] Because there is ample reason to expect that foreseeable pilots *may* have material non-greenhouse gas emissions impacts, either across the board or in particular communities, the Commission should consider requiring the Companies to use the tools and methodology described in Policy Integrity's 2018 report, *Valuing Pollution Reductions*, to quantify the local air pollution created or avoided by pilot programs.[27]

Furthermore, non-greenhouse gas emissions can and should be not only quantified but also monetized. Utilities can approximate the damages caused by their emission of local pollutants using any one of several existing models, including: Estimating Air Pollution Social Impact Using Regression (EASIUR), BenMap, Air Pollution Emission Experiments and Policy Analysis Model, and Co-Benefits Risk Assessment (COBRA). Details on model characteristics and required inputs can be found in our report, *Valuing Pollution Reductions*.[28] DTE has demonstrated its awareness of the feasibility of monetizing public-health impacts associated with air emissions in testimony filed as part of its Integrated Resource Plan proceeding in 2022.[29] As that testimony described, DTE used COBRA to "explore how changes in air pollution can affect

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[24] *See* October Order at 2.
[25] October Order at 1.
[26] For an examination of the wide range of system and societal values that distributed energy resources may provide, *see* Justin Gundlach & Burcin Unel, Inst. for Pol'y Integrity, *supra* note 10 (especially Figure 8 at 30, which illustrates the likely significance of avoided local air emissions relative to other benefits, depending on the location and time at which they accrue).
[27] Jeffrey Shrader et al., *supra* note 9.
[28] *Id*.
[29] *See* MPSC Case No. U-21193, *In the matter of the Application of DTE Electric Company for approval of its Integrated Resource Plan pursuant to MCL 460.6t, and for other relief*, Testimony of B. J. Marietta (Nov. 3, 2021) at BJM-35.

human health and estimate the economic impact that effect on human health may have."[30] The JST methodology that is ultimately adopted should require monetization of air emissions, and should provide a compelling reasons for each instance where an impact that is susceptible to being monetized is not to be monetized.

D. All costs and benefits, especially emissions impacts, need to be assessed against a clearly articulated baseline.

The Proposal recognizes greenhouse gas emissions as potentially among the impacts that may be associated with various pilots, and defines "Greenhouse Gas Emissions" as "GHG [greenhouse gas] emissions created by fossil-fueled energy resources."[31] In practice, piloted policies or technologies could result in *either higher or lower* overall emissions of greenhouse gases or other air pollution than would have resulted absent the adoption of new technologies or practices, and a change in either direction needs to be cognizable by the JST. In the event that the change is a *decrease* relative to the baseline – that is, avoided emissions – the JST must be capable of recognizing that such a change is as a benefit rather than a cost.

While it is of course possible to put the emissions impact on either side of the ledger – with negative costs being equivalent to benefits – the magnitude and direction of any change cannot be established without a clearly articulated baseline that reasonably represents the world absent the thing that is to be piloted. The NSPM allows for categorization of emissions as either a benefit or a cost,[32] depending on the context and whether the program or policy in question results in an increase or decrease in emissions; indeed the "Ensure Symmetry" principle, one of

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[30] *Id.*

[31] Proposal at 25.

[32] *See generally* Tim Woolf, et al., *National Standard Practice Manual For Benefit-Cost Analysis of Distributed Energy Resources* (Julie Michals & Tim Woolf eds., 2020), https://www.nationalenergyscreeningproject.org/wp-content/uploads/2020/08/NSPM-DERs_08-24-2020.pdf [hereinafter NSPM].

the eight NSPM BCA Principles delineated in the NSPM, cautions that "[a]symmetrical treatment of benefits and costs associated with a resource can lead to a biased assessment of the resource. To avoid such bias, benefits and costs should be treated symmetrically for any given type of impact."[33]

The Commission should require the Companies to recognize emissions impacts in a way that accurately captures proposed pilot programs' impact. For example, if a pilot concerns a technology or practice (such as distributed photovoltaics (PV)) that would ultimately have the result of substituting for other electric generation (such as utility-scale natural gas turbines), with the result that future electric system emissions would be lower after the piloted technology scales up than they would have been without that technology, the benefit-cost analysis should be capable of identifying the resulting reductions in emissions in the future that includes a lot of new PV based on the pilot compared to a counterfactual future baseline that does not include that new PV. Further – given that there is considerable diversity in the pollution characteristics of fossil-fueled generators – the analysis would ideally recognize avoided emissions based on some understanding of *which* fossil-fueled power plants would be dispatched less thanks to the new practices that are being piloted. For a helpful explanation of the role of marginal generators and marginal emissions in determining the emissions avoidance value of distributed energy resources, see Policy Integrity's report, *Making the Most of Distributed Energy Resources: Subregional Estimates of the Environmental Value of Distributed Energy Resources in the United States* (2020).[34]

Moreover, the framework ultimately adopted should make it clear that whenever a prospective pilot is evaluated using the JST, the emissions baseline must be established in a

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[33] *Id.* at iv.
[34] *See generally* Matt Butner et al., Inst. for Pol'y Integrity, *supra* note 11.

manner that is adequate to assess the impact of the piloted technology or practices. For example, in a prospective pilot that might affect the total amount of electricity that is generated through natural gas combustion, such a pilot should include emissions associated with the natural gas system that occur upstream of the electric generator, whether at the point of extraction or at a later point in the process, in both its baseline and its projected changes to baseline. Moreover, in the case of a prospective pilot involving electrification – that is, the substitution of electric energy for some other fuel used by end users, such as gasoline in cars or, for example, home heating oil[35] – it is essential that the baseline include emissions that are currently associated with the activity that is to be electrified; otherwise, the emissions reductions available from, for example, reduced gasoline or heating oil combustion would not be cognizable. Given that Michigan's decarbonization and environmental justice goals have been formulated on an economy-wide basis,[36] an electrification pilot's contributions to achieving either of these goals cannot be assessed without considering both decreased emissions from end-use combustion of fuel *and* increased emissions from increased electric generation, if applicable.

E. The JST must account for emissions other than those that are the product of combustion.

The Proposal states that the test will consider "GHG [greenhouse gas] emissions created by fossil-fueled energy resources."[37] This phrase is ambiguous; it is not self-evident what counts as a "fossil-fueled energy resource" and what it means for such a resource to "create" greenhouse gas emissions. Presumably, carbon dioxide emissions resulting from the combustion of natural

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[35] The MI Healthy Climate Plan contemplates electrification of transportation and building heating. *See* MI Healthy Climate Plan at 37-43.

[36] The MI Healthy Climate Plan specifically notes, in its discussion of environmental justice and the need to remedy historic injustices, the disproportionate impacts of emissions associated with electric generation, transportation, and other forms of fossil fuel consumption on many of Michigan's most disadvantaged communities. *See* MI Healthy Climate Plan at 16-17.

[37] Proposal at 25.

gas for electric generation would fall squarely within this phrase. However, other greenhouse gas emissions that are also attributable to the electric utility's activities may not. An example of a type of greenhouse gas emissions that might not considered to be "created by fossil-fueled energy resources," but is in fact *caused* by how Michigan utilities provide their customers with electric service, would be the methane emissions that occur upstream of gas-fired electric generators that are dispatched to provide power to customers. These emissions can be highly relevant to the electric system's impact on economy-wide emissions, and their magnitude may affected by technologies and practices that might reasonably be piloted. A comprehensive account of a pilot program's environmental impact that is well integrated with the jurisdiction's policy priorities must therefore take such emissions into account.

F. The ultimate JST methodology should specify that net benefits are to be maximized.

The Proposal provides a template for reporting BCA results that includes both net benefit and benefit-cost ratio.[38] The Commission should clearly state that decisions about which pilots to pursue should be based on a net present value of benefits and costs rather than a benefit-cost ratio. This is a fundamental, welfare-maximizing principle. In a resource-constrained context, where a choice is required among mutually exclusive alternatives, a ratio-based technique cannot help decisionmakers select the option that will deliver the most net benefits to society, especially when the scales of the projects are different. To take a very simplified example, spending $1 to get $10 in benefits has a much higher benefit-to-cost ratio (10:1) than spending $1 million to get $3 million in benefits (which would have a benefit-to-cost ratio of 3:1); yet from the perspective of net benefits, the $2 million netted by the second project is clearly a much better deal than the

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[38] Proposal at 41.

$9 total offered by the first alternative. A ratio-based decision process could mask scale differences, leading to misleading results. The ability to identify the pilots that offer the greatest net benefits is especially important given Michigan's ambitious climate goals. Achieving net-zero will require significant changes to the energy system that serves the state, including within the electric system as well as switching among fuels, and the benefits of such large changes will be more fully captured using net benefits, not a benefit-to-cost ratio.

Question 2: *The BCA proposal recommends three potential treatments for different impacts: monetized, quantitative, and qualitative. Are the proposed treatments for each impact appropriate? How can qualitative impacts be incorporated into a BCA?*

Monetizing an impact ensures that that impact will be treated on par with the other costs and benefits of a pilot. When all costs and benefits are translated into the common metric of money, the tradeoffs inherent in policy choices become apparent, and decisionmakers can more readily and more transparently compare society's preferences for competing priorities. Monetization of as many potential effects as possible therefore minimizes the risk that a decision will lean too heavily on any one factor or succumb to unintended and unknown biases. For this reason, NSPM guidelines strongly favor monetization.[39] The proposal's language suggests that the Companies have not monetized as aggressively as the NSPM contemplates,[40] a failure to hew to the NSPM's recommendations that threatens to undermine the usefulness of the JST for identifying the best pilot programs.

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[39] NSPM at x (stating that impacts should "ideally be estimated in monetary terms . . . [to] provide a uniform way to compile, present, and compare benefits and costs").

[40] *Compare* Proposal at 23 ("Impacts that are difficult to monetize should be reported through other quantitative metrics") *with* NSPM at 13 (stating that impacts should "ideally be estimated in monetary terms . . . [to] provide a uniform way to compile, present, and compare benefits and costs") *and* NSPM at x (stating that "approximating hard-to-quantify impacts [in monetary terms] using best available information is preferable to arbitrarily assuming a value, including an assumption that the relevant impacts do not exist or have no value").

The Companies' choices about which factors to monetize require explanation. Especially puzzling is the proposal not to require monetization of greenhouse gas emissions.[41] The proposal identifies decarbonization as one of the six overarching policy goals of the JST.[42] A pilot that fails to recognize the monetary value of greenhouse gas emissions will be less likely to assess the significance of emissions increases or decreases accurately, or at all. And although the decision not to monetize greenhouse gas emissions might be justified if meaningful and consistent monetization were impossible, this is far from the case. The Companies' awareness that greenhouse gas emissions can in fact be monetized is illustrated by the Proposal's indication that "a pilot may choose to monetize" greenhouse gas emissions.[43]

A widely accepted way to monetize greenhouse gas emissions exists, and the JST that is ultimately adopted should require its use. The Social Cost of Greenhouse gases (SC-GHG) is a metric designed to quantify and monetize climate damages, representing the net economic cost of greenhouse gas emissions. In other words, the SC-GHG is a monetary estimate of the damage done by each ton of greenhouse gas (e.g., carbon dioxide or methane) that is released into the air. The SC-GHG is the product of extensive and ongoing work by the federal Interagency Working Group on the Social Cost of Greenhouse Gases, and its predecessor, the Interagency Working Group on the Social Cost of Carbon (either as applicable from time to time, the Working Group). The Working Group developed these estimates, and have periodically updated them, through a rigorous and transparent process incorporating the best science available at the time.[44] These values are widely agreed to underestimate the full social costs of greenhouse gas emissions,[45]

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[41] Proposal at 14 n. 23 (labeling greenhouse gas emissions as a "quantified but not monetized impact" that a pilot "may choose to monetize").
[42] Proposal at 18-19.
[43] Proposal at 14 n. 23.
[44] *See* Justin Gundlach & Iliana Paul, Inst. for Pol'y Integrity, *supra* note 13 at 1-1 – 1-3.
[45] *See generally* INTERAGENCY WORKING GROUP ON THE SOCIAL COST OF GREENHOUSE GASES, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON, METHANE, AND NITROUS OXIDE – INTERIM ESTIMATES UNDER

and may be formally updated in the near future.[46] For now, however, they remain appropriate to use as lower bound estimates, as they have been applied in dozens of previous rulemakings,[47] upheld in federal court,[48] and endorsed as the best available estimates by scores of economists and climate-policy experts.[49] Given that the types of pilots contemplated in this proceeding can be reasonably expected to avoid greenhouse gas emissions, the Proposal, by failing to require that such emissions reductions be monetized, risks undervaluing pilot programs' potential contributions to Michigan's achievement of its policy objectives and the wellbeing of its citizens, and failing to identify proposed pilot programs that would have large net benefits.

To estimate the value of greenhouse gas emissions produced or avoided by a pilot, the relevant Company should first quantify the emissions that it would produce or avoid.[50] Once that

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EXECUTIVE ORDER 13,990, at 4 (2021); Richard L. Revesz et al., *Global Warming: Improve Economic Models of Climate Change*, 508 NATURE 173 (2014) (note that co-author Kenneth Arrow was a Nobel-Prize winning economist).

[46] Though the Working Group's valuations relied on the best science available at the time of their initial development in 2010, their underlying data is now largely outdated and their valuations are widely recognized to understate the true costs of climate change. Recognizing this problem, in November 2022, EPA released updated draft climate-damage estimates. EPA's draft valuations faithfully apply recent advances in the science and economics on the costs of climate change and implement the roadmap laid out in 2017 by the National Academies of Sciences for updating the social cost of greenhouse gases. Those estimates were subject to public comment and are currently undergoing peer review. *See* EPA External Review Draft of Report on the Social Cost of Greenhouse Gases (Sept. 2022) (Docket No. EPA-HQ-OAR-2021-0317) ("Draft SC-GHG Update"); Nat'l Acads. Sci., Engineering & Med., Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide (2017).

[47] Peter Howard & Jason A. Schwartz, *Think Global: International Reciprocity as Justification for a Global Social Cost of Carbon*, 42 COLUM. J. ENV'T L. 203, 270–84 (2017) (listing all uses through mid-2016).

[48] *Zero Zone v. Dep't of Energy*, 832 F.3d 654, 679 (7th Cir. 2016).

[49] *See, e.g.*, Richard L. Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 SCIENCE 655 (2017), https://policyintegrity.org/files/publications/Science_SCC_Letter.pdf; Michael Greenstone et al., *Developing a Social Cost of Carbon for U.S. Regulatory Analysis*: A Methodology and Interpretation, 7 REV. ENVTL. ECON. & POL'Y 23, 42 (2013); Richard L. Revesz et al.,*Global Warming: Improve Economic Models of Climate Change*, 508 NATURE 173 (2014), https://policyintegrity.org/files/publications/Nature_SCC.pdf (co-authored with Nobel Laureate Kenneth Arrow, among others); NAT'L HIGHWAY TRAFFIC SAFETY ADMIN. FINAL REGULATORY IMPACT STATEMENT: THE SAFER AFFORDABLE FUEL-EFFICIENT (SAFE) VEHICLES RULE FOR MODEL YEAR 2021–2026 PASSENGER CARS AND LIGHT TRUCKS (Mar. 2020); Decl. of Michael Hanemann ¶17, *Wyoming v. Interior*, No. 16-00285 (D. Wyo. Dec. 14, 2016), https://perma.cc/LG2M-MVN9 (stating that estimates prepared by the Working Group for the cost of methane are "the best available estimate of the environmental cost of an additional unit of methane emissions.").

[50] *See, e.g.*, Natalie Mims, Tom Eckman & Charles Goldman, *Time-Varying Value of Electric Energy Efficiency*, at ix fig. ES-1, 32–36 (2017) (quantifying value of carbon dioxide emissions reduction available from different forms of EE across different regions).

quantification is done, that Company can apply the federally developed social cost of greenhouse gases to determine the avoided emissions' monetary value. Using the social cost of greenhouse gases requires only basic arithmetic once decisionmakers specify several parameters applying the metric.[51] For more guidance on state-level policymaking using SC-GHG, see our report, *The Social Cost of Greenhouse Gasses: A Guide for State Officials*.[52]

Though greenhouse gas emissions represent the Proposal's most striking failure to monetize something that is susceptible to being monetized, there are other such failures. For example, although (as discussed above) the Proposal would omit non-greenhouse gas emissions based on the unsupported claim that their impact would be non-material, the Companies have nonetheless proposed to *include* "public health" (presumably, public health impacts unrelated to air emissions – an oddly truncated conception of public health) as a qualitative factor. The Companies have not stated what sorts of public health impacts they envision are possible other than public health impacts caused by non-greenhouse gas emissions. In any case, however, public health impacts certainly can and should be monetized in benefit-cost analysis;[53] indeed, the feasibility of monetizing public health impacts is foundational to monetizing the public health impacts of air emissions. The JST that is ultimately adopted should require the monetization of all public health impacts.

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[51] One parameter is the applicable year, as the social cost of greenhouse gases increases every year. Another is the appropriate estimate; there are four sets of estimates, three based on different discount rates and one reflective of a low probability catastrophic risk scenario. *See* Iliana Paul, Peter Howard, & Jason A. Schwartz, Inst. For Pol'y Integrity, *The Social Cost of Greenhouse Gases and State Policy* (2017), https://policyintegrity.org/files/publications/SCC_State_Guidance.pdf.

[52] *See generally* Justin Gundlach & Iliana Paul, *supra* note 13.

[53] *See, e.g.*, United States Environmental Protection Agency, *Mortality Risk Valuation*, https://www.epa.gov/environmental-economics/mortality-risk-valuation; United States Environmental Protection Agency, *Guidelines for Preparing Economic Analyses*, https://www.epa.gov/environmental-economics/guidelines-preparing-economic-analyses (especially Chapter 7 (Analyzing Benefits) and Appendix B (Morality Risk Valuation Estimates)).

<u>Question 3:</u> *The BCA proposal includes an assumed discount rate of the after-tax WACC. Is this an appropriate discount rate?*

In economics, a discount rate translates impacts that occur at different times into a common present value. Because individuals have a positive time preference – meaning we value present welfare over future welfare – a discount rate reduces the value of future impacts. While after-tax WACC may be an appropriate discount rate for benefits and costs which affect private capital investment decisions,[54] it may be inappropriate for estimating all future costs and benefits. Specifically, when accounting for costs and benefits that will accrue to future generations, it is appropriate to use lower discount rates because (1) the utility's weighted average cost of capital should not dictate how society treats future generations, and (2) market-based discount rates become increasingly uncertain further in time. Such a lower discount rate would be more appropriate than WACC for discounting, for example, the value of avoidable greenhouse gas emissions or other emissions that may cause harm to future generations, such as mercury pollution.

The Commission "directed that the proposed BCA requirements should be informed by the provisions of the [NSPM]."[55] The Companies noted that "The NSPM recognizes certain unresolved issues involving utility BCA, including the role of discount rates for the estimation of present value impacts."[56] They go on to recommend "the continued use of a post-tax weighted average cost of capital factor (post-tax WACC) for the discounting of costs and monetary

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[54] *See* Peter Howard & Jason A. Schwartz, *Valuing the Future: Legal and Economic Considerations for Updating Discount Rates*, 39 YALE J. ON REG. 595, 603 (2022) ("[d]iscounting all costs and benefits at the capital-based rate would be most theoretically appropriate only when all costs and benefits primarily affect private capital investment decisions").

[55] April Order at 2.

[56] Proposal at 11.

benefits,"[57] noting that it is consistent with BCA performed by the Companies for other areas of utility investments and programs."[58]

Although utilities may have historically used post-tax WACC, the NSPM and other resources note that the choice of discount rate depends on policy-relevant circumstances. The NSPM, for example, suggests using the discount rate that comports with the "regulatory perspective"; if the "regulatory perspective" suggests the same time preference as that of society, then the societal discount rate is appropriate.[59] Because the Commission has directed utilities to propose a BCA which specifically includes a societal cost test, and because Michigan's decarbonization and environmental justice goals incorporate a very long-term perspective (looking forward to 2050 and beyond),[60] pilot projects undertaken by the utilities should be evaluated through a regulatory lens that takes into account societal benefits. Indeed, the Proposal purports to "take[] a societal viewpoint of pilot costs and benefits by incorporating the relevant utility system, host customer, and societal impacts,"[61] but its proposal to rely on WACC as the discount rate situates it as concerned primarily with the utility system.

__Question 4:__ *What, if any, changes to the BCA proposal are required in order for natural gas utilities to make use of the BCA proposal for pilots?*

A defensible methodology for evaluating greenhouse gas emissions associated with natural gas utilities would need to recognize emissions both upstream and downstream of the utility's own system. That is, emissions associated with fuel extraction, transportation, and

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[57] Proposal at 15 n.24.
[58] Proposal at 15 n.24.
[59] NSPM at 5-17.
[60] *See generally*, MI Healthy Climate Plan.
[61] Proposal at 3.

leakage before entering the utility's system; emissions from the utility's own system; and emissions resulting from combustion of the fuel at the customers' premises should all be within scope.

As noted above in the response to Question 1, the definition of "Greenhouse Gas Emissions" included in Table 2 of the utilities' proposal and in the NSPM – "GHG emissions created by fossil-fueled energy resources" – is unclear even in the case of a BCA framework to be used by electric utilities, in part because of the electric system's reliance on natural gas-fired generation. A sizable share of the greenhouse gas emissions associated with the use of natural gas may not fall squarely within the "created by fossil-fueled energy resources" language, but may be very material.[62] This is important even in the context of electric utilities in Michigan, since Michigan electric demand is met in large part by natural gas-fired electric generation.[63] It is, however, all the more important in the context of natural gas utilities.

In addition to potentially omitting upstream emissions, it is also not obvious that the proposed definition for greenhouse gas emissions would capture the carbon dioxide emissions arising from combustion of natural gas by end users.

In short, the definition of greenhouse gas emissions needs to be reworked even for satisfactory application to the electric system, but it will need even more of an overhaul to be made relevant to the natural gas system.

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[62] *See generally* James Bradbury et al., *Greenhouse Gas Emissions and Fuel Use within the Natural Gas Supply Chain – Sankey Diagram Methodology*, Office of Energy Pol'y and Sys. Analysis, Dep't of Energy (2015), https://www.energy.gov/policy/articles/fuel-use-and-greenhouse-gas-emissions-natural-gas-system-sankey-diagram-methodology.

[63] United States Energy Information Administration, *Michigan (State Profile and Energy Estimate)*, Michigan Net Electric Generation by Source (Mar. 2023), https://perma.cc/F98F-6QUB.

<u>Question 6:</u> *Are there regulatory examples of JST or BCA developments in other states that could be instructive for use in Michigan?*

The California Public Service Commission (CPUC) has promulgated an Avoided Cost Calculator as part of its Integrated Distributed Energy Resources effort.[64] According to CPUC, its avoided costs – which are updated annually, most recently in 2022 – are modeled based on generation energy, generation capacity, ancillary services, transmission and distribution capacity, greenhouse gases, and high global warming potential gases. Given that Michigan is pursuing benefit-cost analysis as part of an initiative to maximize the benefits of the transition to clean, distributed energy resources, California's most up-to-date efforts to articulate the value of a variety of distributed energy resources may be instructive. In addition, New York has the beginnings of a serious methodology for assessing natural gas system greenhouse gas emissions, including upstream emissions, leakage, and emissions resulting from natural gas combustion at the point of customer consumption.[65] The Commission could look to this methodology as an example of what a reasonable method for realistically quantifying greenhouse gas emissions associated with the natural gas system might look like.

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[64] *See generally* California Public Service Commission, *IDER Cost-Effectiveness*, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/idsm.

[65] *See, e.g.*, New York Public Service Commission Case 22-M-0149, *Proposal on Motion of the Commission Assessing Implementation of and Compliance with the Requirements and Targets of the Climate Leadership and Community Protection Act*, Joint Utilities' Proposal for an Annual Greenhouse Gas Emission Inventory Report (Dec. 1, 2022), https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={6057FD96-408B-4ED2-9467-76F52D177906}, as supplemented by New York Public Service Commission Case 22-M-0149, *Proceeding on Motion of the Commission Assessing Implementation of and Compliance with the Requirements and Targets of the Climate Leadership and Community Protection Act*, Joint Utilities' Supplement to Proposal for an Annual Greenhouse Gas Emissions Inventory Report (May 31, 2023), https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={E0A67288-0000-CB1E-AE8C-0AA80B419BC6}.

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ELECTRICITY POLICY INSIGHTS

Valuing Pollution Reductions

How to Monetize Greenhouse Gas and Local Air Pollutant Reductions from Distributed Energy Resources

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Executive Summary

Distributed energy resources (DERs)—grid-connected, small-scale electric generators such as rooftop solar installations, micro-turbines, combined heat and power systems, customer backup generators, and distributed energy storage systems—are a growing component of the U.S. electric system. As DERs have become more prominent, state electric utility regulators have begun efforts to more accurately compensate DERs by paying for each of the benefits that they provide.

One such benefit is the avoidance of environmental and public health damages from air pollution (including local air pollution and greenhouse gas emissions) that would have been caused by generation resources that have been displaced by the DERs. This report lays out a practical methodology for calculating this environmental and public health value. It identifies existing tools that states can use, with varying degrees of specificity, accuracy, and complexity, to monetize these pollution reductions. State utility regulators can use the steps outlined here, weighing tradeoffs between accuracy and administrability, to implement their own program to compensate DER for environmental and public health benefits. Regulators can monetize air pollution reductions that DERs provide by using a five-step method:

> **Step 1** determines what generation will be displaced by DERs. The most accurate methods for determining displaced generation require working with grid operators and, potentially, local distribution utilities, to obtain needed data on which bulk system generators would have operated in the absence of DERs. If sufficient data is not available, utility regulators can use electricity system simulation models to estimate which resources would have operated in the absence of DERs.
>
> **Step 2** quantifies the emissions rates for displaced generators. Emissions rates of existing resources vary widely, and therefore, the magnitude of the environmental and public health benefits of DERs will as well. Emissions rates depend on a generator's attributes, including fuel type (for example, coal, oil, natural gas, or renewable), electricity generation technology (for example, inefficient steam boilers or efficient combined-cycle technology), pollution control equipment, and operational practices like capacity factor.
>
> Emission rates of existing generators can be determined based on those generators' historical, measured emissions rates, or can be estimated using engineering analyses, given known information about fuel type, generation technology, pollution control equipment, and operational practices. Databases of historical emissions rates for specific plants and of emission factors broken out by generator attribute (such as fuel type, generation technology, and pollution control equipment) are also available.
>
> **Step 3** calculates the monetary value of the damages from emissions identified in Step 2. Air pollutants cause damage to human health, impair ecosystems, harm crops, and make it harder for workers to be productive. Given knowledge of the emissions rate for a power generator, utility regulators can calculate those damages as a function of:
>
> - The type of the pollutant. Particulate matter, especially fine and ultra-fine particulates, cause severe health damages, including death. Oxides like SO_2 and NOx break down into particulate matter and combine with other pollutants to form asthma-causing ozone pollution. Toxic heavy metals like

mercury and lead cause rapid health deterioration even at low concentrations. Greenhouse gases lead to climate change. Researchers have developed monetized damages estimates per unit of emissions for each of these pollutants.

- The location of emissions. Each unit of a pollutant emitted in population-dense areas or in areas with highly vulnerable populations will cause more damage. Emissions also interact with environmental conditions such as prevailing winds to carry pollutants away from the point of emissions. Damage estimates can be modified to account for these concerns.
- The timing of emissions. Some pollutants, such as ozone, only form when precursors are exposed to direct sunlight. Therefore, emissions that occur at night or in winter may cause less damage than those during the day or in the summer. Granular damage estimates account for these timing issues.

A method that accounts for all of these factors would lead to the most accurate calculations of damage per unit of emissions. However, data constraints and ease of use might make alternative, less granular methods more desirable. There are multiple tools produced by various researchers as well as EPA that provide estimates of pollution damages at the county level, and many of these tools allow for partial customization to meet specific needs of regulators.

Step 4 uses the emissions rates from Step 2 and damage estimate per unit of emissions from Step 3 to monetize the value of avoided emissions from displaced generation. Adjustments are needed if existing policies already put a price on emissions of some or all of the pollutants covered in Steps 1-3.

Step 5 takes into account any emissions produced by the DER itself. DERs such as diesel generators or combined heat and power generators emit pollutants. To arrive at an accurate environmental and public health value, those emissions and the damage they cause must also be taken into account. If damage per unit of generation from the DER is high enough, then the net environmental and public health value of the DER could be negative.

Distributed energy resources can provide substantial value to a state by reducing air pollution from conventional electric generators and the resulting environmental and public health damages. DERs can be particularly valuable to the extent that they avoid local air pollution imposed on vulnerable populations. As state utility regulators implement new compensation policies for these resources, those policies should include payment for DERs' environmental and public health value.

This report presents a straightforward five-step methodology that can be used to calculate this value in a technology-neutral manner while relying on existing, readily accessible tools. The methodology outlined in this report is flexible enough to accommodate a variety of data and resource constraints. State regulators can weigh the tradeoffs between accuracy and administrability of different methods to calculating environmental value, pick the tools that are most accurate given the tradeoffs, and then update their methodology when feasible.

While more comprehensive reforms such as an economy-wide tax on greenhouse gases and local air pollutants are needed to fully value the environmental and public health benefits of all DERs, this methodology would allow utility regulators to implement a DER compensation scheme that incentivizes DERs when and where they are most beneficial to the society.

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Introduction

The electric grid is quickly evolving from its traditional structure, where electricity is generated by large power plants located far from end-users, into a multi-dimensional platform. The modern grid allows a variety of new distributed resources that are located near end-users, such as solar panels, energy storage, and demand response, to provide a multiplicity of electricity services. With rapid innovation and declines in costs, these "distributed energy resources" (DERs) are becoming an integral part of the modern grid, and thus, creating new challenges for regulators.[1]

As technology is transforming the grid, policymakers around the nation are working to reform utility regulation in order to harness the full benefits that these technological changes offer. A number of states have initiated proceedings to implement compensation schemes for electricity generated from DERs, or a subset of DERs, that reflect all of the benefits that those resources provide.[2]

DERs help reduce the need for generation from large-scale generators interconnected to the transmission system ("bulk system generators") such as fossil-fuel-fired power plants, which are often costly to build and highly polluting. Depending on the type of DER, they do so in two ways: by reducing customer demand at a given time, or by actually generating electricity. DERs such as demand response and energy efficiency reduce customer demand for electricity at a particular time. Other DERs, such as distributed solar, generate electricity, which can then be used by consumers to offset grid purchases and/or can be exported to the grid. Energy storage can provide benefits by shifting consumer demand, by charging and discharging at different times.

By avoiding the need for generation from the bulk system, DERs can provide many benefits to grid such as avoided energy costs, avoided or deferred capacity costs, and reduced line losses.[3] This report, however, focuses on one regularly overlooked category in utility regulation: environmental and public health benefits.

Bulk system generators often burn fossil fuels—coal, natural gas, and petroleum—or biogenic fuels—agricultural and wood waste, municipal solid waste, animal waste, and landfill gas—and in doing so, they emit air pollutants. When DERs avoid the need for such bulk system generation, they can help reduce air pollution, benefiting society at large. Currently, however, these benefits are not explicitly valued.

Air pollutants emitted by power plants

Combustion of fossil fuels and biogenic fuels results in the emission of air pollutants, which fall into several categories. Air pollutants that affect human health and are dispersed in the ambient air are referred to under the federal Clean Air Act as "**criteria pollutants**." These include particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen oxides (NOx), and carbon monoxide (CO). These pollutants also combine in the atmosphere with each other and with volatile organic compounds (VOCs) to make other "secondary" criteria pollutants, including $PM_{2.5}$ and ozone.

In addition, combustion releases **greenhouse gases**—including carbon dioxide (CO_2) and nitrous oxide (N_2O)—that alter the climate and so cause a wide range of disruptive health, social welfare, and environmental effects.

Finally, combustion of some fuels results in emission of **hazardous air pollutants** (HAPs), also referred to as "air toxics," which cause significant damage even in small amounts. This category includes mercury and ammonia.

Air pollution is a textbook example of what economists call an "externality." Externalities are costs or benefits of market transactions that are incurred by parties other than the market participants, and thus are not taken into account by market participants. When externalities are present, market prices do not reflect the external costs and benefits of production or consumption, and therefore fail to provide an economically efficient signal for the true social value of the particular good or service, leading to an inefficient outcome. For example, because fossil-fuel-fired power plants are not paying for the environmental and public health damages their electricity generation causes, we get more air pollution than is socially desirable.

When negative externalities are present, social welfare can be increased by imposing a tax on the source of the externality—in this case, the emission of air pollutants—based on the amount of external damage caused. In the absence of efficient pollution taxes, alternative policies can help improve the efficiency of market outcomes.

One such policy approach is to pay generating resources that reduce air pollution. DERs provide environmental and public health benefits by displacing generation from other resources that would have emitted more air pollution.[4] Therefore, utility regulators can improve social welfare by ensuring that low and zero-emitting DERs are paid for the environmental and public health benefits they produce by displacing higher-emitting generation.

Appropriately valuing these benefits involves identifying the extent to which air pollution is avoided due to DERs, and then monetizing the economic, health, and climate damages those emissions would have caused. This report lays out a practical, technology-neutral methodology for identifying those values. Utility regulators can incorporate this methodology into proceedings aimed at establishing compensation structures for DERs.

It is important to note that, ideally, the same framework would be used to compensate all types of DERs for all the value they provide. However, because the price signals for load reductions manifest as avoided electricity purchases (at the retail electricity rate that customers pay), such comprehensive compensation would require complementary retail rate reforms in order to internalize the externalities.[5] Addressing this is beyond the scope of this report.

The methodology outlined in this report, therefore, is appropriate for compensating energy supplied to the grid by DERs. This limitation likely leads to an underestimation of the environmental and public health benefits of DERs that reduce on-site electricity consumption. However, despite the limitation of the methodology outlined here, compensating even just injections to the grid for the environmental and health benefits DERs provide would significantly improve social welfare.

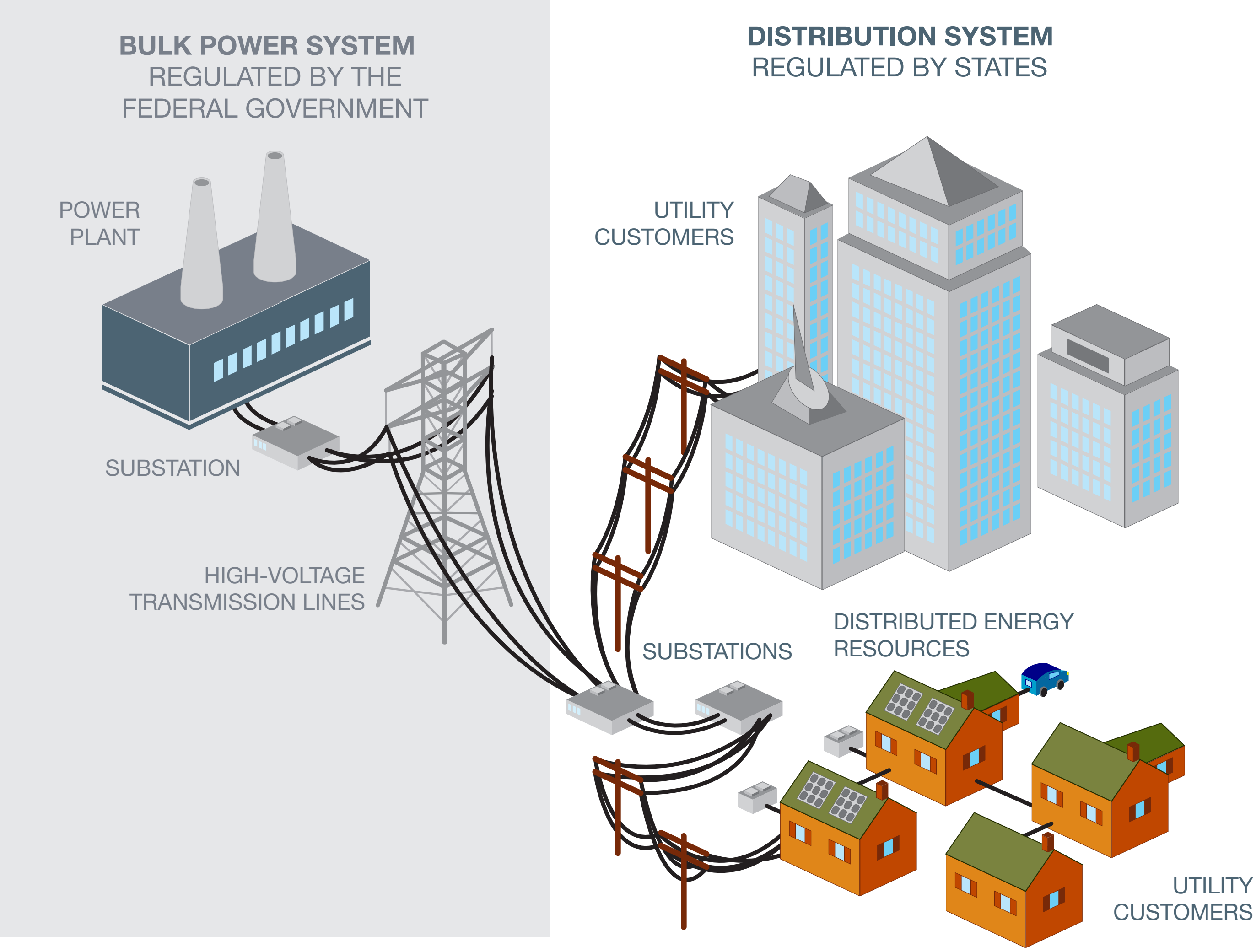
A brief overview of distributed resources, utility regulators, and grid operators

The regulation of electricity is divided between the federal government and the states.[6] Federal regulators have primary responsibility over interstate transmission and wholesale electricity, or the bulk power system, and state regulators have primary responsibility over the distribution system.

State regulators, commonly called “public utility commissions” or “public service commissions,” are responsible for regulating local distribution utilities and setting retail rates, as well as deciding on other state-level policies such as DER compensation, renewable portfolio standards, and energy efficiency programs.

In much of the country, the bulk power system, consisting of most generators and large transmission lines, is regulated by the Federal Energy Regulatory Commission and operated by grid operators called “independent system operators” (“ISOs”) or “regional transmission organizations (“RTOs”). ISOs/RTOs ensure that supply and demand of the bulk power system are constantly balanced using complex algorithms that take into account the location of both generators and demand, the costs of generation, and congestion on the transmission system. Grid operators dispatch resources from least expensive to most expensive (taking into account the congestion on the transmission system), until demand has been met.

Figure 1: Regulatory Domains of the Electric Grid



Valuing Environmental Benefits of Distributed Energy Resources – An Overview

Public Utility Commissions can calculate the environmental and public health value of DERs based on emissions avoided by the DER and the monetary value of the damage that those emissions would have caused. These two values will depend on the location of the DER and the avoided emissions, the time of day and year when emissions are avoided, and the type of pollutants avoided.[7]

DERs in different locations or generating at different times will displace different sources of generation, with various levels of emissions. Because different generators use a variety of fuel types, electricity generation technologies, control equipment, and operation practices that result in a wide range of air pollutant emissions rates, the type of generators displaced is an important driver of the value. DERs are worth more to society when they offset generation from higher-emitting sources.[8]

DERs are also more valuable when they reduce air pollution in areas with high population density and more vulnerable populations. The time of year also matters because NOx and VOC emitted in the summer carry greater health consequences, due to their role in the formation of ozone in the presence of sunlight. Therefore, DERs that can reduces pollutants in such areas and times are more valuable.

Finally, different pollutants cause different levels of public health and climate damage. If a DER offsets a generator that emits more damaging pollutants, it should receive a higher payment to reflect its environmental and public health value.

Any approach should take into account not only the generation displaced by a DER but also the emissions created by the distributed resource. For example, behind-the-meter DER generators include oil, gas/coal combined heating and power, and storage systems charged by fossil-fuel-fired generation resources. For emitting DERs, payment should be reduced based on their emissions and could potentially be negative if the negative impact of emissions from the DER is higher than the value of emissions avoided by that DER.

Key Terms

Emissions rate

The emissions rate is the amount of pollution emitted by a generator per unit of generation. If a generator emits 1 metric ton of SO_2 and generates 1 megawatt-hour (MWh) of electricity, then its emission rate of SO_2 is 1 metric ton/MWh, or 1 kilogram (kg)/kWh. The emissions rate can be affected by, among other things, installation of pollution control equipment, changes in the efficiency of the generator, or use of different fuels by generators that have fuel flexibility.

Damage per unit of avoided emissions

The damage per unit of avoided emissions is the monetized value of the harm that the pollution would have done had it been emitted. For instance, each kilogram of SO_2 released by a generator causes roughly $50 of damage. Therefore, if a DER avoids the emission of one kilogram of SO_2 by displacing generation of a fossil fuel power plant, then it would avoid $50 of damage.

Environmental value of displaced generation

The value of displaced generation is the dollar value of damages avoided, per unit of displaced generation. It is the product of the emissions rate and the damage per unit of avoided emissions.

Harnessing all the benefits DERs can provide requires compensating them for their environmental and public health value in a technology-neutral way that can take into account these different factors, while balancing accuracy and administrability. To achieve this goal, regulators must first identify the generation that is displaced by DERs, determine the emissions avoided by this displacement based on the emissions rates of the displaced resources, calculate the monetary damages per unit of avoided emissions, and then calculate the monetary value of the net damages avoided by DERs.

Below, we outline the necessary steps and then explain each step in detail.

Methodology Outline for Valuing the Environmental Benefits of DERs:

1. Identify the generation that is displaced by a DER
2. Calculate emissions rates (kg/kWh) of the displaced resource
3. Calculate the damage per unit ($/kg) of avoided emissions
4. Monetize the value of avoided damage from displaced generation ($/kWh)
5. Subtract any damages from the DER itself from the displaced generators' damages, to calculate *net* avoided damages

Step 1: Identify Displaced Generation

Distributed energy resources produce environmental and public health benefits by displacing generation from emitting power generators. The first step in calculating the value of those benefits, then, is to identify what generation will be displaced by a DER.

If sufficient grid operation and market information is available, it is possible to identify, with a reasonable degree of precision, the specific generator or generators that would have operated in the absence of DERs. If such data is not available, there are techniques that can be used to approximate which generators were displaced by DERs.

This section outlines three techniques for identifying displaced generation: (1) using counterfactual dispatch scenarios, (2) identifying the marginal generator, and (3) using electric market simulation models. These options are explained in order of decreasing levels of precision and decreasing information requirements.

All of these methodologies will identify those generators that have been displaced by DER resources *in the short run*. That is, these methodologies identify which of the *existing* resources would have generated in the absence of the DERs. They do not account for the potential effect that DERs have on the longer-term entry and exit incentives for emitting resources. Installation of DER capacity may contribute to the retirement of an existing fossil fuel-fired generator or may avoid the need for a new fossil fuel-fired generator. Therefore, methodologies presented in this section likely understate the extent to which DERs reduce emissions. Complex methodologies have been developed to account for these emissions effects; however, incorporating these effects into a DER valuation methodology is beyond the scope of this report.[9]

Running Counterfactual Dispatch Scenarios

Overview. It is possible for market operators to identify all of the generating resources that would have operated in the absence of DERs with precision and confidence. A market operator can run a counterfactual dispatch scenario in which the operator runs its regular dispatch algorithm while assuming no DERs. The generators that would have operated in this counterfactual dispatch scenario but were not actually dispatched are the generators that were displaced by DERs. These identified resources can be used in Steps 2-3 to calculate the avoided damages attributable to DERs.[10]

Advantages. The primary advantages of this approach are that it is accurate, granular, and flexible. Because it relies on actual grid operations and market data used to make dispatch decisions, this method can accurately capture which resources would have operated in the absence of DERs. Because this approach can identify the specific generators that have been displaced, it will also provide specific information on the location of displaced emissions, which is useful for calculating accurate public health damages in Step 3.

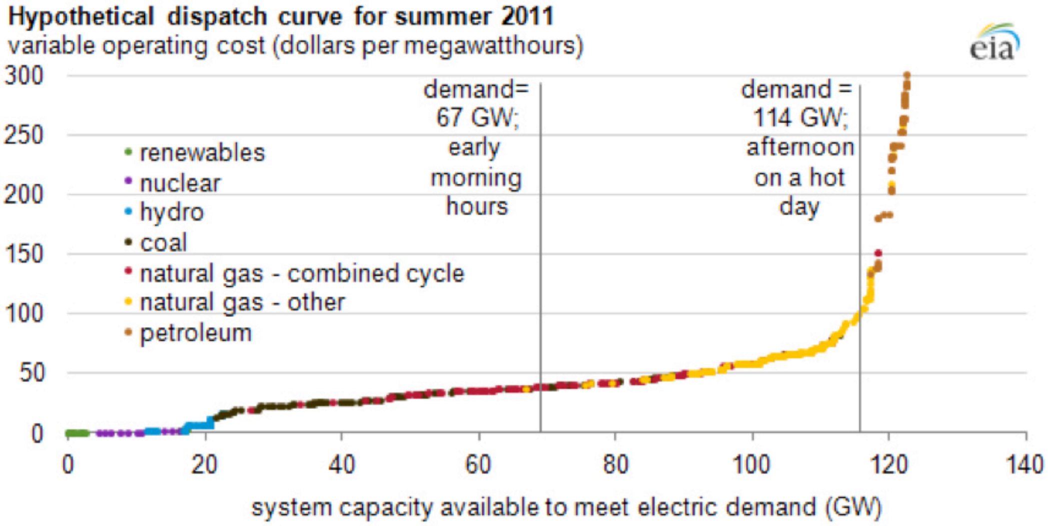
Counterfactual dispatch scenarios could be run as often as the grid operator reruns its dispatch algorithm. However, this approach is also flexible and can be updated less frequently if the administrative costs of frequently identifying counterfactual dispatch outweigh the benefits. For example, if there is limited variability in which resources are displaced over short intervals, grid operators could run counterfactual dispatch scenarios once per hour; during key parts of the day (such as during periods that typically have high electric demand and periods with low electric demand, or periods with high DER injections and periods with low DER injections); or during key times over each season of the year.

Limitations. The primary limitation of this approach is its significant data requirement. Regulators will have to work with distribution utilities to obtain the information—location, timing, and magnitude of DER penetration—needed for counterfactual dispatch scenarios, and then work with grid operators to produce counterfactual dispatch scenarios.

Identifying the Marginal Generator

Overview. An alternative approach to identifying displaced generation is to use information from the grid operators on marginal generators. Grid operators usually dispatch generators based on their cost of operation, as well as technical constraints of the system, until the total generation is high enough to meet the demand. The "marginal generator" for a given interval is the last generator that is needed to satisfy demand at that interval. Additional DERs at this time will reduce the need for generation from the marginal generator, and therefore avoid emissions from the marginal generator. States can work with grid operators to identify the generator on the margin at the time of DER operation, which can provide an accurate up-to-date estimate of which generators DERs are displacing.

Figure 2: Illustrative Market Supply Curve[11]



Source: Energy Information Administration (2012)

Figure 2 is an illustrative market supply curve, which shows available generators in ascending order of marginal cost from left to right. Different levels of demand are illustrated by the vertical lines. The marginal generator for a given level of demand is the generator at the intersection of the vertical line and the supply curve. Based on this curve, when load is at its minimum, a gas generator with a relatively low bid will be on the margin. Any DER at this time will reduce the need for generation from that gas generator. When load is at its maximum, the marginal generator may be an oil-fired generator. DER will replace generation from the oil-fired generator.

Because the transmission system can be congested, the marginal generator will often be location dependent. If transmission lines are congested, electricity cannot be transmitted from distant locations even if there are available cheap generators, and therefore grid operators must rely on more expensive local resources. Take, for example, the New York Independent System Operator. When there is no congestion, a DER in New York City can indeed displace a system-wide marginal generator, which can be located anywhere in the state. However, the transmission lines going in and out of New York City are often congested. During periods of such congestion near New York City, the marginal generator displaced by a DER in New York City will likely be local and different from the marginal generator displaced by a DER located in other parts of the state. States should therefore identify marginal generators at a level of geographic granularity appropriate given the level and location of congestion on the system.

If real-time information is not available from grid operators, regulators could identify marginal generators by matching load levels with generators on representative dispatch curves, such as the one outlined in Figure 2 above.[12] Such use of historical dispatch curves rather than actual dispatch curves for a given interval reduces the accuracy of this measure but it can be done with less involvement of the grid operator. These curves can be constructed using grid operator data, based on historical information on generator operation and energy bids. To most accurately reflect the generation mix available at a particular time, regulators should use historical dispatch curves applicable for times of day and seasons to reflect variations in renewable energy and seasonal outages.

Advantages. While identifying the marginal generator will require working with the grid operator, this approach requires significantly less involvement and data from the grid operator. This approach also will not require specific information from distribution utilities on the location, timing, and magnitude of DER load and generation profiles.

Limitations. This approach assumes that the magnitude of DERs is not large enough to change the marginal resource. Currently the level of DER penetration is small enough to meet this requirement in most contexts. In addition, especially during high-demand times when a small generator is on the margin, the next resource that would be marginal if that small generator is displaced may have quite similar emission characteristics. However, as DER penetration increases, it is possible that DERs will begin to change which generators are on the margin. This will reduce the accuracy of this approach as compared to the counterfactual dispatch scenario approach.

Electric Grid Dispatch Modeling

Overview. A number of sophisticated models of the electric grid have been developed that can be used to simulate the dispatch of generators under a variety of conditions.[13] These models generally incorporate databases of generators (including the location, size, fuel type, and other operational characteristics) and transmission, assumptions about fuel and other operational costs of generation, and assumptions about electric demand to simulate operation of a given electric grid. Regulators can use these dispatch models to identify the resources that have been displaced by DERs, similar to how a grid operator would identify displaced generation through counterfactual dispatch scenarios. The electric model would be run both with and without DERs to identify the resources that have been displaced.

Regulators should perform model runs under a variety of assumed operating conditions (e.g., varying levels of electric demand, transmission congestion, and DER availability). They can then use the simulation that best matches the appropriate real-world circumstance.

Advantages. The primary advantage of this approach is that it can be used without involvement of the ISO/RTO or distribution utility. While the relevant models are complex and require expertise to use, Public Utility Commissions can develop this expertise rather than having to rely on outside entities for ongoing data requirements.

Limitations. Because these models rely on assumptions, rather than realized outcomes, they are not likely to be as accurate as the first two approaches outlined. In addition, this approach will be even less likely to incorporate any sectoral changes over time including generator entry and exit and generator outages, unless the model used is updated to reflect these changes.

An Approach to Avoid: Grid-Average Generators and Grid-Average Emissions rates

While there are many acceptable options to identify generators that will be displaced by DERs, regulators should *not* assume that DERs displace all generators in equal amount (either numerically or generation-weighted). Similarly, regulators should not use grid average emission factors when determining the avoided emissions attributable to DERs. Assuming DERs displace all resources equally or using *average* emissions rates will incorrectly include substantial zero-emission generators that are unlikely to be affected by DERs. Use of averages will also miss significant temporal and locational variation in the amount of air pollution displaced by DERs. Research has shown that using average emissions rates significantly misstates emission impacts of new resources.[14] While this approach is computationally easy, and therefore appealing, using grid averages will not lead to accurate estimates.

Step 2: Identify Emissions Rates of the Displaced Generation

Once the resources that are displaced by DERs have been identified, the next step is to determine the emissions rates of those displaced resources. These emissions rates are necessary to determine the economic benefits of avoiding emissions from each kWh of the displaced emitting generation. Table 1 presents average emissions rates of select criteria and greenhouse gas pollutants by fuel burned.

Table 1: Average Emissions Rates of Select Pollutants for Generators in 2016[15]

Fuel Type	NOx (kg/MWh)	SO_2 (kg/MWh)	CO_2 (kg/MWh)
Oil	2.92	2.86	862.80
Coal	0.75	1.08	1003.38
Biomass	1.58	0.67	211.06
Gas	0.16	0.00	405.94

Generator Features Affecting Emissions rates

Emissions rates are a function of (1) the type of fuel combusted, (2) the combustion and electric generation technology, (3) any pollution control equipment, and (4) environmental and operational considerations.

Fuel Type

The type and amount of pollutants emitted by electricity generators is primarily a function of the type of fuel used. Some plants are designed to burn only one type of fuel. Others, called "dual fuel" plants, are able to switch between fuels depending on fuel availability and price. Dual fuel plants generally can burn either natural gas or oil-based fuel (e.g., diesel fuel).

Uncontrolled combustion of coal, oil and wood biomass emits relatively large quantities of most criteria pollutants, HAPs, and greenhouse gases.[16] Combustion of gas, including natural gas and landfill gas, primarily emits NOx, CO, VOCs, and CO_2, with little to no direct emissions of PM, SO_2 and HAPs.[17] On the other end of the spectrum, nuclear, hydroelectric, solar, and wind generation do not emit any air pollution.

Generation Technology

For a given fuel type, the primary determinant of the emissions rate is the efficiency by which a combustion technology converts fuel into electricity, called the generator's "heat rate".

Key Term

Heat rate is a measure of power plant efficiency. It is a measure of the amount of energy, embedded in the combusted fuel, measured in British Thermal Units, that it takes to generate a kWh of electricity.[18] The higher the heat rate, the *less* efficient the plant.

Steam boilers generate electricity by combusting fuel to produce heat, which warms water to produce steam that turns an electric turbine. Steam boilers generally have high heat rates.[19] In other words, they are not efficient. Steam boilers primarily use coal (and almost all coal plants use steam boilers), but they can also combust natural gas, fuel oil, or biomass.[20]

Stationary internal combustion engines (ICE), which generally burn fuel oil, have similar heat rates to steam boilers and are most often used as "peaker plants" when demand is particularly high, for backup power, or as distributed generation.[21]

Combustion turbines use heat produced from fuel combustion to turn a turbine that generates electricity. They use liquid or gaseous fuel, including natural gas, fuel oil and biogenic fuels (e.g., landfill gas).[22] Combustion turbines can range in efficiency and often function as peaker plants.

Finally, highly efficient combined-cycle plants combine the technologies to produce more electricity for the same amount of fuel.[23] In a combined-cycle plant, a combustion turbine produces electricity and heat, while the excess heat produces steam that generates more electricity. These plants primarily use natural gas (and much less often fuel oil).

Pollution Control Equipment

Emissions rates can also vary significantly depending on whether a plant has installed air pollution control technology. Almost all plants can implement some pollution control equipment, but there is significant variation in the type and effectiveness of installed equipment. For instance, flue gas desulfurization technology can reduce SO_2 concentrations of coal plant emissions by 98%, while catalytic reactions reduce NOx pollution by 80%.[24] Pollution control equipment can also negatively affect the efficiency of power plants.[25]

Operational and Environmental Considerations

A variety of environmental and operational considerations affect emissions rates. These include:

- **The age of the plant.** Plant efficiency generally declines with age.
- **The utilization of the plant.** Power plants that are operating below full capacity are generally less efficient and so have higher emissions rates.
- **Ambient weather conditions.** Ambient weather conditions including temperature, humidity, and pressure can affect the efficiency of a power plant.[26]

These operational and environmental considerations vary over time, while other features like fuel type, generation technology, and pollution control equipment are relatively static. Therefore, it is not possible to know a particular generator's emissions rate without measuring, in real time, its emissions and generation. Even though such data is rarely available, there are a number of existing or easy-to-develop tools that states can use to determine reasonably accurate emissions rates for generators.

Methods for Determining Emissions rates

States can use one of two primary options for determining reasonably accurate emissions rates: (1) historical, measured emissions rates of the generator, and (2) engineering estimates of a generator's emissions rates based on design characteristics and operational assumptions.

Historical Emissions Rates

Historical emissions rates calculate a given generator's emissions rate for each pollutant based on measured historical emissions and measured historical generation.

Historical Emissions. Generators above a specific size threshold are required to directly measure and report the volume of emissions for some pollutants to state environmental agencies and/or the U.S. EPA Clean Air Markets Division (CAMD). Continuous emission monitors are used to measure and report NOx, SO_2, and CO_2 emissions from generators subject to certain federal environmental program requirements.[27] For pollutants where continuous emission measurement is not feasible or is particularly expensive (such as for PM), generators calculate and report emissions through monitoring of parameters that have a known relationship with emissions, such as operational characteristics of plant systems (temperature, pressure, liquid flow rate, pH), through periodic emissions testing, or based on quantities of fuel consumed and the technology used to generate electricity.[28]

Historical Electric Generation. Generators are required to measure and regularly report various characteristics and operational performance of their plants to the U.S. Department of Energy's Energy Information Agency (EIA).

Dividing historic emissions by historic generation yields historic emissions rates. This calculation should be done with as high degree of granularity as possible in order to yield representative emissions rates for a generator's operational performance. For example, for a dual fuel generator, dividing annual total emissions of SO_2 by annual generation will not yield an accurate SO_2 emissions rate because SO_2 is only emitted in the hours that the generator burns fuel oil. Significant emissions rate changes for a generator can be captured by more daily or hourly emissions rate calculations.

Engineering Estimates

Engineering estimates of emissions rates are based on assumptions about known characteristics of generators. Accurate engineering estimates use the considerations identified above (fuel type, heat rate of generating technology, emission control technology, and environmental and operational considerations) to develop emissions rates that can be applied to generators with similar characteristics. Because of this, engineering estimates are sometimes referred to as "emission factors."

Selecting Between Historical Emissions and Engineering Estimates

Short of real-time continuous measurements, historical measured emissions rates are generally the best measure of a particular generator's emissions rate. Therefore, they should be used when available.

However, measured historical emissions rates are not always available for all sources. Existing databases are limited to those generators that exceed certain size and operational thresholds. Smaller generators, newer generators, or generators that did not operate over the historical period used to set emissions rates are not included in certain databases. In addition, because it is difficult to directly measure certain pollutants such as PM and air toxics, historical emissions rates for all pollutants may not be known for a given generator.

Finally, lack of temporal granularity of may produce misleading emissions rate estimates. In particular, the use yearly-average emissions rates may be problematic for generators that do not operate consistently over the course of a year, such as dual fuel peaking plants that may burn oil instead of natural gas when natural gas is unavailable or particularly expensive.

Where historical emissions rates are not available at all, or lack sufficient granularity, engineering estimates should be used.

Existing Tools and Databases

There are a number of existing databases that regulators can use to determine emissions rates. Different tools may be appropriate for different pollutants or for different desired levels of granularity.

This section outlines tools that fall into a number of categories: (1) Databases of generator-specific historical measured emissions; (2) databases of generator-specific historical measured generation, which, together, can be used by a state to develop generator-specific historical emissions rates; (3) databases of engineering estimates of emission factors; and (4) integrated databases that combine data from other sources to produce readily available emissions rates.

Table 2: Databases for Calculating Emission Rates

Tool	Data type	Pollutants covered	Covered sources	Data source	Update Frequency (last data year)
Historical Emissions Databases					
EPA CAMD	Generator-specific hourly emissions (can be aggregated)	NOx, SO_2, CO_2	Boilers > 25MW; combustion turbines, combined-cycle plants, & ICE online after 1990	Mandatory source-level reporting based on continuous monitoring	Monthly (Sept. 2017)
National Emissions Inventory	Unit-specific annual emissions	SO_2, NOx, PM_{10}, $PM_{2.5}$, CO, VOC, NH_3, Hg, HCl	Power plants with criteria pollutant emissions over certain thresholds	State environment office reporting, supplemented by EPA CAMD data and emission factors	3 years (2014)
Historical Electric Generation Databases					
EIA Form 923	Unit-specific monthly electric generation and fuel consumption	n/a	Sources > 1 MW	Operator-level reporting	Monthly (Oct. 2017)
Engineering Estimate Databases					
EPA AP-42	Engineering-based estimates by fuel and technology type	SO_2, NOx, PM_{10}, $PM_{2.5}$, CO, VOC, CO_2, CH_4	Boilers, combustion turbines, and ICE using coal, natural gas, fuel oil, and biomass	EPA tests of representative technology	Infrequent (1998-2008)
National Energy Technology Lab	Engineering estimates	CO_2, SO_2	Modern highly-efficient natural gas combined-cycle plants	Department of Energy engineering analysis of modern plants	Infrequent (2010)
Integrated Databases					
eGrid	Unit-specific annual emissions and electric generation	NOx, SO_2, CO_2	Electric generating units that report electric generation data on EIA-923	Emissions: EPA CAMD and AP-42 Generation: EIA-923	Sporadic, generally 1-4 years (2016)
Argonne National Labs GREET	Attribute-based emission factors using statistical analysis of historic emissions rates and open literature review	CO_2, CH_4, NOx, SO_2, CO, VOC, PM_{10}, $PM_{2.5}$	Boilers, combustion turbines, combined-cycle plants, ICE burning coal, nat. gas, fuel oil, and biomass, with various pollution control equip.	EPA eGRID, AP-42, open literature	Sporadic (2012 for full update, 2017 for limited update)

Generator-Specific Historical Emissions Databases

EPA maintains a number of databases of power plant emissions. However, no single database contains information on all important pollutants. Combining datasets is necessary to get a full picture of generator emissions.

EPA Clean Air Markets Division

Overview. EPA's CAMD collects emission data from large air pollution sources, including power plants, in order to administer a number of federal environmental programs. Electric generators subject to reporting requirements include steam generators with at least 25 MW capacity, non-steam generators – gas turbines, combined cycles, internal combustion engines – that came on-line after 1990, and independent power producers/co-generators that sell over a specific amount of electricity.[29] These generators report hourly emissions of NOx, SO_2, and CO_2, collected from CEMs, to EPA on a quarterly basis. The hourly data can then be aggregated into daily, monthly, or seasonal data.

Advantages. Using hourly emission data would allow state utility regulators to calculate emissions rates that take into account environmental and operational characteristics. Because the data is collected from continuous monitoring, it is also more accurate than data collected through other means.

Limitations. The biggest limitation is that CAMD does not include historical data on a number of key pollutants, such as PM. CAMD only recently began collecting data on mercury, hydrogen chloride, from some coal and oil-fired steam generators.[30]

National Emissions Inventory

Overview. The National Emission Inventory (NEI) is a database of annual emissions for a wide variety of sources, including power plants with a potential to emit criteria pollutants above a 100 tons per year threshold.[31] NEI data includes generator-specific emissions of PM_{10}, $PM_{2.5}$, VOCs, CO, HAPs, SO_2 and NOx emissions.[32] Data is based primarily on data reported to EPA from state environmental agencies, supplemented and modified by data that EPA itself collects and other EPA assumptions.[33] New data is collected by EPA every three years, and released three years later after it goes through a substantial quality assurance process. The 2014 National Emissions Inventory was released in 2017.

Advantages. The primary advantage of NEI data is that it contains emissions of a wider variety of air pollutants than CAMD, including PM.

Limitations. Infrequent updating is the primary limitation of the NEI. The NEI is updated only every 3 years, on a 3-year delay. Therefore, accurate emissions rates will not be available for sources built or substantially modified after 2014. In addition, NEI contains only annual (and for NOx, summer season) emissions.[34] Therefore, emissions rates calculated using this data source will be limited to annual average emissions rates (and, for NOx, ozone season average emissions rates), and will have limited accuracy for plants whose emissions rates vary with operational changes, such as mid-year changes in fuel used.

Generator-Specific Historical Generation Databases

EIA-923

Overview. Operators of electric generators greater than 1 MW report net electric generation (as well as fuel consumption) to the Department of Energy's Energy Information Agency (EIA) on form EIA-923.[35] All generators report generation annually, and a large subset report generation on a monthly basis.[36] For generators that are not included as part of the sample, EIA imputes monthly generation data using statistical techniques.[37]

Advantages. EIA data is readily accessible online and practitioners consider it as the best source of widely available generation data.

Limitations. Emissions rates more granular than monthly averages are not available.

Engineering Estimate Databases

EPA AP-42

Overview: EPA has developed *AP-42 Compilation of Air Pollution Emission Factors* for a wide variety of pollutants and source categories. These factors are often used by EPA when measured data is not available and can be used by states to develop assumed emissions rates for sources where EPA data is not available.[38]

AP-42 provides emission factors for the following combustion technologies: steam boilers;[39] stationary combustion turbines;[40] and large stationary diesel and dual-fuel engines.[41] It generally includes emission factors for criteria pollutants and their precursors, HAPs, and greenhouse gases (including CO_2 and methane).

Advantages. AP-42 provides a standard set of widely used emissions factors. It is therefore easy to use when historical emissions data is not available.

Limitations. AP-42 emission factors have not been updated since the late 1990s and early 2000s. This is particularly an issue for generation technology that has seen significant advancements since the last AP-42 update, including natural gas combined-cycle combustion technology. In addition, recent analysis has shown that the factors do not capture the wide variety of emissions rates from actual facilities.[42]

NETL Natural Gas Combined-Cycle Analysis.

Overview: In 2010, the Department of Energy's National Energy Technology Laboratory (NETL) evaluated the cost and performance of representative fossil fuel-fired power plants, including new NGCC power plants. As part of this report, NETL developed air pollution emissions rate estimates for a standard NGCC plant.[43] These emission factors have been used by academic researchers studying the economic costs of air pollution externalities from power plants.[44] For relatively modern, large NGCC plants, states could use generic emissions rates based on this research.

Advantages. Up-to-date and widely used emission factors for modern NGCC technology.

Limitations. Limited to emission factors for a single generation technology type.

Integrated Emissions and Generation Database

There are two integrated databases that combine available emissions and generation data from the databases outlined above and other sources. These databases can help determine emissions rates with minimal additional work by utility regulators.

EPA eGrid Database

Overview. EPA maintains the eGrid database[45], which contains annual average emissions data and annual average generation data for most electric generators, compiled from a variety of data sources. The primary source for generation data is EIA form 923.[46] The primary source of EPA's emission data is EPA CAMD.[47] For generators that do not report to CAMD, EPA calculates annual emissions by multiplying emissions factors from AP-42 by the plant's heat rate (as reported to EIA).[48]

Advantages. The primary advantage of eGrid is that EPA has already done the work to compile and validate relevant data from CAMD, AP-42, and EIA.

Limitations. eGrid does not include data on key pollutants, such as PM and air toxics. Because eGrid provides *annual* emissions and generation data,[49] eGrid data does not take into account emissions rate changes that could result from variation in the fuel used by a plant throughout the course of a year, changes in capacity factor, or other operational and environmental characteristics.

Argonne National Laboratory GREET Emission Factor Database

Overview. Argonne National Laboratory (ANL) has developed a model for estimating lifecycle greenhouse gas and criteria pollutant emissions associated with various vehicle technologies: the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model.[50] In order to estimate lifecycle emissions of electric vehicles with this model, ANL has compiled a database of power sector emission factors broken out by relevant attributes such as fuel type, generation technology, and pollution control equipment.[51] The GREET emission factor database was developed using data from CAMD, EIA, AP-42 and the open literature.

Advantages. The GREET emission factor database includes emission factors for a wide variety of pollutants, including those not included in eGrid, such as $PM_{2.5}$. The database is broken out by many generator characteristics, so more accurate emissions rates can be identified, so long as relevant attributes of a given generator are known. It is updated more frequently than AP-42 (the last comprehensive update was in 2012, but limited updates were made in 2013 and 2017).[52] ANL conducted robust statistical analysis to arrive at emission factors.

Limitations. The GREET emission factor database includes general attribute-based emissions rates. Therefore, it is not as accurate as historical emissions rates for specific generators when such rates are available.

Estimating Displaced Emissions if Step 1 is Not Feasible

The methodologies described in Steps 1 and 2 of this report identify the emissions avoided by a DER by identifying specific generators that would be displaced and determining the emissions rate of those generators. However, when it is not possible to identify specific generators due to lack of data, it is possible to estimate the emissions displaced by DER by using econometric techniques.

Academic researchers have been using regression analysis to directly estimate the grid's marginal emissions rates.[53] This method requires high-frequency data on emissions of the pollutant of interest and the quantity of electricity demand – the load – for a particular electric grid. A linear regression of emissions on load will yield the relationship between changes in measured emissions from all generators on the grid and changes in electricity demand. The marginal emissions rates at a given time and location can then be estimated based on the level of electricity demand at that location and time.

The granularity of this method depends on the granularity of the underlying data. For example, if data are available on zonal level emissions and load, then marginal emissions can be calculated to the zonal level for each season or time of day.

Limitations: Because marginal emissions rates are estimated for a given area, assumptions are required about where specifically emissions will occur. This will limit the accuracy of damage estimates outlined in Steps 3-4 below. In addition, this approach will not be responsive to changes in the electric sector such as short-run changes caused by generator outages and medium-run changes in the composition of generators over time. Therefore, this approach should be used only to the extent that utility regulators are not able to obtain information from grid operators and cannot use electric market models.

Step 3: Calculate the Monetary Damages from Emissions

Air pollutants cause damage to human health, impair ecosystems, and harm crops and other production activities. The goal of this step is to find the monetary value of the damages from each unit of emissions identified in the previous step. Given knowledge of the emissions rate for a power generator, regulators can calculate damages as a function of the pollutants being emitted, the location where those emissions occur, the time of day and year when they occur, and ambient environmental conditions like weather and pollution concentrations. The most accurate calculation of damages would incorporate each of these elements.

Relevant Factors for Calculating Monetary Damages

The sections below discuss the factors needed for calculating monetary damages from emissions, as well as the motivation for incorporating these different elements and the key issues related to granularity versus ease of administration.

Pollutants Emitted

The previous section identified a number of pollutants emitted by fossil power generators. Each pollutant has its own relationship between exposure and impact, called the *dose-response function* or *damage function* in epidemiological and economic research. These different damage functions should be accounted for when calculating damage per unit of emissions for accurate assessment of the value of avoided emissions.

Toxic Heavy Metals

Toxic heavy metals like mercury or lead cause rapid health deterioration even for low concentrations and quickly become fatal. Heavy metals like mercury and lead can also decrease brain function, leading to marked reduction in IQ.[54] The harms also occur over long periods of time because heavy metals do not break down once they are released, leading to long-run harms as the public is exposed the pollutant over longs periods of time and permanent, negative health effects for individuals whose bodies cannot get rid of the toxins. Because the harm caused by these metals is so extreme, the damage per unit of emissions is correspondingly high.[55]

Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2) is a gas released during combustion of oil and coal that negatively affects the environment and human health. SO_2 irritates mucous membranes in the lungs, eyes, nose, and throat, exacerbating conditions like asthma.[56] SO_2 also breaks down into particulate matter. Fine particulates, especially those smaller than 2.5 micrometers, called $PM_{2.5}$, penetrate into the lungs, causing or exacerbating cardiovascular problems like asthma and heart disease. Fine particulate matter is also a primary contributor to haze and visibility reduction in much of the United States.[57] SO_2 is also a major contributor to acid rain.[58]

Nitrogen Oxides (NOx)

Nitrogen oxides are gases including nitrogen dioxide, nitrous acid, and nitric acid. Collectively, these gases are referred to as NOx.[59] Like SO_2, NOx breaks down into particulate matter, causing cardiovascular health effects and contributing to haze.[60] NOx, along with other pollutants like VOCs, react with sunlight to create ozone pollution, which is a respiratory irritant that aggravates conditions like asthma.[61]

Greenhouse Gases

Greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), lead to climate change.[62] Greenhouse gases exert a warming effect on the global climate. This warming is already having noticeable, damaging effects on the environment and the economy.[63] These damages are expected to increase in the future as further climate change occurs.[64]

Ambient Concentration

Ambient pollution concentrations affect the amount of damage that results from additional pollution emissions. Some pollutants cause severe health effects at low concentrations, so even small emissions of such pollutants can be dangerous, depending on ambient levels. One such pollutant is mercury. Even small concentrations of mercury can cause mortality, so an increase in emissions of mercury in an area with a high pre-existing concentration can cause severe health effects.[65] In contrast, an increase in emissions of a pollutant like particulate matter will cause declining marginal damage as the ambient concentration rises.[66]

Pollutants can also interact, exacerbating effects. For instance, ozone creation is more likely in the presence of both VOCs and NOx.[67] Pollutant interaction makes it potentially important to account for ambient concentration of other pollutants when calculating damages per unit of emissions. Such interaction effects might be challenging to quantify in a way that is also easy to administer, so a reasonable alternative would be to incorporate damages that vary by location depending on the average or usual concentration of important ambient pollutants.

Pollution Transport

Pollution can be carried away from the area where it is created through a process called pollution transport. Wind and water carry pollutants away from the point of emission, potentially exposing populations far from the emission source.[68] Rain washes particulate matter out of the air and into bodies of water.[69] Pollution transport models are useful for understanding this movement of pollutants from source to final location. For instance, lighter pollutants like fine particulates can be carried farther than heavier pollutants like PM_{10}, making modelling of transport for fine particulates relatively more important for correct damage estimation.[70]

Secondary Pollutants

Related to pollution transport, pollutants break down and potentially create other, secondary pollutants as they travel through the atmosphere. As discussed above, SO_2 and NOx break down to create particulate matter. Ozone forms when sunlight reacts with oxides and organic compounds in the air.[71] Thus, ozone is less likely to form at night and is also less likely to form in the winter, making time of day and year important for damage from this pollutant.[72]

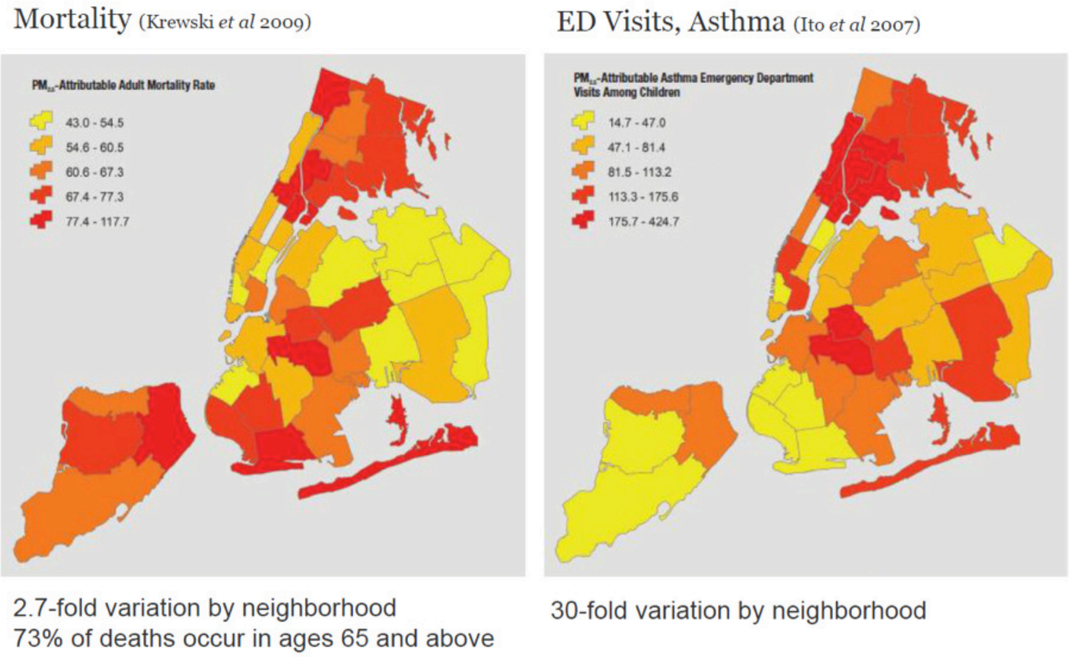
Exposed Population

Pollution causes damage when individuals are exposed to that pollution, so the size of the exposed population is one of the most important drivers of changes in damage from pollution. Densely populated areas experience more damage from a given amount of pollution simply because more people are exposed to that pollution. For instance, $PM_{2.5}$ released in the eastern region of the United States causes between \$130,000 and \$320,000 in damages per ton according to EPA estimates. A ton of $PM_{2.5}$ emitted in the western part of the United States, however, causes \$24,000 to \$60,000 in damage.[73] The difference in these estimates is primarily attributable to differences in population density.

Population Health

The healthiness of the exposed population also affects damage. Ozone created in an area with high asthma rates will cause more health damage than ozone released in an area with very few asthma sufferers. Overall health affects the vulnerability of individuals to mortality from pollutants. For example, Figure 3 shows that in New York City, $PM_{2.5}$-attributable mortality rate is higher in portions of Brooklyn than in southern Manhattan.[74]

Figure 3[75]



Source: NYC Department of Health and Mental Hygiene Bureau of Environmental Surveillance and Policy (2013).

The left panel shows the relationship between $PM_{2.5}$ and adult mortality for neighborhoods in New York City. The same quantity of $PM_{2.5}$ causes about twice as much mortality in a neighborhood colored red versus yellow. The right panel shows the relationship between $PM_{2.5}$ and child emergency room visits for asthma in New York neighborhoods. For asthma, the same quantity of $PM_{2.5}$ causes about ten times more emergency room visits in a neighborhood colored red versus yellow. Both panels show that the damage from air pollution usually depends on local characteristics like population health.

Methodologies for Calculating the Damage per Unit of Emissions for Pollutants that Depend on Time and Location

Accounting for all of the factors that affect damages using custom models would lead to the most accurate calculations of damage per unit of emissions. However, data constraints and ease of use might make alternative, less granular methods more desirable. Table 1 shows examples of different damage calculation methods that tradeoff between these two goals of accuracy and administrability. The most granular methods use high-resolution population data with time-varying pollution transport models. Less granular methods make stronger assumptions or use more aggregated data to reduce the complexity of calculation.

Custom Solutions

On the most granular side, policymakers could build a custom model that takes into account as many factors affecting damage per unit of emissions as possible. A recent example of such an approach is the Bay Area Clean Air Plan.[76] The Bay Area Air Quality Management District created a custom tool that translates emissions of multiple different pollutants into changes in pollution concentration throughout the Bay Area. The tool uses weather data to understand how pollutants are transported around the Bay Area, and it uses atmospheric chemistry models to understand how different primary pollutants cause secondary pollutants in the region. For instance, ozone is created by a complex interaction between different pollutants and sunlight, so the atmospheric chemistry models are important to understanding how ozone pollution can be addressed.

The model then uses population density to translate pollution concentration changes into human exposure. The exposure determines health effects according to the pollutant being considered and the health conditions of the exposed population.[77] The Bay Area Air Quality Management District focuses on PM, ozone, and greenhouse gas pollution, but in principle, any pollutants could be incorporated into a similar methodology.

One of the primary benefits of a custom method is the ability to incorporate variation in population density and population health. This ability is especially important for states that are characterized by a high degree of heterogeneity in population density. Pollutants emitted in areas near big urban cities would cause substantially higher exposure than the same pollutant emitted in more sparsely populated rural regions. This effect might be exacerbated if higher-emission power plants are located in the higher-population areas, leading to higher ambient pollution levels.[78] This correlated heterogeneity means that policymakers should avoid an approach that uses a state-wide average damage per unit of emissions, since such an approach would vastly understate damages in some areas of the state while overstating damages in others.

Estimating Air Pollution Social Impact Using Regression

Estimating Air Pollution Social Impact Using Regression (EASIUR) is a model of the damages from emission of primary $PM_{2.5}$, SO_2, NOx, and NH_3. The damage estimates are based on mortality due to secondary particulate matter.[79] One of the primary benefits of EASIUR is easy-to-use but accurate modeling of pollution transport. EASIUR was created by taking high-resolution, detailed pollution transport model output from the Comprehensive Air Quality Model with Extensions (CAMx)[80] to derive simple estimates of pollution transport on a 36 by 36-kilometer grid for the United States.[81] As a result, EASIUR provides relatively accurate estimates of air pollution damage based on the location of emissions without the cost of complex and time-consuming modeling of detailed pollution transport. EASIUR also provides estimates of damages for three different stack heights—ground level, 150m, and 300m.

BenMAP

BenMAP is a tool created by EPA to calculate and map damages from ozone and $PM_{2.5}$ in the United States. BenMAP does not include pollution transport modeling. Users specify the change in ambient concentration of pollution that they expect will occur due to a policy, and BenMAP monetizes the health impacts of that change based on population density and pollution damage functions derived from academic publications. It includes high-resolution population data (a 12 by 12-kilometer grid) and can be customized with user-defined population data, baseline health data, and pollution damage functions.[82]

Air Pollution Emission Experiments and Policy Analysis Model

Air Pollution Emission Experiments and Policy analysis models county-by-county marginal damage estimates for SO_2, NOx, $PM_{2.5}$, PM_{10}, NH_3, VOCs. This model allows specification of stack height. This is important in locations like New York City, where the combination of low stacks and large population combine to create high marginal damages for peak generators that often have relatively high emissions rates.[83]

Co-Benefits Risk Assessment

The Co-Benefits Risk Assessment (COBRA) tool from EPA uses a simple pollution source-receptor matrix and a subset of the BenMAP health damage functions to estimate county-level damages from the creation of secondary $PM_{2.5}$ from emissions of NOx, SO_2, NH_3, $PM_{2.5}$, and VOCs. Like BenMAP, COBRA can be modified with custom population, baseline health, and baseline emission data as well as custom damage functions. COBRA damages are based on mortality and morbidity due to nonfatal heart attacks and cardiovascular illness.[84]

Table 3: Tools to Calculate Damage per Unit of Emissions

Tool	Geographic Granularity	Additional Data Requirement	Pollutants Covered	Notes	Source
Custom model	Variable	High	ozone (NOx,VOC), $PM_{2.5}$ (directly emitted $PM_{2.5}$, NOx, VOC, SO_2), air toxics	Geographic-specific damage estimates based on: • Air transport • Ambient concentrations • Population • Comorbidity	Bay Area Air Quality Management District Multi-Pollutant Evaluation Method (2017)
BenMAP	High (default); Variable (custom)	Medium (default); Varies (custom)	ozone, $PM_{2.5}$	• Translates all pollutants into secondary PM & ozone • Driven primarily by mortality • Can input own data	U.S. EPA
EASIUR	36 km	Low	SO_2, NOx, NH_3, $PM_{2.5}$	• Detailed air transport model • Seasonal damages	Heo, Adams, and Gao (2016)
AP2	County	Low	SO_2, NOx, VOC, NH_3, $PM_{2.5}$, PM_{10}	• Accounts for air transport • Broader monetized damage categories	Muller, Mendelsohn, Nordhaus (2011)
COBRA	State or county	Low	$PM_{2.5}$ (directly emitted $PM_{2.5}$, NOx, VOC, SO_2)	• Recently updated (2017) • Previously used by NY PSC • Accounts for air transport • Driven primarily by mortality	U.S. EPA (2017)

Greenhouse Gases – Methodology for Calculating Damage per Unit of Emissions

Damages from greenhouse gases do not depend on the time or location of release, making the calculation of their damage per unit of emissions particularly straightforward.[85] The Interagency Working Group's Social Cost of Carbon is the best estimate of the damages caused by greenhouse gas emissions.[86]

The Social Cost of Carbon is the net-present value of damage caused by the emission of one metric ton of carbon dioxide today. The emissions of greenhouse gases like methane and nitrous oxide from electricity generation can be translated into carbon dioxide-equivalent units using methodologies developed by EPA.[87] The Social Cost of Carbon can then be used to calculate the damage per unit of emissions of all greenhouse gases.

The Interagency Working Group first developed the Social Cost of Carbon in 2010 and updated the estimate in 2013 and 2015.[88] In 2016 and 2017, the National Academies of Sciences issued two reports that recommended future improvements to the methodology.[89] In response to those reports, researchers at Resources for the Future and the Climate Impact Lab are working on further updates.[90]

The Interagency Working Group's estimate has been repeatedly endorsed by government reviewers, courts, and experts. In 2014, the U.S. Government Accountability Office reviewed the Interagency Working Group's methodology and concluded that it 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.[91] In 2016, the U.S. Court of Appeals for the Seventh Circuit held that relying on the Interagency Working Group's estimate was reasonable.[92] And though the current Administration recently withdrew the Interagency Working Group's technical support documents,[93] experts continue to recommend that agencies rely on the Interagency Working Group's Social Cost of Carbon estimate as the best estimate for the external cost of greenhouse gases.[94]

Step 4: Monetize the Avoided Externality from Displaced Generation

Once the displaced resource has been identified and both the emissions rates and the damage per unit of emissions are known, these two values can be multiplied to get the monetary value of avoided damages per unit of generation.

If other existing policies already internalize externalities, such as a cap-and-trade program, an additional step to take these policies into account is necessary. Failing to take these policies into account could lead to double counting of the benefits generated by pollution reduction. To see this, consider a case where bulk system generators are subject to a policy that requires payment per ton of CO_2 emitted. The cost of operation for such emitting generators will be higher, and therefore they would submit higher bids to the wholesale electricity market. These higher bids would result in a higher equilibrium price in the market, so any resource that did not emit CO_2 (or emitted less CO_2 than the marginal resource) would receive the benefit of this higher price. In this way, zero or low emitting resources—like a clean DER—would be incentivized to produce more, and high emitting resources would be incentivized to either reduce their emissions or to produce less. If DERs also received direct payments for the full environmental and public health externality of emissions on top of this price increase, the result would be double payment for the same benefits.

If the existing policies do not fully internalize the externality from pollution, then DERs should receive payment that is sufficient to achieve full internalization. States participating in the Regional Greenhouse Gas Initiative (RGGI), a cap-and-trade program run by nine states in the Northeast, provide a good example. Generators in these states that are larger than 25 megawatts must pay for emissions of CO_2 by purchasing emissions permits under RGGI.[95] If the generator displaced by a DER is a participant in RGGI, then the price in the wholesale market already incorporates a payment for CO_2 emissions, and the monetized value of avoided emissions should take that into account. Current and forecasted RGGI permit prices, however, are not sufficient to fully internalize the external damage from CO_2, so clean DERs should still receive a payment for CO_2 emissions that they avoid. The payment should be reduced to reflect the degree to which the CO_2 externality has been internalized by RGGI.

Numerically, consider a case where the displaced resource is a combined-cycle natural gas plant that emits one ton of CO_2 per MWh of generation.[96] If there were no policies that required the displaced generator to pay for carbon emissions, then the value of avoided damages from each kWh injection would be the emissions rate times the external damage per unit of emissions. The external damage caused by carbon dioxide, as discussed in the previous section, is given by the Social Cost of Carbon and the central estimate is currently around \$46 per metric ton in 2017 dollars.[97]

$$\textbf{External value of avoided } \mathbf{CO_2} = 1\ \frac{kg\ CO_2}{kWh}\ \times\ 0.046\ \frac{\$}{kg\ CO_2e} = 0.046\ \frac{\$}{kWh}$$

Therefore, for every kWh of displaced generation, a zero-emitting DER would provide a benefit of roughly 5 cents by internalizing the externality from CO_2 emissions.

The payment for a concurrently existing cap-and-trade policy such as RGGI changes this calculation. The current RGGI price is around $4 per metric ton of CO_2. If the displaced generator is paying for RGGI permits, then $4 of the external cost of CO_2 has already been internalized, meaning that the uninternalized damage from CO_2 is $46–$4=$42. The value of avoided damage from CO_2 in this case would be:

$$\textbf{External value of avoided } \mathbf{CO_2} \textbf{ with RGGI} = 1\ \frac{kg\ CO_2}{kWh} \times (0.046 - 0.004)\ \frac{\$}{kg\ CO_2} = 0.042\ \frac{\$}{kWh}$$

The value of avoided external damage falls to reflect the fact that some of the external damage from carbon has already been internalized.

As another example, consider an alternative policy that is being discussed in several jurisdictions: carbon pricing. If a carbon charge is levied on electricity sold in a state, the charge would raise the price that wholesale electricity generators pay for carbon emissions and hence help internalize the externality. If this charge is based on the Social Cost of Carbon, then the external value of avoided emissions of CO_2 would fall to zero since the externality would be fully internalized.

$$\textbf{External value of avoided } \mathbf{CO_2} \textbf{ with charge} = 1\ \frac{kg\ CO_2}{kWh} \times (0.046 - 0.046)\ \frac{\$}{kg\ CO_2} = 0.00\ \frac{\$}{kWh}$$

In practice, the benefits from implementing a carbon charge in the state would come from both the incentive it would provide to clean generation and the disincentive to emitting generation, leading to a higher likelihood of the displaced generator having a lower emissions rate as well.

When setting the level of payment for other pollutants, policies including the Cross-State Air Pollution Rule (CSAPR) for NOx and SO_2, the Mercury Air Toxics Standard (MATS), and other future policies should also be taken into account. In the case of a policy like the RGGI cap-and-trade program, discussed above, a positive permit price that results from a binding cap should be taken into account by reducing the payment to DERs in proportion to the amount of the environmental and public health externality that has been internalized. For other programs, like CSAPR, where the cap is currently not binding and the permit price has settled near $0, no adjustment needs to be made.[98] If the cap binds in the future and prices rise above zero, then the payment to DERs would need to be adjusted.

The table below summarizes recent values of the damage per unit of generation from three different analyses done by different state and federal agencies. As the table shows, these different agencies come to similar conclusions regarding the value of avoiding these different pollutants.

Table 3: Examples of Dollar Value of Average Damage per MWh[99]

Pollutant	2016 EPA RIA	New York DPS	Bay Area Clean Air Plan
SO_2	$76 to $171 per MWh	$52 to $55 per MWh	$77 per MWh
NOx	$4 to $12 per MWh	$5 per MWh	$3 per MWh
$PM_{2.5}$	$7 to $16 per MWh		$22per MWh

Step 5: Monetize and Subtract DER Damages

The final step is to take into account any emissions generated by the DER itself. Distributed energy can come from non-emitting resources like solar panels or small wind turbines or it can come from emitting resources like combined heating and power generators, diesel generators, or small natural gas fuel cells. In fact, the Department of Energy estimates that the majority of DERs in the United States are emitting backup generators, and that in 2006, 42% of DER energy produced in the country came from combined heating and power.[100] If the DER emits pollutants, then those emissions and the damage they cause must be taken into account to accurately quantify the environmental and public health values of the resource. Damages from energy storage systems that are charged by emitting resources should be calculated similarly. In this case, damages from the DER's own emissions must be calculated and netted out from the value of emissions avoided by the DER. In cases where the DER does not emit, this additional step is not necessary, and the calculation of environmental value is simply the external value of avoided emissions calculated in the previous step.

Step 5A: Monetize the Externality from DER

If the DER emits pollutants, then the externality associated with emission of those pollutants must be accounted for, in the same way that the value of emissions from displaced generation was calculated in Steps 2, 3, and 4. First, policymakers need to know the DER's emissions rate for each pollutant. Lack of data on emissions rates presents a unique challenge for calculating damages from DERs. Resources like eGrid and the National Emissions Inventory do not record emissions or generation for very small generators. Instead, policymakers will likely need to rely on engineering estimates of emissions rates. As an alternative, policymakers could also use EPA emissions standards for non-road generators to estimate emissions.[101] Note that fossil-fuel-burning DERs generally produce higher emissions per unit of generation than otherwise comparable, large generators because the latter benefit from returns to scale in generator efficiency.[102]

Second, the policymaker must determine the damage per unit of emissions given the DER's location, time, and pollutants emitted. Damages per unit of emissions from DERs will also likely be different than from a similarly located large generator given that large generators generally have tall stacks that allow pollutants to disperse their over a larger area. Moreover, since DERs are generally located near load centers, they are also generally located nearer to areas of relatively high population density.[103] Proximity to higher population will raise the damage per unit of emissions from emitting DERs.

Using these numbers, the value of damage per unit of electricity generation can be calculated for the DER in the same way that the value is calculated for larger generators. In particular, the value per unit of generation will be the sum across all pollutants of the emissions rate times the damage per unit of emissions.

Step 5B: Subtract the Value of DER Emissions from the Value of Avoided Emissions

The last step for finding the environmental and public health value of DERs is to subtract the value of emissions from the DER calculated in Step 5A from the value of avoided emissions calculated in Step 4. Subtracting these two values must be the last step of the process. In other words, the dollar value of damages per unit of generation from the two resources should be calculated first, then the value of damage from the DER should be subtracted from the value of damage from the displaced resource. This procedure will correctly estimate the net environmental value of the DER by including differences in emissions rates and damage per unit of emissions discussed above. Incorrect calculations would net out either generation or emission before calculating the damages. Netting out generation first would not account for unique emissions by the two resources. Netting out emissions first would not account for the differences in location and exposed population between the two resources.

For instance, consider a case where the DER emits pollution in a high population area while the displaced resource would have emitted pollution in an area with lower population. The damage per unit of emissions is higher from the DER, but if the emissions are first subtracted from each other, then this difference between the two resources would be lost. In such a case, the DER would be erroneously incentivized to produce more electricity, increasing the damage experienced by the high population area.

If damage per unit of generation from the DER is high enough, then the net environmental value of the DER could be negative. This might be the case, for instance, if a diesel generator located in close proximity to a high-population area is displacing generation from a relatively clean natural gas plant located further from a populated area.[104] In these cases where the DER causes more environmental damage than it avoids, it should be penalized for that damage. In other words, the "compensation" for the environmental and public health value may be negative. Failing to do so would also fail to fully internalize the environmental externality associated with emissions.

Example Calculation

To illustrate the calculation of the value of DER using all of the above steps, consider an example of DERs in New York State. New York's current generation mix primarily includes hydropower, nuclear, natural gas, oil, and renewables.[105] Figure 2 shows a representative dispatch curve for New York. During periods of low electricity demand, a DER might offset hydro or nuclear generators, resulting in no avoided emissions. During these periods, the environmental and health value paid to the DER would be zero for a zero-emitting DER and would be negative for any DER like a diesel generator that produces emissions.

During periods with near-average load, the marginal fuel is natural gas. Typical natural gas generators in New York emit relatively low levels of NOx and PM, and moderate levels of CO_2. They do not emit SO_2. As demand rises during periods of particularly high load, oil becomes the marginal fuel and the emissions per unit of generation rise. Currently, New York does not produce any power from coal. A small amount of biomass production occurs in the state, but biomass has, historically, not been the marginal fuel in any region of the state.[106] During the course of a single day, the marginal generator might change from zero-emitting nuclear, to gas, and to oil and back again as load shifts. Table 4 summarizes the emissions rates for typical gas and oil generators in the state. These emissions rates provide the necessary data for Step 2 of the method described above.

Table 4: Average Emissions Rates for Fossil Fuel Generators in New York[107]

Fuel Type	SO_2 (kg/MWh)	NOx (kg/MWh)	CO_2 (kg/MWh)	$PM_{2.5}$ (kg/MWh)
Oil	2.10	2.62	1059.3	0.35
Biomass	0.16	2.71	481.7	0.02
Gas	0.00	0.12	397.3	0.02

The damages from emissions depend on both the location of the avoided emissions and the time of year. For this example, consider the damages from primary $PM_{2.5}$, SO_2, and NOx as given by EASIUR for two locations in the New York. These damages are shown in Table 5. Per unit of emissions, fine particulate matter is the most damaging of the three pollutants. In densely populated Queens County in New York City, damages per unit of particulate matter are much higher than damages in sparsely populated Franklin County. Moreover, pollution emitted in the two locations disperses to areas with much different populations. Emissions from a generator in Queens affect not only residents of Queens County, but other residents in New York City and Long Island. For these three pollutants, damages are higher in the spring and summer than in the winter or fall. In the EASIUR model, these different damages are largely a function of changes in pollution transport due to seasonal weather changes as well as seasonal differences in the rate at which primary pollutants become particulate matter.

The bottom of Table 5 shows the damages from emissions of CO_2.[108] As discussed above, damages from CO_2 do not depend on the time or location of the emissions. In this example, we have chosen the current Social Cost of Carbon minus a hypothetical $5 price for permits in the Regional Greenhouse Gas Initiative.

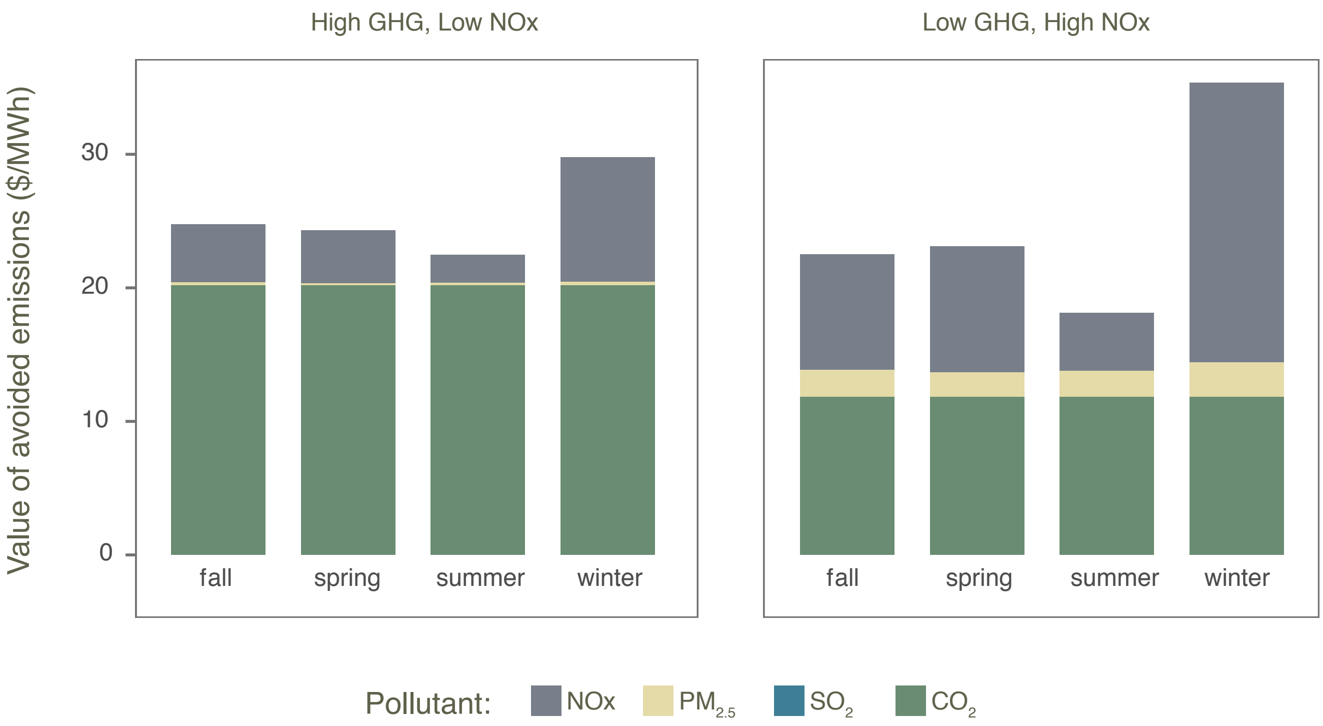
Table 5: Damage Per Unit of Emissions in Two Regions of New York[109]

PM$_{2.5}$ ($/kg)				
Population	Winter	Spring	Summer	Fall
High	355	872	712	316
Low	107	48	50	80
NOx ($/kg)				
Population	Winter	Spring	Summer	Fall
High	19	133	38	38
Low	21	4	2	4
SO$_2$ ($/kg)				
Population	Winter	Spring	Summer	Fall
High	12	102	71	21
Low	23	31	35	23
CO$_2$ ($/kg)				
Population	Winter	Spring	Summer	Fall
High	0.04			
Low	0.04			

Putting together the emissions rates from Table 4 and the damage per unit of emissions in Table 5, the environmental and health value for a zero-emitting DER can be calculated. For example, if a typical gas-powered generator was on the margin in the high-population, downstate region in the spring, then a zero-emitting DER would create roughly 5 cents of value per kWh of generation. In the lower-population upstate region, this value would be lower—around 2 cents per kWh. If higher-emitting fuels like oil were on the margin, then the value of DERs would be even higher. Previous publications show that oil heating and power generation lead to particularly high environmental and health damages in the New York City area.[110] In contrast, if a zero-emitting resource like hydro power were on the margin, then a zero-emitting DER would create zero additional environmental value.

Figure 4 shows how the environmental and health value varies even among similar generators. The generator in the left panel is relatively inefficient—emitting a larger amount of carbon dioxide per unit of electricity generation than a typical plant in the state—but it is located in a sparsely populated area where NOx and PM$_{2.5}$ emissions reach a smaller population. The generator in the right panel is relatively efficient, but its emissions of local air pollutants reach a larger population, increasing the value of avoiding those emissions.[111]

Figure 4: Value of Avoided Emissions from Two Natural Gas Plants



The figure shows the value of avoided emissions for natural gas generators in New York state. The generator in the left panel emits more pollution per unit of generation than the typical gas generator in New York, but it is located in a sparsely populated area where NOx and PM2.5 emissions reach a smaller population. The generator in the right panel is located in a heavily populated area, so despite being relatively low emitting, its emissions of local air pollutants cause more health damage, increasing the value of avoiding those emissions.

Conclusion

Distributed energy resources can provide substantial value to a state by reducing the need for large-scale bulk system generation, thereby reducing pollutant emissions. The environmental and public health damage from this pollution is often imposed on vulnerable populations. As state utility regulators implement new compensation policies for these distributed resources, a key component of those policies should include payment for that value.

A straightforward five-step methodology, relying on existing or readily accessible tools, can be used to calculate the environmental and public health value of DERs. These tools can allow utility regulators to implement a compensation scheme that rewards DERs when and where they most enhance social welfare.

The methodology presented here is flexible enough to accommodate a variety of data and resource constraints. State regulators should weigh the tradeoffs between accuracy and administrability of different methods to calculating environmental and health value, pick the tools that are as accurate as possible given the tradeoffs, and then update their method when feasible.

Endnotes

[1] Different states have implemented different definitions of DERs. *See* Staff Subcommittee on Rate Design, Nat'l Ass'n Regulatory Util. Comm'rs, Distributed Energy Resources Rate Design and Compensation 43 (2016), https://pubs.naruc.org/pub/19FDF48B-AA57-5160-DBA1-BE2E9C2F7EA0.

[2] *Id.* at 133-136, 142.

[3] Richard L. Revesz & Burcin Unel, *Managing the Future of the Electricity Grid: Distributed Generation and Net Metering*, 41 Harv. Envtl. L. Rev. 43, 78-91 (2017), http://policyintegrity.org/files/publications/Managing_the_Future_of_the_Electricity_Grid.pdf [hereafter Revesz & Unel, *Distributed Generation*]; Richard L. Revesz & Burcin Unel, *Managing the Future of the Electricity Grid: Energy Storage and Greenhouse Gas Emissions*, 42 Harv. Envtl. L. Rev. (2018), http://harvardelr.com/wp-content/uploads/2018/03/revesz_unel.pdf [hereafter Revesz & Unel, *Energy Storage*].

[4] In fact, every resource that avoids emissions—that is, any generating resource that emits less than the resource that would have generated instead—should be paid commensurate with the value of avoided health, climate, and economic damage. This report is specifically focused on DER because Public Utility Commissions in different states are presently focused on reforming the compensation structure of those resources. However, the methodology discussed could be applied more generally.

[5] Revesz & Unel, *Distributed Generation*, *supra* note 3, at 101-108.

[6] For more detail on the changing nature of federal-state divide over regulation of electricity, *see* Robert R. Nordhaus, *The Hazy "Bright Line": Defining Federal and State Regulation of Today's Electric Grid*, 36 Energy L.J. 203 (2015), http://felj.org/sites/default/files/docs/elj362/19-203-216-Nordhaus_FINAL%20%5B11.10%5D.pdf.

[7] Revesz & Unel, *Distributed Generation*, *supra* note 3, at 85-86; Revesz & Unel, *Energy Storage*, *supra* note 3.

[8] Revesz & Unel, *Distributed Generation*, *supra* note 3, at 85-86; Revesz & Unel, *Energy Storage*, *supra* note 3.

[9] *See* Derik Broekhoff et al., World Resources Institute, Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects (2005), http://www.ghgprotocol.org/sites/default/files/ghgp/standards_supporting/Guidelines%20for%20Grid-Connected%20Electricity%20Projects.pdf.

[10] To the extent that the counterfactual scenario identifies multiple generators that are offset by DERs, a generation-weighted average of displaced generators can be used in Steps 2-3.

[11] *Electric Generator Dispatch Depends on System Demand and the Relative Cost of Operation*, Energy Info. Agency: Today in Energy (Aug. 17, 2012), https://www.eia.gov/todayinenergy/detail.php?id=7590.

[12] *See* Broekhoff et al., *supra* note 9, at 63-65.

[13] *See* Erin Boyd, Dep't of Energy Office of Energy Policy & Sys. Analysis, Overview of Power System Modeling 17-19 (2016), https://energy.gov/sites/prod/files/2016/02/f29/EPSA_Power_Sector_Modeling_020416.pdf. The models particularly well suited to this type of analysis are "grid operation models" (otherwise known as "unit commitment and dispatch models" or "production cost models"). Models primarily designed for policy assessments, screening, and data analysis are not as well suited to this use. This includes EPA's AVoided Emissions and geneRation Tool (AVERT), a "high-level gross analysis" tool intended to estimate the emissions implications of new renewable capacity. *Id.* at 8. Nor are "capacity expansion models," such as IPM, NEMS, Haiku, ReEDS, and PLEXOS, which simulate generation and transmission *investment* decisions. *Id.* at 9, 11.

[14] Nathaniel Gilbraith & Susan E. Powers, *Residential Demand Response Reduces Air Pollutant Emissions on Peak Electricity Demand Days in New York City*, 59 Energy Policy 459, 461 (2013); Kyle Siler-Evans et al., *Regional Variations in the Health, Environmental, and Climate Benefits of Wind and Solar Generation*, 110 Proc. Nat'l Acad. Sci. 11768 (2012), www.pnas.org/cgi/doi/10.1073/pnas.1221978110.

[15] *Emissions & Generation Resource Integrated Database* (eGRID), U.S. Envtl. Prot. Agency (Feb. 15, 2016), https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid [hereafter eGrid (2016)].

[16] *See* Hao Cai et al., Updated Greenhouse Gas and Criteria Air Pollutant Emission Factors and Their Probability Distribution Functions for Electric Generating Units (2012), https://greet.es.anl.gov/publication-updated-elec-emissions.

[17] *Id.*

[18] *Frequently Asked Questions: What is the Efficiency of Different Types of Power Plants?*, U.S. Energy Info. Agency (May 10, 2017), https://www.eia.gov/tools/faqs/faq.php?id=107&t=3 (defining "heat rate").

[19] U.S. Energy Info. Agency, Electric Power Annual 2016 169 (2018), https://www.eia.gov/electricity/annual/pdf/epa.pdf.

[20] U.S. Envtl. Prot. Agency, Compilation of Air Pollutant Emission Factors Vol. I [hereafter AP-42] at 1.0-1 (5th ed. 1995), *available at* https://www3.epa.gov/ttn/chief/ap42/ch01/final/c01s00.pdf.

[21] *Id.* at 3.4-1, *available at* https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf.

[22] *Id.* at 3.1-1, *available at* https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf.

[23] *Id.*

[24] Coal plants can install selective catalytic reduction technology that reduces NO_x pollution by over 80%, flue gas desulfurization (aka "scrubbers") that can reduce SO_2 by up to 98%, and electrostatic precipitators and baghouse fabric filters that can drastically reduce PM emissions. Emanuele Massetti et al., ORNL/SPR-2016/772, Environmental Quality and the U.S. Power Sector: Air Quality, Water Quality, Land Use and Environmental Justice 24-27 (2017), https://energy.gov/sites/prod/files/2017/01/f34/Environment%20Baseline%20Vol.%202--Environmental%20Quality%20and%20the%20U.S.%20Power%20Sector--Air%20Quality%2C%20Water%20Quality%2C%20Land%20Use%2C%20and%20Environmental%20Justice.pdf. Combustion Turbines can utilize water injection, dry controls (varying the amount of air needed for combustion), and selective catalytic reduction technology. AP-42, *supra* note 22, at 3.1-7. For combined cycle plants and stationary ICE, there are not pollution control technologies that are in wide use, beyond technologies and operational practices to improve plant efficiency.

[25] Massett, *supra* note 25, at 110-111

[26] Felipe R. Ponce Arrieta & Electo E. Silva Lora, *Influence of Ambient Temperature on Combined-Cycle Power-Plant Performance*, 80 Applied Energy 261 (2004).

[27] *See* 40 C.F.R. part 75.

[28] *See* National Emission Standards for Hazardous Air Pollutants from Coal- and Oil-Fired Electric Utility Steam Generating Units, 77 Fed. Reg. 9,304, 9,370-72 (Feb. 16, 2012) (outlining compliance reporting options for the EPA Mercury and Air Toxics rule); *Stationary Source Emissions Monitoring*, , U.S. Envtl. Prot. Agency (last visited March 11, 2018), https://www.epa.gov/air-emissions-monitoring-knowledge-base/basic-information-about-air-emissions-monitoring#stationary.

[29] U.S. Envtl. Prot. Agency, The Emissions & Generation Resource Integrated Database Technical Support Document for eGRID with Year 2016 Data 18 (2018), https://www.epa.gov/sites/production/files/2018-02/documents/egrid2016_technicalsupport-document_0.pdf [hereafter eGrid (2016) TSD].

[30] *See Air Markets Program Data*, U.S. Envtl. Prot. Agency (last visited March 11, 2018), https://ampd.epa.gov/ampd/.

[31] *2014 National Emissions Inventory (NEI) Data*, U.S. Envtl. Prot. Agency, https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data (last visited March 11, 2018) [hereafter NEI (2014)]; U.S. Envtl. Prot. Agency, 2014 National Emissions Inventory Version 1Technical Support Document at 1-1, 1-5, 3-1 (Dec. 2016), https://www.epa.gov/sites/production/files/2016-12/documents/nei2014v1_tsd.pdf [hereafter NEI TSD].

[32] *Id.*

[33] Where state data was not available, EPA supplements the NEI with emissions using data reported directly to EPA (from CAMD data) and by multiplying heat input data by predetermined emission factors (based on AP-42). EPA also performs some modifications to state-reported data, including PM emission data. NEI TSD, *supra* note 32, at 2-7.

[34] EPA defines the NO_x ozone season as the period between May 1 and October 1. During this period, NO_x emissions are more likely to lead to the formation of ozone. *See, e.g.* Finding of Significant Contribution and Rulemaking for Certain States in the Ozone Transport Assessment Group Region for Purposes of Reducing Regional Transport of Ozone, 63 Fed. Reg. 57,356 (Oct. 27, 1998).

[35] U.S. Energy Info. Agency, Form EIA-923 Power Plant Operations Report Instructions https://www.eia.gov/survey/form/eia_923/instructions.pdf [hereafter Form EIA-923 Instructions]. Power plant owners report additional facility-level information on EIA form 860, which can be used to supplement the generation information reported on EIA form 923. *Form EIA-860 Detailed Data*, U.S. Energy Info. Agency (Nov. 9, 2017), https://www.eia.gov/electricity/data/eia860/.

[36] Form EIA-923 Instructions, *supra* note 35.

[37] EIA form 923 is submitted monthly by a large sample of potential respondents and annually by all units. U.S. Energy Info. Agency, Electric Power Monthly Technical Notes 14-15 (Feb. 2018), https://www.eia.gov/electricity/monthly/pdf/technotes.pdf.

[38] Emission factors are provided as pounds of emission per unit of fuel input. Therefore, in order to develop emission rates denominated in kWh, states would have to use the unit's heat rate. This may be available from EIA or through engineering estimates provided by the unit's manufacturer.

[39] AP-42, *supra* note 21, at Chapter 1, https://www3.epa.gov/ttn/chief/ap42/ch01/index.html

[40] *Id.* at Section 3.1, at https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s01.pdf.

[41] *Id.* at Section 3.4, https://www3.epa.gov/ttn/chief/ap42/ch03/final/c03s04.pdf.

[42] Rachel Leven, *Bad Science Underlies EPA's Air Pollution Program*, Scientific American, (Jan 29, 2018), https://www.scientificamerican.com/article/bad-science-underlies-epa-rsquo-s-air-pollution-program.

[43] Nat'l Energy Tech. Lab., Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity 458 (Nov. 2010), https://www.nrc.gov/docs/ML1217/ML12170A423.pdf.

[44] Gilbraith & Powers, *supra* note 14.

[45] eGrid (2016), *supra* note 15.

[46] eGrid (2016) TSD, *supra* note 29, at 16.

[47] *Id.*

[48] *Id.* 17.

[49] The notable exception is the inclusion of both annual NO$_x$ emissions and ozone season-specific NO$_x$ emissions. *Id.*

[50] *The Greenhouse Gases, Regulated Emissions, and Energy Use in Transpiration Model*, Argonne Nat'l Lab. (Oct. 9, 2017), https://greet.es.anl.gov/index.php.

[51] Hao Cai et al., *supra* note 16.

[52] Hao Cai et al., Updated Greenhouse Gas and Criteria Air Pollutant Emission Factors of the U.S. Electric Generating Units in 2010 (2013), https://greet.es.anl.gov/publication-electricity-13; Hao Cai et al., Update on Generation Efficiency and Criteria Pollutant Emissions of Integrated Coal Gasification Combined-Cycle Power Plant (2017), https://greet.es.anl.gov/publication-coal_igcc_2017.

[53] *See* Joshua Graff Zivin, Matthew Kotchen & Erin Mansur, *Spatial and Temporal Heterogeneity of Marginal Emissions*, 107 J. Econ. Behavior & Org. 248 (2014).

[54] Daniel A Axelrad et al., *Dose-Response Relationship of Prenatal Mercury Exposure and IQ: An Integrative Analysis of Epidemiologic Data.*, 115 Environ. Health Perspect. 609 (2007).

[55] Richard L. Revesz & Jack Lienke, Struggling for Air: Power Plants and the "War on Coal" 11 (2016).

[56] *Id.* at 10.

[57] *Particulate Matter (PM) Basics*, U.S. Envtl. Prot. Agency (last visited March 11, 2018), https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM; For a more detailed description of the health effects of PM$_{2.5}$ and ozone, *see* U.S. Envtl. Prot. Agency, Regulatory Impact Analysis for the Proposed Carbon Pollution Guidelines for Existing Power Plants at 4-16 to 4-24 (2014), https://www3.epa.gov/ttn/ecas/docs/ria/utilities_ria_proposed-carbon-poll-existing-egus_2014-06.pdf.

[58] Revesz & Lienke, *supra* note 55, at 11.

[59] *Id.*

[60] *Id.*

[61] Matthew MJ Neidell, *Information, Avoidance Behavior, and Health: The Effect of Ozone on Asthma Hospitalizations*, 44 J. Hum. Resources 450 (2009).

[62] Endangerment and Cause or Contributed Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 74 Fed. Reg. 66,495 (Dec. 15, 2009).

[63] D. B. Lobell, W. Schlenker & J. Costa-Roberts, *Climate Trends and Global Crop Production Since 1980*, 333 Science. 616 (2011).

[64] Intergovernmental Panel on Climate Change [IPCC], *Climate Change 2014 Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects*, 1132 (2014), http://www.ipcc.ch/report/ar5/wg2/.

[65] Axelrad et al., *supra* note 54.

[66] For instance, EPA, in their BenMAP tool for calculating the health effects of particulate matter exposure, estimate that the relationship between myocardial infarction and PM$_{2.5}$ follows the function (1-(1/((1-Incidence)*exp(b*(change in PM$_{2.5}$))+Incidence))), where "Incidence" is a measure of the baseline rate of myocardial infarction and b is a parameter derived from Annette Peters et al., *Increase Particulate Air Pollution and the Triggering of Myocardial Infarction*, 103 Circulation 2810–2815 (2001).

[67] Claire E. Reeves et al., *Potential for Photochemical Ozone Formation in the Troposphere Over the North Atlantic as Derived from Aircraft Observations During ACSOE*, 107 J. Geophys. Res. Atmos, no. D23, 2002, at ACH 14-1. Paola Michelozzi et al., *High Temperature and Hospitalizations for Cardiovascular and Respiratory Causes in 12 European Cities*, 179 Am. J. Respiratory Critical Care Med. 383 (2009).

[68] *See, e.g.*. Jerald L. Schnoor, Environmental Modeling: Fate and Transport of Pollutants in Water, Air, and Soil (1996).

[69] *Id.*

[70] Alex A. Karner, Douglas S. Eisinger & Deb A. Niemeier, *Near-Roadway Air Quality: Synthesizing the Findings from Real-World Data*, 44 Envtl. Sci. Tech. 5334 (2010).

[71] Reeves *et. al.*, *supra* note 67.

[72] Revesz & Lienke, *supra* note 55, at 108.

[73] U.S. Envtl. Prot. Agency, Regulatory Impact Analysis for the Clean Power Plan Final Rule at 4-23 (2015), https://www3.epa.gov/ttn/ecas/docs/ria/utilities_ria_final-clean-power-plan-existing-units_2015-08.pdf.

[74] *See* N.Y.C. Department of Health and Mental Hygiene, Air Pollution and the Health of New Yorkers: The Impact of Fine Particles and Ozone at 16, 22 (2013), https://www1.nyc.gov/assets/doh/downloads/pdf/eode/eode-air-quality-impact.pdf.

[75] Iyad Kheirbek, N.Y.C. Department of Health and Mental Hygiene, Estimating Morbidity and Mortality Attributable to Air Pollution in New York City 10 (2013), https://www.epa.gov/sites/production/files/2014-10/documents/hia_for_benmap_webinar_8.7.13.pdf.

[76] Bay Area Air Quality Mgmt. District, Spare the Air Cool the Climate: Final 2017 Clean Air Plan (2017), http://www.baaqmd.gov/~/media/files/planning-and-research/plans/2017-clean-air-plan/attachment-a_-proposed-final-cap-vol-1-pdf.pdf.

[77] David Fairley & David Burch, Bay Area Air Quality Mgmt. District, Multi-Pollutant Evaluation Method Technical Document 2016 Update 7 (2016), http://www.baaqmd.gov/~/media/files/planning-and-research/plans/2017-clean-air-plan/mpem_nov_dec_2016-pdf.pdf.

[78] Aleksandr Rudkevich & Pablo A Ruiz, *Locational Carbon Footprint of the Power Industry: Implications for Operations, Planning and Policy Making*, in Handbook of CO$_2$ in Power Systems 148 (Qipeng P. Zheng et al. eds., 2012) (showing that the highest levels of carbon dioxide emissions occur in the southern part of the state). Kathryn Hansen, *New NASA Images Highlight U.S. Air Quality Improvement*, NASA (June 26, 2014), https://www.nasa.gov/content/goddard/new-nasa-images-highlight-us-air-quality-improvement/ (showing that this same area also experiences higher ambient levels of non-carbon dioxide air pollution).

[79] Jinhyok Heo, Peter J. Adams & H. Oliver Gao, *Public Health Costs of Primary PM$_{2.5}$ and Inorganic PM$_{2.5}$ Precursor Emissions in the United States*, 50 Envtl. Sci. & Tech. 6061 (2016) (hereafter "EASIUR").

[80] *See* CAMx, http://www.camx.com/ (last visited March 11, 2018).

[81] Jinhyok Heo, Peter J. Adams & H. Oliver Gao, *Reduced-form Modeling of Public Health Impacts of Inorganic PM$_{2.5}$ and Precursor Emissions*, 137 Atmospheric Env't 80 (2016).

[82] Erik P. Johnson & Juan B. Moreno-Cruz, *Air-quality and Health Impacts of Electricity* (June 2015) (unpublished manuscript), http://jmorenocruz.econ.gatech.edu/wp-content/uploads/sites/62/2015/03/Health_Electricity_Congestion.pdf.

[83] Gilbraith & Powers, *supra* note 14, at 460.

[84] U.S. Envtl. Prot. Agency, User's Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) (3rd ed. 2017), https://www.epa.gov/sites/production/files/2017-10/documents/cobra_user_manual_september2017_508_v2.pdf.

[85] Leo Goldberg & Edith A. Müller, T*he Vertical Distribution of Nitrous Oxide and Methane in the Earth's Atmosphere*, 43 J. Optical Soc'y. Am. 1033 (1953); *and* IPCC, *supra* note 64.

[86] *See* Comments of Institute for Policy Integrity, *Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision*, Case No. 14-M-0101 (August 21, 2015), http://policyintegrity.org/documents/REV_Comments_Aug2015.pdf; Comments of Institute for Policy Integrity, *Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard*, Case No. 15-E-0302 (April 22, 2016), http://policyintegrity.org/documents/Comments_on_Clean_Energy_Standard_White_Paper.pdf; Comments of Institute for Policy Integrity, *Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard*, Case No. 15-E-0302 (July 22, 2016), http://policyintegrity.org/documents/Policy_Integrity_Comments_on_Staffs_Responsive_Proposal_for_Preserving_Zero-Emissions_Attributes.pdf; Joint Comments of Environmental Defense Fund and the Institute for Policy Integrity, *Proceeding in the Matter of the Value of Distributed Energy Resources*, Case 15-E-0751 (April 18, 2016), http://policyintegrity.org/documents/NYPSC_Comments_April2016.pdf.

[87] Alex L. Marten et al., Incremental CH$_4$ and N$_2$O Mitigation Benefits Consistent with the U.S. Government's SC-CO$_2$ Estimates, 15 Climate Policy 272 (2015).

[88] *See* Nat'l Acad. Sci., Eng'g & Med., Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near-Term Update 6 (2016), https://www.nap.edu/catalog/21898/assessment-of-approaches-to-updating-the-social-cost-of-carbon.

[89] Nat'l Acad. Sci., Eng'g & Med, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide 3 (2017), https://www.nap.edu/catalog/24651/valuing-climate-damages-updating-estimation-of-the-social-cost-of; eGrid (2016) TSD, *supra* note 29, at 6.

[90] *RFF's Social Cost of Carbon Initiative*, Resources for the Future, http://www.rff.org/research/collection/rffs-social-cost-carbon-initiative (last visited March 11, 2018); *Social Cost of Carbon*, Climate Impact Lab, http://www.climateprospectus.org/research-area/social-cost/ (last visited March 11, 2018).

[91] U.S. Gov't Accountability Off., GAO-14-663, Regulatory Impact Analysis: Development of Social Cost of Carbon Estimates 12-19 (2014), https://www.gao.gov/products/GAO-14-663.

[92] *Zero Zone, Inc. v. Dep't of Energy*, 832 F.3d 654, 677-79 (7th Cir. 2016).

[93] Exec. Order No. 13,783 § 5, 82 Fed. Reg. 16,093, 16,095-96 (Mar. 31, 2017).

[94] *See* Richard Revesz *et al.*, *Best Cost Estimate of Greenhouse Gases*, 357 Science 655 (2017).

[95] *See Elements of RGGI*, The Regional Greenhouse Gas Initiative https://www.rggi.org/design/overview/regulated_sources (last visited March 11, 2018).

[96] These example values are based on the Bethpage combined-cycle natural gas generator and come from the 2014 editions of eGrid and NEI. The calculations are the authors' own.

[97] Interagency Working Group on the Social Cost of Greenhouse Gases, Technical Update on the Social Cost of Carbon for Regulatory Impact Analysis (2016), https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc_tsd_final_clean_8_26_16.pdf [hereafter IWG (2016)].

[98] *See 2017 SO_2 Allowance Auction*, U.S. Envtl. Prot. Agency (Apr. 20, 2017), https://www.epa.gov/airmarkets/2017-so2-allowance-auction-0.

[99] Each column shows examples of the dollar value of damages from emissions of SO_2, NO_x, and $PM_{2.5}$ (direct) in 2016 dollars. U.S. Envtl. Prot. Agency, *supra* note 73, at 4-23; Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision, Staff White Paper on Ratemaking and Utility Business Models, PSC Case No. 14-M-0101 (July 28, 2015), at C-9; and the Bay Area Air Quality Mgmt. District, *supra* note 76, at C/3.

[100] U.S. Dep't of Energy, The Potential Benefits of Distributed Generation and Rate-Related Issues That May Impede Their Expansion ii (2007), https://www.ferc.gov/legal/fed-sta/exp-study.pdf.

[101] *See, e.g.,* U.S. Envtl. Prot. Agency, EPA-420-B-16-022, Nonraod Compression-Ignition Engines: Exhaust Emission Standards (2016), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OA05.pdf.

[102] *Environmental Impacts of Distributed Generation*, U.S. Envtl. Prot. Agency, https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts#impacts (last visited March 11, 2018).

[103] U.S. Dep't of Energy, *supra* note 100, at 7-3.

[104] If the displaced resource is non-emitting like utility scale renewables or hydro power, then any emitting DER would have a negative environmental value.

[105] *Real Time Fuel Mix*, N.Y. Indep. Sys. Operator (March 12, 2018 2:55 pm EST), http://www.nyiso.com/public/markets_operations/market_data/graphs/index.jsp?load=pie

[106] David Patton, Pallas LeeVanSchaick, & Jie Chen, Potomac Economics, 2016 State of the Market Report for the New York ISO Markets at A-10 (2017), http://www.nyiso.com/public/webdocs/markets_operations/documents/Studies_and_Reports/Reports/Market_Monitoring_Unit_Reports/2016/NYISO_2016_SOM_Report_5-10-2017.pdf.

[107] Emissions rates are calculated based on data from eGrid (2016), *supra* note 15, and NEI (2014), *supra* note 31.

[108] The values are for CO_2e, or carbon dioxide equivalent. This includes carbon dioxide as well as other greenhouse gas emissions in CO_2 equivalent values.

[109] Damages from SO_2, NO_x, and $PM_{2.5}$ come from EASIUR, *supra* note 79. Damages from CO_2 come from the IWG (2016), *supra* note 97.

[110] Kevin R. Cromer & Jason A Schwartz, Inst. for Policy Integrity, Residual Risks: The Unseen Costs of Using Dirty Oil in New York City Boilers (2010), http://policyintegrity.org/files/publications/ResidualRisks.pdf.

[111] Data are from EPA eGrid (2016), *supra* note 15 and EPA NEI (2014), *supra* note 31. The $PM_{2.5}$ measure from NEI are based, in some cases, on engineering estimates and interpolation, which both introduce measurement error into the calculation.

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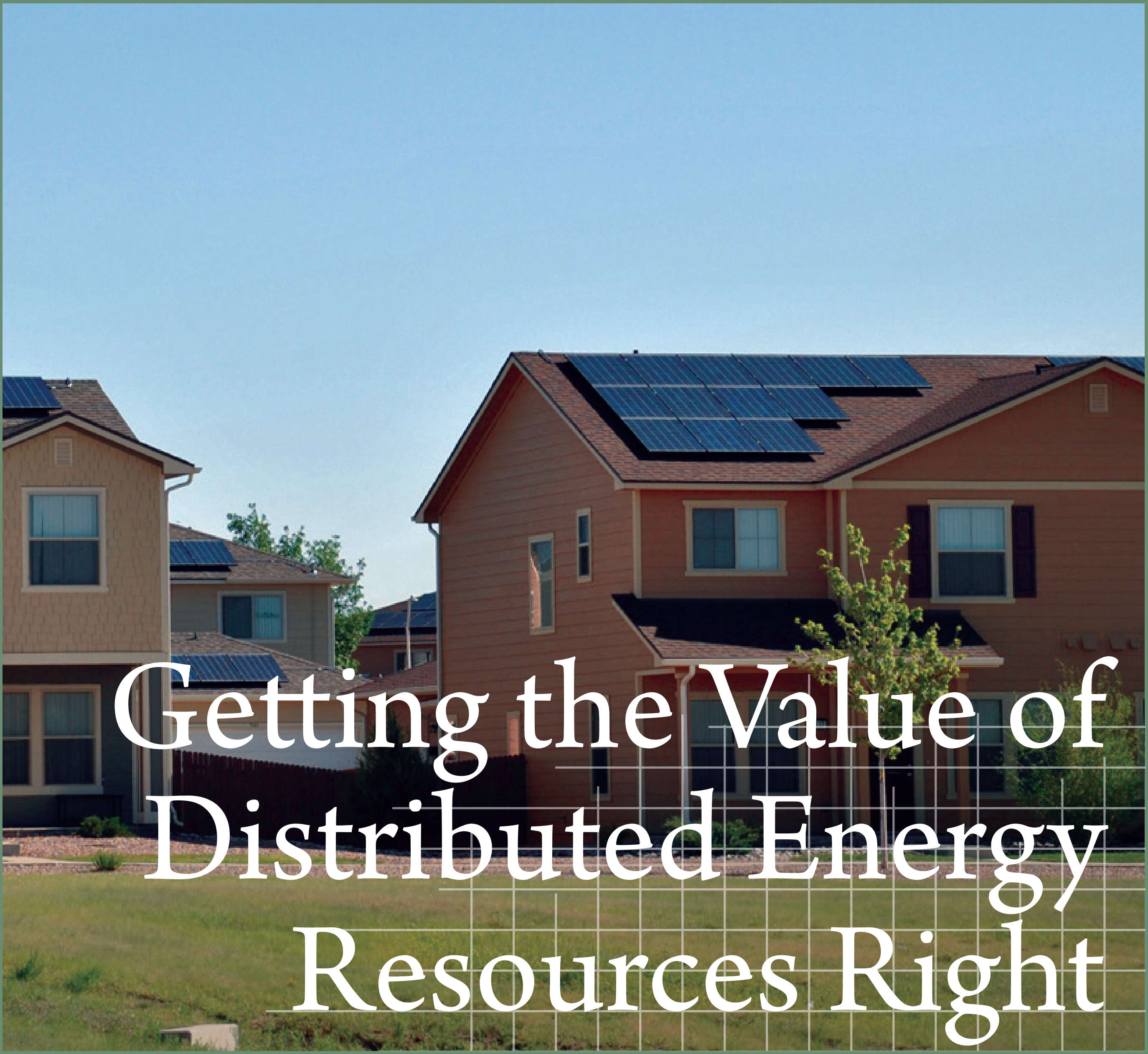

Getting the Value of Distributed Energy Resources Right

Using a Societal Value Stack

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Executive Summary

Distributed energy resources (DERs) are small assets that can reduce or supply some or all onsite demand for electricity. Some DERs, such as solar photovoltaic (PV) systems and combined heat and power (CHP) facilities, generate electricity. Others, such as energy storage and demand response resources, do not generate electricity themselves but can modify or reduce customers' electricity demand. DERs' presence has grown over the past decade, and their proliferation is sure to continue.

DERs' growing prevalence increases the pressure on state legislatures and public utility commissions to resolve disputes over how DERs should be compensated for providing services valued by utilities and their customers. The most contentious of these disputes relates to compensating DERs like solar PV and energy storage for the electricity that they export to the grid. Currently, 40 states use net energy metering (NEM) programs to compensate electricity exports from DERs. NEM credits DER owners for their exported excess generation against their consumption of electricity from centralized resources, based on the underlying retail rate. That rate is usually time-invariant and uniform across a utility's service territory. As a result, NEM-based compensation does not capture differences in the value of DERs across time or location. Diverse concerns over how NEM allocates the benefits and costs of DERs have led many states to examine their NEM programs, and in some cases to revise or abandon them.

This report analyzes a promising alternative to NEM, "value stacking." It describes the sources of value added by DERs and recommends adopting an approach to DER compensation that is inclusive of those values. Once DERs' presence in a given utility service territory has become significant, value stacking is preferable to other alternatives, because it:

- Compensates all DERs for the services they provide, using uniform criteria and based on measured performance;
- Reflects differences across times (e.g., "peak" versus "off-peak" demand) and locations (e.g., where congestion is absent versus where it makes it relatively expensive to deliver electricity services from the centralized grid);
- Recognizes the costs of emitting greenhouse gases and local pollutants and compensates DERs for avoiding them;
- Relies on a uniform, accurate compensation scheme to inform where DERs are installed and operated (instead of prescribing volumes or locations of DER capacity); and
- Is neutral with respect to technology and scale.

In addition to explaining the benefits of this value stacking methodology, the report also provides suggestions for how to implement this approach.

Introduction

Distributed energy resources (DERs) are small physical assets that can reduce or supply some or all onsite electricity demand ("load"). They tend to be located "behind the meter," meaning that they are owned and operated by electricity customers rather than utilities.[1] Some, but not all, types of DERs generate electricity; those that can do so, such as solar photovoltaic (PV) systems and combined heat and power (CHP) facilities, are called distributed generation (DG). Other types of DERs, such as energy storage and demand response resources, can modify or reduce customers' electricity demand, even though they do not generate electricity themselves. DERs' presence in the United States has been growing, and there is little reason to doubt that DERs will eventually become a standard feature of electricity systems nationwide.[2]

DERs can provide many services to the grid. For example, PV systems can reduce customers' need for electricity from the grid as well as inject electricity into the grid. Energy storage systems can modify customers' electricity demand throughout the day, reduce their peak demand, and help with system balancing. Currently, different types of DERs receive compensation through a variety of programs and mechanisms, some market-based, others regulatory. Demand response resources, for instance, can participate in wholesale or retail electricity markets in most states, individually or in aggregations.[3] Solar PV owners most often receive bill credits for the electricity they generate and export to the electricity grid. And the purchase and installation of energy-efficient assets can often be financed through utility- or third-party vendor-sponsored programs and property-assessed clean energy or "PACE" programs.

Today, as DERs are becoming more common, state legislatures and public utility commissions are wrestling with the question of how best to compensate them for providing these electricity services.[4] At present, the most contentious policy debates focus on how to compensate DERs that are capable of exporting electricity to the centralized grid, such as DG and some forms of energy storage.

Net energy metering (NEM) has been the predominant approach to compensating owners of DG. As of April 2019, 40 states, plus DC and four territories, use some form of mandatory NEM to assign a value to electricity that DERs inject into the grid.[5] Under NEM, generation in excess of what customers consume onsite is exported to the electricity grid

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[1] In a 2016 report, the National Association of Regulatory Utility Commissioners (NARUC) collected definitions used by several states and other authorities before suggesting the following definition:

> A DER is a resource sited close to customers that can provide all or some of their immediate electric and power needs and can also be used by the system to either reduce demand (such as energy efficiency) or provide supply to satisfy the energy, capacity, or ancillary service needs of the distribution grid. The resources, if providing electricity or thermal energy, are small in scale, connected to the distribution system, and close to load.

NARUC, Distributed Energy Resources Rate Design and Compensation 43-44 (2016), https://perma.cc/37A5-D5S6.

[2] *See generally* Ignacio J. Perez-Arriaga et al., Utility of the Future: An MIT Energy Initiative Response to an Industry in Transition 36 (2016), https://perma.cc/56VC-H8EN.

[3] "Aggregation" involves the coordination of multiple, dispersed DERs, and is usually conducted by an entity that also acts as a liaison between the DER owners and a buyer of the aggregated service they provide. DERs can interact with the bulk power system through an aggregator, usually a distribution utility or a third-party who bids the aggregated service offering into a wholesale market. *See* Scott Burger et al., *A review of the value of aggregators in electricity systems*, 77 Renewable & Sustainable Energy Revs. 395 (2017) (describing role and functions of aggregators).

[4] North Carolina Clean Energy Technology Center, The 50 States of Solar: Q1 2019 Quarterly Report Executive Summary (2019), https://perma.cc/PCR7-RC7P (cataloguing regulatory proceedings related to distributed solar in 43 states, DC, and Puerto Rico); *see also* Tom Stanton, Nat'l Reg'y Research Inst., Review of State Net Energy Metering and Successor Rate Designs (2019), https://perma.cc/2XCF-TQX8 (surveying recent and ongoing efforts).

[5] DSIRE/NC Clean Energy Ctr., Net Metering—April 2019 (2019), https://perma.cc/GLM4-9F87.

where it is distributed to other retail electricity consumers. DER owners are generally credited for this excess generation against their consumption for each billing period.[6] That is, under NEM, both excess generation and retail electricity service are valued at the same rate, based on the underlying retail rate that the customer faces.

States initially adopted NEM in large part because it was a simple mechanism that allowed customers to install and own DERs capable of injecting excess generation into the grid. It required no upgrades to electric meters, few if any changes to how utilities conducted billing, and no change to the legal status of DER owners even though they exported electricity to the grid. As a result, NEM allowed for DER integration without disrupting the rules or relationships that governed electricity service. NEM programs fostered growth in DERs, especially distributed solar PV.[7] As participation has grown, however, problems with NEM have become increasingly evident. First and foremost among those problems is that, because NEM is based on retail rates, whenever retail rates fail to reflect the costs of electricity service accurately, NEM likewise inaccurately values DERs.[8] This means, for instance, that NEM often *undercompensates* DERs for avoiding emissions of greenhouse gases and local pollutants.[9] And, in general, NEM does a poor job of guiding developers and would-be DER owners to put the right sort of DER in the right place, resulting in economically inefficient patterns of development.

A second, related problem is how NEM allocates the costs and benefits of DER owners' participation in the electricity grid. Specifically, utilities and others have argued that, under NEM, DER owners pay too little towards the cost providing access to reliable grid electricity when they get bill credits. The costs of DER owners' access are thus—so the argument goes—borne by other electricity consumers, who pay more to help make up the difference,[10] and by utilities that absorb the rest of the shortfall. Casting these cost allocations as misallocations leads to the conclusion that NEM runs afoul of core regulatory principles like cost causation.[11]

Concerns about NEM and responses to those concerns vary markedly across states. Reform efforts in California, Hawaii, and New York, for instance, aim to support DERs' further proliferation but ensure that it is cost-effective. Meanwhile, in Indiana, Kentucky, and Louisiana, reforms aim primarily to curb DERs' impacts on utility cost recovery. And in New Hampshire, Nevada, and Vermont, reforms aim to strike a balance between encouraging continued DER adoption while also curbing DERs' effects on utility cost recovery.

This report recommends that state policymakers, as they grapple with how to integrate DERs effectively, make two changes to their regulatory approaches to DER integration. First, any approach to DER compensation should be centered

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[6] Some states' programs now require customers to pay a "non-bypassable" charge or "minimum bill" that cannot be offset by credits for excess generation. *See* STANTON, note 4, at 23. Many programs also include provisions that allow customers to carry over excess credits across billing periods. *See, e.g.*, NV Energy, https://www.nvenergy.com/account-services/energy-pricing-plans/net-metering/net-metering-faqs (accessed Nov. 15, 2019).

[7] Stephen Comello & Stefan Reichelstein, *Cost Competitiveness of Residential Solar PV: The Impact of Net Metering Restrictions*, 75 RENEWABLE & SUSTAINABLE ENERGY REVS. 46, 46, 54 (2017).

[8] *See* Richard L. Revesz & Burcin Unel, *Managing the Future of the Electricity Grid: Distributed Generation and Net Metering*, 44 HARV. ENVTL. L. REV. 43, 71-77 (2017), https://policyintegrity.org/files/publications/Managing_the_Future_of_the_Electricity_Grid.pdf.

[9] Steven Sexton et al., *Heterogeneous Environmental and Grid Benefits from Rooftop Solar and the Costs of Inefficient Siting Decisions* 19 (Nat'l Bureau of Econ. Research, Working Paper No. 25241, 2018), https://perma.cc/TK7G-YPQ2 ("...more than 25 percent of states provide subsidies that are at least $0.05 per kWh less than avoided damages.").

[10] The term "cost shift" describes when costs incurred to serve one group of customers are paid, in part or in full, by another. Cost shift represents a departure from the regulatory principle of "cost causation," which holds that a customer should pay the costs incurred to provide that customer with benefits.

[11] *See, e.g.*, Sanem Sergici et al., *Quantifying Net Energy Metering Subsidies*, 32 ELECTRICITY J. 106632 (2019), https://doi.org/10.1016/j.tej.2019.106632 ("… NEM policies create a subsidy issue from non-DG customers to DG customers."); Willis Geffert & Kurt Strunk, *Beyond Net Metering: A Model for Pricing Services Provided by and to Distributed Generation Owners*, 30 ELECTRICITY J. 36, 37 (2017).

on a “value stack” framework that reflects diverse, time- and location-specific value categories. Second, the scope of these value categories should be consistent with the perspective of society as a whole, not just a utility or its ratepayers.

It is important to note, however, that these recommendations still represent a second-best alternative to rate design reforms that cause electricity prices to more accurately reflect the costs of providing electricity services. In particular, if rates reflected accurate costs—including those related to emissions—based on time and location, consumers could respond by changing their patterns of consumption and DER adoption and use in a socially efficient manner.[12]

Before fully explaining these recommendations, part I of this report offers some background about the electricity grid and its regulation to provide context, and part II describes the benefits of DER deployment. Part III begins by describing the origins and effects of NEM and the problems that result from using it to compensate DERs. It then explains how a value stack framework can translate multiple, time-and-location-specific inputs into a rate of DER compensation, with inputs reflecting DERs’ full value to society rather than merely the perspective of a utility or electricity consumers. The last part offers some conclusions.

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[12] *See generally* Richard L. Revesz & Burcin Unel, *Managing the Future of the Electricity Grid: Modernizing Rate Design*, 44 Harv. Envtl. L. Rev. (forthcoming 2020), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3373163.

I. Background

To comprehend the value provided by DERs, one must understand the components of the centralized electricity grid as well as what DERs are and what they can do.

The electricity grid's main components

The centralized electricity grid is made up of several parts. (See Figure 1.) The bulk power system encompasses large-scale generators and transmission facilities. Large generators are usually located some distance away from those who ultimately consume electricity. Transmission lines carry electricity at high voltage across most of that distance. Distribution lines carry it the rest of the way at lower voltage. The bulk power and distribution segments of the grid interact, but they are managed mostly independently of one another, such that the real-time balance of electricity generation and consumption effectively happens at two levels. Grid managers at each level have limited access to detailed, real-time information about operations on the other level.

Figure 1. Segments of the electricity grid and where DERs can interconnect to it.

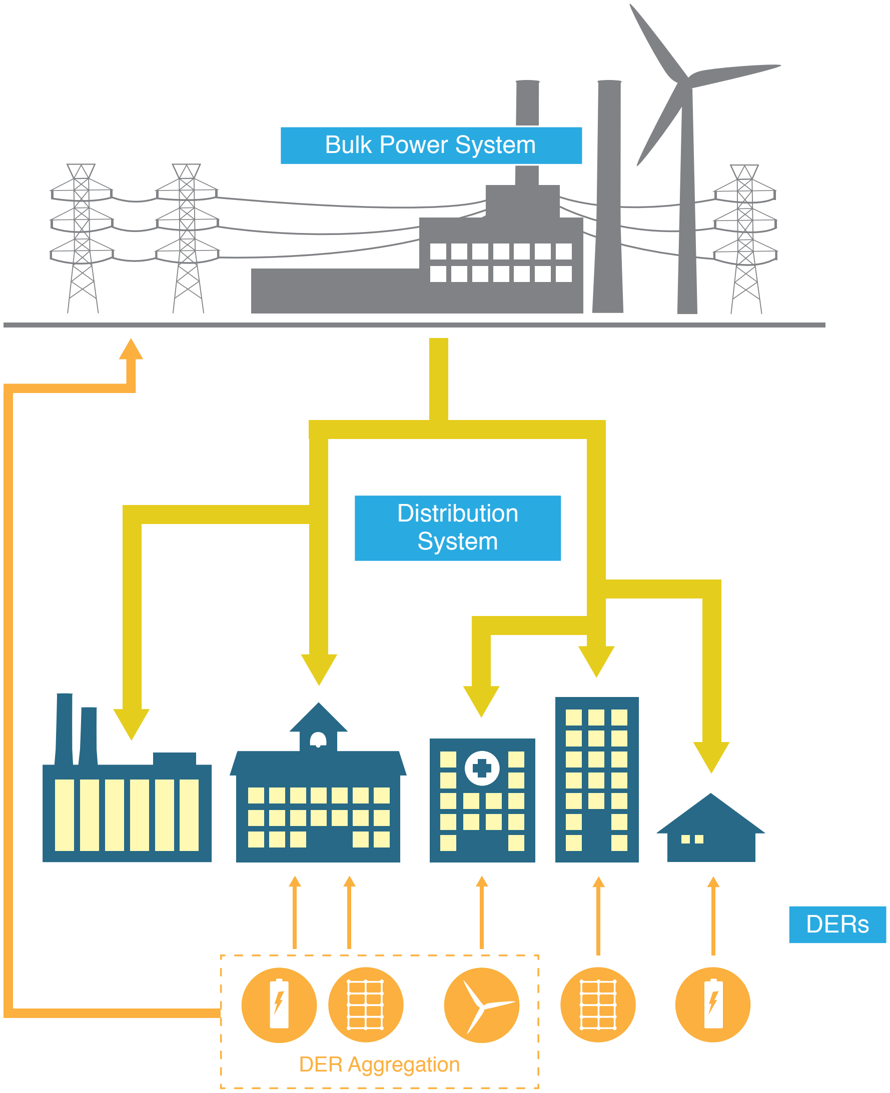

Figure 1 shows a simplified rendering of the electricity grid. Most generation and all transmission occurs in the bulk power system (above the line); electricity flows from there through the distribution system to customers (below the line). DERs generally interconnect to the distribution segment of the system, but can also participate in the bulk power system in aggregations. Where distribution grids have integrated both DERs and "smart" components, two-way flows of electricity and information have converted a once-centralized grid into a partly decentralized one.[13]

Distributed energy resources: a brief taxonomy

There are several subcategories of DERs, which are each comprised of a variety of physical devices and techniques (sometimes enabled by software and communications technology). Table 1 illustrates this point.

Table 1. DER subcategories and examples.[14]

Subcategory	Examples
Distributed generation	• solar PV • small-scale wind • CHP • fuel cell • microturbine • small reciprocating engine
Energy storage	• chemical batteries (lithium-ion, nickel-cadmium, flow, others) • battery-powered electric vehicles • chilled water heating/cooling systems
Demand response	• curtailable residential water heaters and pool pumps • appliances and programmable thermostats that respond to signals from the grid • building energy management systems
Energy efficiency	• LED lighting • improved building envelope insulation • improved seals on doors and windows • high-efficiency equipment and appliances

Although Table 1 lists particular assets or techniques separately, several of them can be deployed in combination.[15] Solar PV plus battery storage, for instance, is an increasingly popular combination. The combination ensures that the storage component is charged using a renewable primary energy source and that the owner will have access to electricity generated by the solar PV system even at times when the sun is not shining.

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[13] *See* JEFFREY J. COOK ET AL. EXPANDING PV VALUE: LESSONS LEARNED FROM UTILITY-LED DISTRIBUTED ENERGY RESOURCE AGGREGATION IN THE UNITED STATES (2018), https://perma.cc/3FCP-3XYH (describing efforts by 23 utilities to coordinate the operation of DER in their service territories so that they can perform ancillary services and enhance reliability).

[14] The assets and techniques listed are not exhaustive. For a more complete list, see LISA SCHWARTZ ET AL., LAWRENCE BERKELEY NAT'L LAB., ELECTRICITY END USES, ENERGY EFFICIENCY, AND DISTRIBUTED ENERGY RESOURCES BASELINE: DISTRIBUTED ENERGY RESOURCES, ch. 1 (2017), https://perma.cc/9LJY-L2VY. Table 1 also does not list all DER examples for each subcategory, and it omits large-scale energy storage and demand response assets, which tend to either be owned by commercial and industrial facilities or to be located in front of the meter, where they serve the bulk power system.

[15] *See generally* JOHN SHENOT ET AL., CAPTURING MORE VALUE FROM COMBINATIONS OF PV AND OTHER DISTRIBUTED ENERGY RESOURCES (2019), https://perma.cc/P63S-TGQR.

DERs differ in their ability to perform different services that are required for electricity system operation.[16] For example, solar PV can export electricity to the grid, while demand response can only reduce net load or modify load shapes. However, distributed solar PV cannot provide "black start" capability to restore service after an outage, but CHP and storage can.[17] DER profiles also vary with respect to how, how much, and for how long, they can perform some of those functions.[18]

Table 2. Potential functions of DERs.

Function	Type of DER					
	Solar PV*	Solar PV + Storage	Standalone Storage	CHP	Demand Response	Energy Efficiency
Generation	Yes, limited	Yes, limited	No	Yes	No	No
Generation capacity	Yes, limited	Yes, limited	No	Yes	Yes	Yes, limited
Voltage control	No	Yes	Yes	Yes	No	No**
Frequency regulation	No	Yes	Yes	Yes	Yes, limited	No
Spinning reserves	No	Yes	Yes	Yes	Yes, limited	No
Nonspinning reserves	No	Yes	Yes	Yes	No	No***
Flexibility to support renewables integration	No	Yes	Yes	Yes	Yes	No
Line loss reduction	Yes	Yes	Yes, limited	Yes	Yes	No**
Black start capability	No	No	Yes	Yes	No	No

** Newer inverters enable solar PV modules to perform a wider range of functions than those deployed even a few years ago. As new modules' prevalence grows, some of the "No" entries in this column—such as "Flexibility to support renewables integration"—will switch to "Yes."*
*** Conservation voltage reduction (CVR) is an exceptional form of energy efficiency that can provide voltage control and reduce line losses.*
**** A small subset of energy efficiency resources can bid to provide services in wholesale capacity markets.*

It is important to note that while Table 2 indicates various DERs' inherent abilities, DERs' ability to perform functions cost-effectively—or at all—also depends in part on the location and design of supporting infrastructure.[19]

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[16] The Smart Electric Power Alliance recently assembled a bibliography of reports that discuss the functions DER can perform. It indicates which reports focus on which categories of electricity service. TANUJ DEORA ET AL., SMART ELEC. POWER ALLIANCE, BEYOND THE METER: RECOMMENDED READING FOR A MODERN GRID 12 tbl.4 (2017).

[17] JOHN LARSEN & WHITNEY HERNDON, RHODIUM GRP. (prepared for U.S. Dep't of Energy), WHAT IS IT WORTH? THE STATE OF THE ART IN VALUING DISTRIBUTED ENERGY RESOURCES 11 (2017), https://perma.cc/KQ96-3C9U.

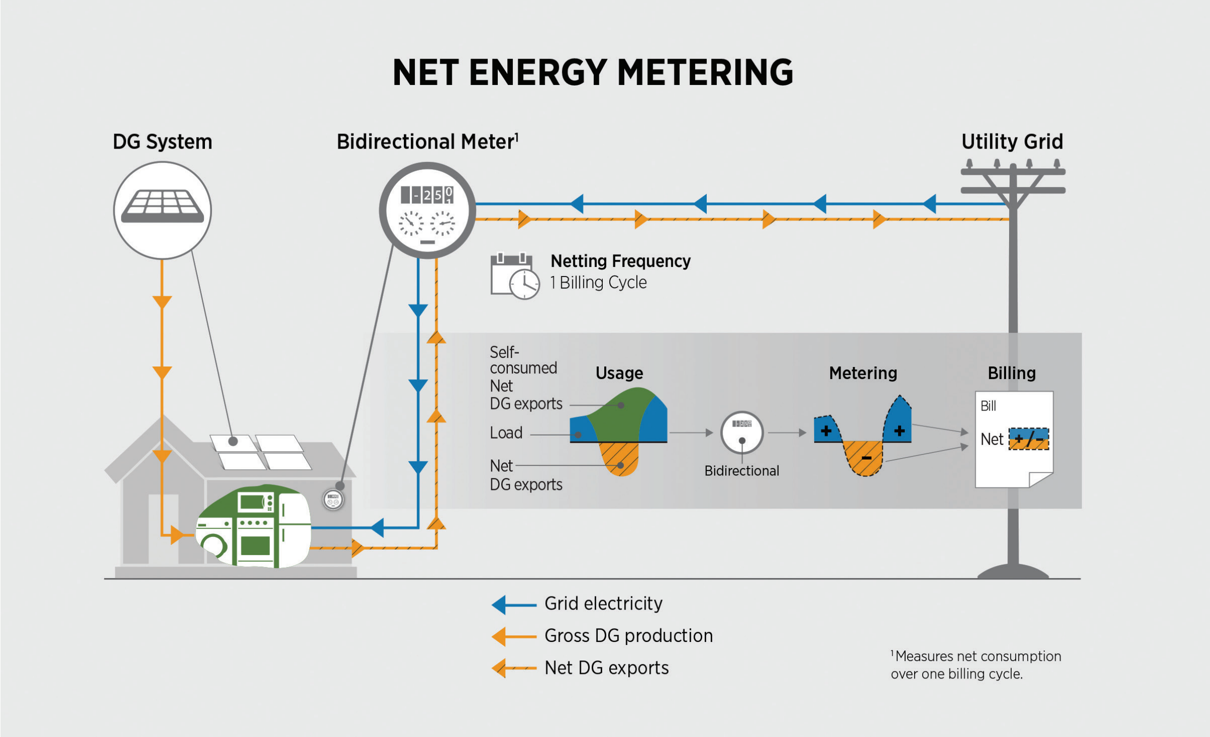
[18] RYAN EDGE ET AL., SMART ELEC. POWER ALLIANCE, DISTRIBUTED ENERGY RESOURCES CAPABILITIES GUIDE 6 (2016).

[19] *See* SAN DIEGO GAS & ELEC. CO., DISTRIBUTION RESOURCES PLAN; DEMONSTRATION PROJECT A: ENHANCED INTEGRATION CAPACITY ANALYSIS 30 fig.16 (2016), https://perma.cc/HJ44-UBJ8 (describing differences in solar PV, battery, and electric vehicle profiles under different circumstances).

Net energy metering

NEM programs vary in their particulars,[20] but the generic version of NEM is broadly representative. It involves a utility customer that has (1) an onsite DER capable of generating electricity, and (2) a single electricity meter. Essentially, when customers draw electricity from the grid, the meter runs forward, and when customers generate more than they consume, the excess flows to the grid and the meter runs backward.[21] Utilities charge customers at the retail rate, a volumetric, or per kilowatt-hour (kWh) charge, for their net consumption of electricity. This arrangement credits customers through their electricity bill for their excess generation. Notably, if electricity generated by DERs only reduces customers' net consumption from the grid without any excess flows, the arrangement resembles the adoption of energy efficiency measures that reduce electricity demand. The National Renewable Energy Laboratory developed Figure 2 to summarize NEM visually.

Figure 2. National Renewable Energy Laboratory's schematic of NEM, showing physical and financial interaction between DER owner and utility.[22]



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[20] For a survey of current NEM programs, see the "Programs" webpage of NC Clean Energy Technology Center's Database of State Incentives for Renewables & Efficiency, https://programs.dsireusa.org/system/program.

[21] Older, analog meters literally spin in reverse; newer metering technology, called advanced metering infrastructure or AMI, is digital and can track flows in both directions. *See* Qie Sun et al., *A Comprehensive Review of Smart Energy Meters in Intelligent Energy Networks*, 3 IEEE Internet of Things J. 464, 465-67 (2016). By 2018, 53% of electricity customers had AMI installed. U.S. Energy Info. Admin., Form EIA-861 (2018), Spreadsheet labeled "Advanced_Meters_2018," https://www.eia.gov/electricity/data/eia861/zip/f8612018.zip. This was up from 4.7% in 2008 and 37.6% in 2013. Fed. Energy Reg'y Comm'n, 2018 Assessment of Demand Response and Advanced Metering—Staff Report 3 tbl.2.1 (2018).

[22] Owen Zinaman et al., Nat'l Renewable Energy Lab., Grid-Connected Distributed Generation: Compensation Mechanism Basics 3 (2017), https://perma.cc/L9CB-Z8TL.

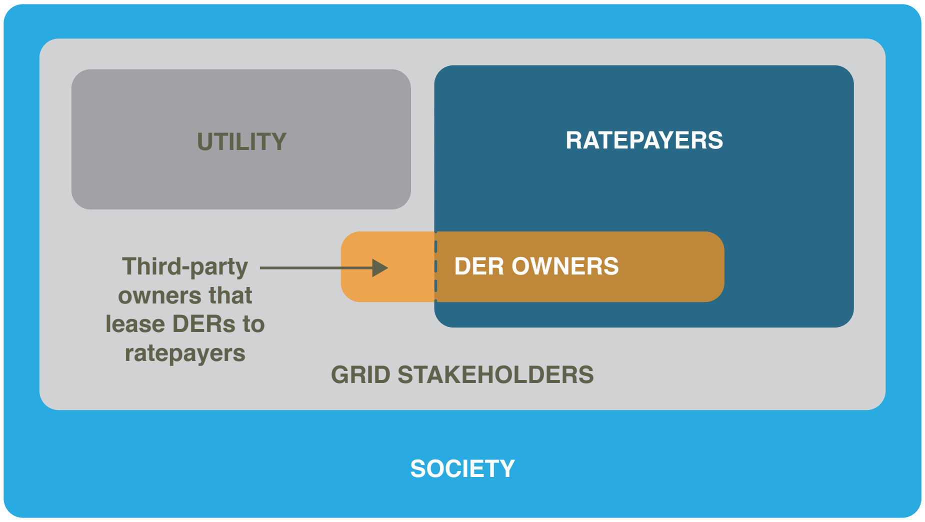
II. The value of distributed energy resources

Whether by reducing a customer's need to buy electricity from the grid, exporting excess electricity from that customer to the grid, or performing some other function listed in Table 2 above, DERs can reduce the need for operation of one or more components of the centralized grid. Assessing the value of DERs requires identifying these benefits and costs, then measuring those benefits and costs in comparison to the benefits and costs of the centralized resources that DERs would displace. As explained below, the first of these steps involves adopting one or more analytical perspectives. And the subsequent steps involve specifying where, when, and how the DERs being analyzed would operate, as well as a baseline scenario to which their operations can be compared.

Adopting the right perspective(s)

The state agencies charged with regulating electric utilities require estimates of a given investment's costs and benefits before authorizing utilities to pay for it using ratepayers' money. But because the economic value of the assets and systems that contribute to electricity service provision accrues differently to different stakeholders, deriving an estimate of that value requires adopting the perspective of one or more stakeholders. Figure 3 shows the overlapping perspectives of stakeholders affected by decisions to install and operate electricity resources, whether distributed or centralized. The perspective chosen determines three key aspects of valuation: (1) the scope of effects to be counted in the analysis, (2) whether to count them as benefits or costs, and (3) to whom and how much those benefits and costs accrue.

Figure 3. Overlapping perspectives on electricity-related benefits and costs.



Public utility regulatory commissions recognize the importance of perspective in at least some contexts—most often in relation to energy efficiency programs—and require utilities to employ one or more tests that embody prescribed perspectives when proposing to recover particular costs.[23] The five tests that were initially developed by California's Energy

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[23] *See* Nat'l Efficiency Screening Project, Database of State Efficiency Screening Practices, https://nationalefficiencyscreening.org/state-database-dsesp/ (accessed Oct. 20, 2019) (indicating tests prescribed in 46 states and the District of Columbia).

Commission and Public Utilities Commission in 1983,[24] and later adopted elsewhere, are summarized in Table 3 below. The entries in the "perspective" column indicate the scope of benefits and costs to be considered when implementing the corresponding test. The Participant Cost Test provides the perspective with the narrowest scope and the Societal Cost Test the broadest, with the others arrayed in between. Crucially, of those listed in table 3, only the societal perspective takes the costs of emissions—and the benefits of avoiding emissions—into account.

Table 3. Perspectives associated with tests of DER benefits and costs.

Perspective	Test
Society as a whole	Societal Cost
Utility system + customers participating in one or more sanctioned programs	Total Resource Cost
Utility system	Utility Cost
Impact on rates paid by all electricity customers	Rate Impact Measure
Customers who participate in a given program, e.g., NEM	Participant Cost

Many states direct utilities to use at least two of these perspectives when analyzing the value of energy efficiency investments,[25] in order to discern both the magnitude and distribution of those investments' benefits and costs. California and New York direct their utilities also to do so for DER compensation. Specifically, California's Public Utilities Commission recently updated its directive to utilities regarding cost-effectiveness analyses, instructing them to make the Societal Cost Test the primary analytic screen and also to apply, secondarily, the Total Resource Cost Test and Ratepayer Impact Measure to all DERs and supply-side resources.[26] And in New York, a 2016 Public Service Commission Order directs utilities to employ a standard benefit cost test, complete with societal, utility, and ratepayer perspectives, to assess the value of proposed DER procurements and energy efficiency projects. [27]

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[24] *See generally* CAL. PUB. UTILS. COMM'N, STANDARD PRACTICE FOR COST-BENEFIT ANALYSIS OF CONSERVATION AND LOAD MANAGEMENT PROGRAMS: JOINT STAFF REPORT (1983).

[25] *See* NAT'L EFFICIENCY SCREENING PROJECT DATABASE, *supra* note 23 (listing analytic perspectives prescribed for use by utilities in numerous states, including California, Minnesota, and New York). The National Energy Efficiency Screening Project, recognizing that jurisdictions vary in their policy objectives and treatment of particular costs and benefits as relevant, has developed a framework that regulators can use to develop a jurisdictionally specific Resource Value Test for identifying and estimating benefits and costs of investments in energy efficiency. NAT'L EFFICIENCY SCREENING PROJECT, THE RESOURCE VALUE FRAMEWORK: REFORMING ENERGY EFFICIENCY COST-EFFECTIVENESS SCREENING (2014), https://perma.cc/TQG6-9KBP. They plan to publish a manual in June 2020 on how to apply that framework to DERs. NAT'L EFFICIENCY SCREENING PROJECT, NATIONAL STANDARD PRACTICE MANUAL FOR BENEFIT-COST ANALYSIS OF DISTRIBUTED ENERGY RESOURCES (NSPM FOR DERs)—OVERVIEW 3 (2019), https://perma.cc/ZG3A-CQ9E.

[26] Decision adopting cost-effectiveness analysis framework policies for all distributed energy resources, Cal. Pub. Utils. Comm'n, RM 14-10-003, at 2, 65-67 (May 21, 2019), https://perma.cc/L73F-KPNX.

[27] Order Establishing the Benefit Cost Analysis Framework, N.Y. Pub. Serv. Comm'n, Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision 1-2 (Jan. 21, 2016), https://perma.cc/9UQD-3PQA.

Distributed energy resources' benefits and costs

Numerous reports already identify and categorize benefits and costs of DERs.[28] Tables 4 and 5 organize a conventional list of those benefits and costs using the perspectives described above. Note that these tables contain illustrative lists—not comprehensive or definitive ones[29]—of potential benefits and costs.

Table 4. Potential Benefits of DERs.

Perspective	Category	Benefit
Electricity system stakeholders (i.e., utilities and their customers, including DER owners)	Bulk power system	Avoided energy costs
		Avoided generation capacity costs
		Avoided reserves and ancillary services costs
		Avoided transmission capital costs and line loss
		Avoided financial risk of primary energy source price volatility
		Avoided environmental compliance costs
	Distribution system	Avoided distribution capital costs and line losses
Society	Public health and safety	Improved resilience to disruptive hazards and stressors
		Public health benefits of avoided local pollution
	Environmental	Environmental benefits of avoided local pollution
		Avoided greenhouse gas emissions

As Table 4 shows, by avoiding the need to incur various costs, DERs can yield diverse benefits to centralized electricity system stakeholders. And, by avoiding emissions and improving electricity system resilience, they can also benefit society as a whole. Compared with these benefits, the costs of DERs, listed in Table 5 below, tend to be easier to measure. Capital and maintenance costs for a DER owner and interconnection costs for the local utility, for instance, which are available from accounting records, do not require estimation.

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[28] *See, e.g.*, Shay Bahramirad, *Intro to Value of DER*, Presentation to NextGrid Working Group 1 (Feb. 28, 2018), https://perma.cc/Z44Q-XRSL; Galen Barbose, Lawrence Berkeley Nat'l Lab., Putting the Potential Impacts of Distributed Solar into Context 12 tbl.2 (2017), https://perma.cc/WLP3-2J2P; Susan F. Tierney, The Analysis Grp., The Value of "DER" to "D": The Role of Distributed Energy Resources in Supporting Local Electric Distribution System Reliability (2016), https://perma.cc/36ND-XDR9.

[29] Other potential benefits not listed here include, for instance, lower bills for low-income electricity consumers and reduced adverse emissions impacts for environmental justice communities. Gridworks et al., The Role of Distributed Energy Resources in New Jersey's Clean Energy Transition 4, 9 (2019), https://perma.cc/7MMU-7Y6Z; Tim Woolf et al., Synapse Energy Econ. (prepared for Advanced Energy Econ. Inst.), Benefit-Cost Analysis for Distributed Energy Resources: A Framework for Accounting for All Relevant Costs and Benefits 30-31 (2014), https://perma.cc/5LQ3-Q437.

Table 5. Costs of DERs.

Perspective	Category	Costs
Utilities + ratepayers who do not own DERs	Program costs	Measure costs (to utility)
		Financial incentives
		Program and administrative costs
		Evaluation, measurement, and verification
	Integration	Interconnection costs (in excess of utility's own costs of interconnection)
	Capital costs (if any)	Distribution grid segment upgrades prompted by DER additions*
DER owners	Costs of DER adoption and operation	Measure costs (to participants)
		Interconnection fees
		Annual operations and maintenance costs
		Resource consumption by participant
		Transaction costs to participant

** At least some of this category of costs is often paid by DER developers*

As the descriptions below make clear, estimating DERs' benefits tends to require several more analytical steps than estimating their costs. Importantly, however, the relative ease of measuring costs is not a reason to ignore benefits and should be recognized as a source of potential over-weighting of costs and under-weighting of benefits in DER valuations.

Non-Wires Alternatives (NWAs)

NWAs generally combine a variety of DER types, ranging from energy-efficient lighting to battery storage. They deserve special mention because their development is generally led by utilities, which undertake them in lieu of distribution system upgrades that would be more expensive. Several states either direct or authorize retail utilities to recover the costs of NWAs through rates, so long as the suite of DERs performs as needed over the relevant timeframe.[30]

Bulk power system

Installing and operating DERs can avoid some of the costs to various stakeholders—and society as a whole—of operating the bulk power system. Those bulk power system costs that could be avoided include the generation of electricity (usually called "energy"), the capacity to generate electricity, ancillary services (i.e., measures that maintain voltage, frequency, and other features of the quality of delivered electricity), and additional costs, which arise indirectly from bulk power system operations, including hedges against changes in primary fuel prices and environmental compliance costs. The following brief descriptions summarize what gives rise to each of these costs and how DERs can potentially avoid them.

Energy costs. These costs reflect multiple factors, including the cost of the primary fuels used to generate electricity, availability of generation, congestion in the transmission system, and line losses. Because each of these constituent factors is sensitive to time and location, energy costs vary based on time and location.

Generation capacity and ancillary services. Retail utilities purchasing services from the bulk power system not only pay for electricity (akin to water flowing through a pipe), but also for (1) generators to invest in adequate capacity (i.e., a big enough pipe) to meet load under both ideal and adverse conditions in future years; and (2) the ancillary services

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[30] *See* Brenda Chew et al., Non-Wires Alternatives: Case Studies from Leading U.S. Projects (2018).

required for electricity to maintain its voltage and frequency (akin to water that flows steadily and without turbulence or sloshing from side to side) required for smooth consumption. As with energy, regular auctions conducted by regional wholesale market managers assign prices to capacity and ancillary services.

DERs can help avoid the costs of energy, generation capacity, and ancillary services by reducing the need to deliver electricity to a particular location at a given time. Specifically, DERs can reduce the volume of bulk power system generation needed, avoid the need to turn on the most expensive generators in the fleet, and reduce both congestion and line losses in the short run. Over longer timeframes, DERs can obviate the need to build or maintain expensive generators altogether and can contribute to plans to reduce or eliminate congestion.

Other bulk power system costs. DERs can avoid several other costs, such as the financial risk arising from primary fuel price volatility, which results from changes in the supply of and demand for coal, natural gas, and uranium. These costs accrue in different ways, some of them easier to measure and relate to DER usage than others.

Distribution system

Location and timing of electricity consumption are as important to the costs of operating the distribution system as the bulk power system. Capital expenditure to replace, upgrade, or build new distribution system facilities is the largest component of distribution system costs.[31] Other significant costs include line losses between the bulk power system and customers, the fine balancing required to maintain power quality, and averting or dealing with reliability failures.[32] All of these costs can vary significantly across even small geographies and distribution system segments.[33]

DERs can help avoid some of these costs, depending on where DERs are located and when and how they operate.[34] For instance, if load in a particular location peaks when solar PV is most productive, then simple rooftop solar installations could offset growth in local demand for electricity and thereby help to avoid or defer the costs of upgrading local distribution facilities to handle that growth. However, if load peaks in the early evening, after the sun has set, then solar PV combined with storage could offset local load growth but a standalone rooftop solar PV installation could not. Another important factor affecting DERs' ability to avoid costs in a particular location is the availability of supporting infrastructure and assets, such as AMI. If the local distribution system is unable to make full use of DERs as compared to centralized resources, it could impede a local DER's performance and cost-effectiveness.[35]

Distribution system capacity can also be a *limiting* factor in relation to DER deployment. If the DER to be deployed is DG, then local distribution facilities must be able to absorb the excess generation it is expected to export to the grid—otherwise that DER would threaten reliability by sometimes overloading those facilities. This constraint is called "host-

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[31] *See* TIERNEY, *supra* note 28, at 17 ("the opportunity for greatest economic value rests with the ability . . . to avoid specific distribution-system upgrades"); MELISSA WHITED ET AL., SYNAPSE ENERGY ECON. (prepared for Consumers Union), CAUGHT IN A FIX: THE PROBLEM WITH FIXED CHARGES FOR ELECTRICITY 26 (2016), https://perma.cc/RJ33-B8X7.

[32] *See* PAUL DE MARTINI & LORENZO KRISTOV, LAWRENCE BERKELEY NAT'L LAB., DISTRIBUTION SYSTEMS IN A HIGH DISTRIBUTED ENERGY RESOURCE FUTURE 21 (2015), https://perma.cc/PM66-D2LN.

[33] Bahramirad, *supra* note 28, at 6 (describing that system costs and thus potential DER value "varies not only by each of the approximately 5,500 feeders on the ComEd system [in and around Chicago], but potentially within a given feeder.").

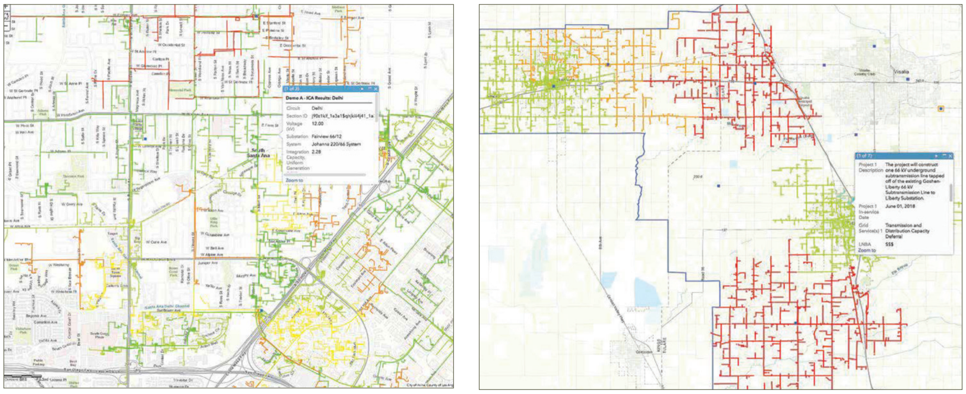
[34] Scott Burger et al., *Why Distributed?: A Critical Review of the Tradeoffs Between Centralized and Decentralized Resources*, 17 IEEE POWER & ENERGY MAG. 16, 19 (2019) ("To capture locational value due to network constraints, DERs must be able to operate both where and when constraints are binding."); *see also* Revesz & Unel, *supra* note 8, at 74-75.

[35] Burger et al., *supra* note 34, at 19 (emphasizing relevance of binding performance constraints to valuation); TIERNEY, *supra* note 28, at 19 (similar).

ing capacity," and like the distribution system costs that DERs can avoid, it varies significantly across different locations. Upgrading distribution facilities specifically to increasing DER hosting capacity is a cost *caused* (rather than avoided) by DER. Notably, different types of DERs have different hosting capacity needs: whereas storage might require capacity to draw more electricity from the grid to charge at particular times, and solar-plus-storage or CHP might require capacity to export excess generation to the grid, some rooftop solar might be expected to simply reduce local loads and so can itself open up more local capacity.

Locational analyses done in California show how sensitive costs are to even small locational variations. The maps shown in Figure 4 below were developed by Southern California Edison.

Figure 4. Maps showing integration capacity (left) and locational net benefits (right).[36]



On the left panel, green indicates distribution line segments that can easily host additional DER capacity; red indicates little or no hosting capacity; yellow and orange are in between. On the right panel, green indicates line segments with higher expected value for DER due to an opportunity for deferral of distribution capacity upgrades; red indicates little or no value; yellow and orange are, again, in between.[37]

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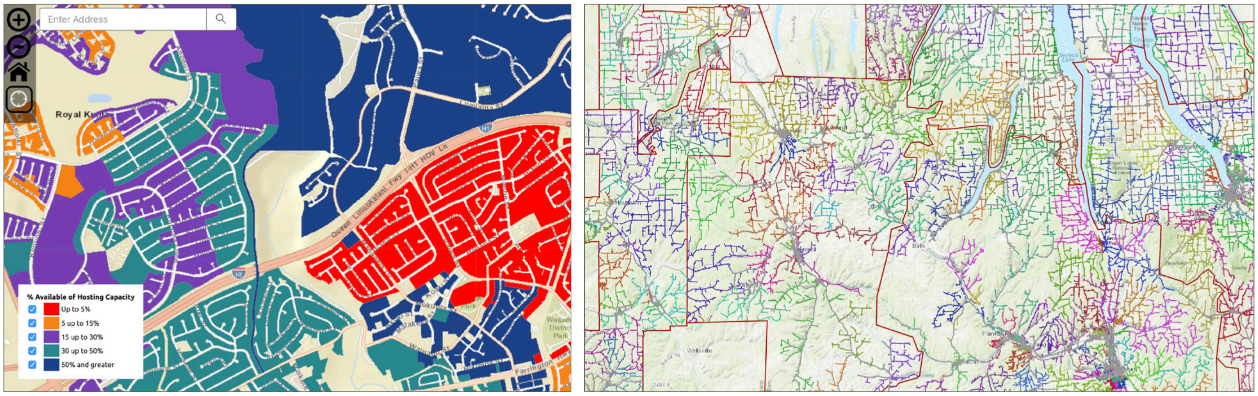
[36] Tim McDuffie, *Distributed Energy Resource Optimization*, SolarPro, July/Aug. 2018, at 39-40 figs.2, 3 & 4 https://www.solarprofessional.com/.

[37] Note that these maps reflect expected load growth as adjusted by the expected installation of DERs. The maps do not reflect the counterfactual scenario of distribution system costs with *no* DERs, which would reveal where and how much the installation of DERs could add value by avoiding those costs. In September 2017, California's Public Utilities Commission ordered the state's electric utilities to develop long-term forecasts of load growth and related distribution system costs, unadjusted by assumed DER installation, to facilitate clearer analyses of DERs' value. Decision on Track 1 Demonstration Projects A (Integration Capacity Analysis) and B (Locational Net Benefits Analysis), Cal. Pub. Utils. Comm'n Decision 17-09-026, Rulemaking 14-08-013, at 45-48 (Sept. 28, 2017), https://perma.cc/2Q4Q-NHSG. In June 2019, the Commission issued a white paper further specifying how utilities should comply. *See* Administrative Law Judge's Amended Ruling Requesting Comments on the Energy Division White Paper on Avoided Costs and Locational Granularity of Transmission and Distribution Deferral Values, Cal. Pub. Utils. Comm'n Rulemaking 14-08-013, Order Instituting Rulemaking Regarding Policies, Procedures and Rules for Development of Distribution Resources Plans Pursuant to Public Utilities Code Section 769 (June 13, 2019), https://perma.cc/R62G-BBZV.

As Figure 5 shows, Hawaii and New York State's utilities make similar "heat maps" and accompanying data available to DER developers.[38]

Figure 5. Oahu hosting capacity and locational value map (left); Hornell, NY hosting capacity map (right).



Maps like these show developers both where there is adequate capacity to accommodate DERs, and whether the addition of DERs would be likely to avoid costs to the distribution system. Recently updated (but still a work in progress)[39] Marginal Cost of Service Studies for New York distribution utilities provide a detailed description of the multiple components that underlie maps like these. For instance, the study conducted for Orange & Rockland examines the marginal cost of increasing existing capacity to serve prospective load growth for each of the utility's 50 feeders, and breaks that cost down into five "cost centers" for each feeder.[40] Placed on a map, that cost information would resemble the right panel of Figure 4 above. By examining load shapes on feeders with above-average costs, the Orange & Rockland study also highlights where DERs could avoid costs and the sort of load DERs would need to serve in order to do so.[41]

Effects beyond the electricity system

As indicated in Table 4, above, the activities involved in providing electricity services have numerous effects that are felt beyond the operation of the electricity grid. For instance, centralized, fossil-fueled electricity generators emit both greenhouse gases, which contribute to anthropogenic climate change, and local air pollution, which results in direct harms to public health and the environment. Centralized electricity generation also consumes water resources and results in water pollution (thermal and toxic), among other impacts. Installing and operating DERs can avoid these detrimental effects. DERs can also improve electricity system resilience to disruptions, such as from storms and wildfires that are expected to

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[38] Hawaiian Electric, Oahu Locational Value Map (LVM), https://www.hawaiianelectric.com/clean-energy-hawaii/integration-tools-and-resources/locational-value-maps/oahu-locational-value-map-(lvm) (accessed Nov. 21, 2019); New York State Electric & Gas and Rochester Gas & Electric, Distributed Interconnection Guide Map, https://iusamsda.maps.arcgis.com/apps/webappviewer/index.html?id=2f29c88b9ab34a1ea25e07ac59b6ec56 (accessed Nov. 21, 2019).

[39] *See, e.g.*, Synapse Energy Econ. (prepared for Clean Energy Parties), Appendix B: Information Requests Round #2 Regarding NY Utilities' MCOS Studies, N.Y. Pub. Serv. Comm'n Case 19-E-0283, Proceeding on Motion of the Commission to Examine the Utilities' Marginal Cost of Service Studies (Sept. 16, 2019), https://perma.cc/JT4L-3S7R; City of New York's First Set of Information Requests to Consolidated Edison Company of New York, Inc. Regarding Its Marginal Cost of Service Study, N.Y Pub. Serv. Comm'n Case 19-E-0283, Proceeding on Motion of the Commission to Examine Utilities' Marginal Cost of Service Studies (July 15, 2019), https://perma.cc/2QD7-92CT.

[40] PHILIP Q. HANSER ET AL., THE BRATTLE GRP. (prepared for Orange & Rockland), MARGINAL COST OF SERVICE STUDY, 16 tbl.8 (2019). The "[Marginal Cost] Map" in the study itself appears on page 27.

[41] *Id.* at 20, 22.

increase in frequency and severity as the climate changes.[42] And DERs can help provide predictable and secure electricity access for low-income individuals and communities.[43]

Quantifying and monetizing some of these effects, like reduced water usage, is straightforward because the necessary data inputs and valuations are generally already available from prices assigned by markets or regulators.[44] Monetizing others, like the global and local costs of emissions, requires data to be gathered and analyzed, but, as explained below, can be made a routine step in electricity-related cost accounting.[45] Monetizing still others, such as improved resilience to disruption, often requires more significant and project-specific analysis.[46]

Finally, DERs can affect local economic activity, either by promoting local spending and causing job creation or undermining economic activity that relies on the operation of centralized resources.[47] These effects can be monetized but are rightly considered benefits or costs to *local* communities only—to society as a whole they might not represent a benefit or cost per se but a mere transfer of resources.

Specifying a baseline for scenario analysis

Estimating the value that a DER provides to society requires two scenarios—the baseline or "business as usual" scenario in which grid-based assets and existing DERs provide service, and the alternative scenario in which new DERs account for some or all of the relevant service provision. If a baseline is not updated with appropriate frequency, then it provides an inaccurate set of parameters for comparison to the new DER deployment scenario. It is, therefore, necessary to establish and maintain data sources for deriving accurate baseline values, and to correctly specify intervals for updating data inputs.

Calculating the value of distributed energy resources

Assigning monetary value to the operation of a DER at a particular time and place builds upon the data requirements and analytical decisions described above, namely identifying benefits and costs, deciding which are relevant, and specifying key features of the DER project and the baseline scenario to which it is an alternative. Valuing the effects of a specific DER's operation in comparison to a baseline scenario involves five component steps:

(1) identifying the resource(s) whose operation will be modified or displaced by operation of the DER;

(2) characterizing the timing and degree of that modification or displacement by comparing DER operation/output to that of the displaced resource(s);

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[42] Resilience is distinct from reliability, the costs of which are already internalized in the rates paid for electricity service. Nat'l Acad. Scis., Eng. & Med., Enhancing the Resilience of the Nation's Electricity System 9 (2017), https://doi.org/10.17226/24836. [hereinafter "NAS, Enhancing Resilience"].

[43] Gridworks et al., *supra* note 29, at 4, 9.

[44] *See, e.g.*, Indep. Evaluation Monitor, Arkansas Technical Reference Manual, Protocol L, Version 7.0, at 88-90 (Aug. 2016), https://perma.cc/2ZXC-BWTN (describing derivation of value of avoided water use from retail water rates).

[45] *See generally* Jeffrey Shrader et al., Inst. for Pol'y Integrity, Valuing Pollution Reductions: How to Monetize Greenhouse Gas and Local Air Pollutant Reductions from Distributed Energy Resources (2018), https://policyintegrity.org/publications/detail/valuing-pollution-reductions.

[46] For an example of this sort of analysis, *see* San Francisco's analysis of the resilience value of adding solar + storage facilities to shelters and public libraries throughout the city. Abigail Rolon et al., Arup (for San Francisco Dep't of the Env't), Solar and Energy Storage for Resiliency (2018), https://perma.cc/9FFU-MV9R. For a general methodology for monetizing resilience value, see Burcin Unel & Avi Zevin, Inst. for Pol'y Integrity, Toward Resilience: Defining, Measuring, and Monetizing Resilience in the Electricity System (2018), https://policyintegrity.org/publications/detail/toward-resilience.

[47] *See* Woolf et al., *supra* note 29, at 4, 17 n.8, 33.

(3) estimating the costs avoided as a result of this displacement (including the costs of infrastructure development and pollution);

(4) comparing those avoided costs to the costs of installing and operating the DER; and

(5) determining the appropriate frequency of and process for updates.[48]

The rest of this subpart describes how these steps apply to different categories of benefits DERs could provide.

Avoided bulk power system costs

Wholesale electricity markets already do much of the analysis required to assign a monetary value to a DER's avoidance of bulk power system costs. The following short descriptions build on those above. Implementing what is described here requires access to models of the relevant bulk power system region and detailed knowledge of the profile of the DER to be deployed.

Generation. The locational marginal price (LMP) is the marginal cost of providing electricity to a specific location (either a zone or node) in the bulk power system at a specific time.[49] More specifically, it reflects three costs: generation, congestion (i.e., costs incurred to deal with transmission capacity limits), and transmission system line losses.[50]

Calculating the value of avoided generation relies heavily on LMP, which is specified at the level of a wholesale market zone,[51] as shown on the map of real-time wholesale zonal prices in figure 6, below, or a transmission system node.

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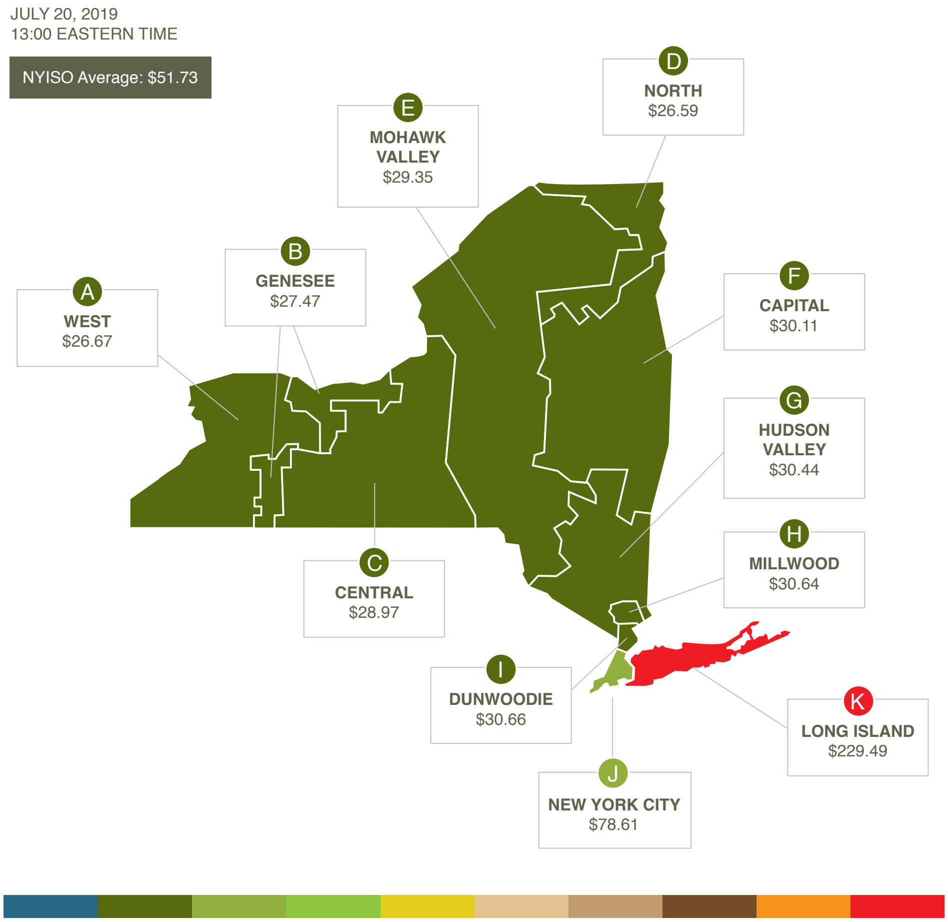
[48] *Cf.* Natalie Mims Frick et al., Lawrence Berkeley Nat'l Lab., A Framework for Integrated Analysis of Distributed Energy Resources: Guide for States 7-8 (2018), https://perma.cc/CNG2-N6KC (listing "minimum data requirements" for DER valuation).

[49] Fed. Energy Reg. Comm'n, Energy Primer: A Handbook of Energy Market Basics 60-61 (2015), https://perma.cc/AAU7-JZYN.

[50] This calculation can use the systemwide annual average rate of line losses, but it is more accurate to use the marginal loss rate for the relevant zone or node over different time periods, e.g., seasonal and daily. This granularity is important because loss rates tend to be higher at peak times and increase over greater distances. NYISO, for example, uses a marginal rate. New York Independent System Operator, Market Services Tariff § 17.2.2.1 (Aug. 16, 2019) ("Marginal Losses Component LBMP").

[51] In locations where electricity system ownership is vertically integrated and no wholesale market operates, estimates of marginal energy costs can be derived from "system lambda," an engineering statistic used to estimate the shadow cost of a one-unit change in production. *See* Severin Borenstein & James Bushnell, Energy Inst. at Haas, *Do Two Electricity Pricing Wrongs Make a Right? Cost Recovery, Externalities, and Efficiency* 11 (Nat'l Bureau of Econ. Research, Working Paper No. 24756, 2019), https://perma.cc/FJ9D-KQ6Y.

Figure 6. Real-time energy prices (LMP) across New York Independent System Operator (NYISO) Zones A through K at 1pm on July 20, 2019.[52]



Zonal prices sometimes diverge significantly, for instance when extreme weather occurs in combination with congested transmission capacity. Figure 6 shows the zonal prices at 1pm on July 20, 2019, the hottest day of 2019 in New York State. From 11:00am to 10:00pm on that day LMP for Zone K (Long Island) ranged from just over twice the NYISO average to almost six times the average.[53] That ratio was highest at 2:15pm, when the LMP in Zone K was over $360/MWh and the average of all 11 NYISO zones was just under $62/MWh.[54] The limited capacity of congested transmission facilities to carry more electricity to Long Island accounted for most of the difference at that hour.[55]

Generation capacity. In regions with competitive wholesale markets, auctions between generators and wholesale electricity purchasers (chiefly retail utilities, but also competitive retail providers in states with retail choice) establish the

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[52] For the sake of simplicity and clarity, this report draws heavily on the example of the New York State electricity grid, where the ISO and wholesale market's boundary matches that of the state. Other ISO/RTO regions operate in a broadly similar fashion—deriving prices for energy, capacity, and ancillary services from regular auctions—but contain multiple states (e.g., ISO-NE, PJM, SPP, and MISO) or portions of individual states (e.g., ERCOT and CAISO).

[53] Data retrieved from NYISO's Open Access Same-Time Information System, Real-Time Market LBMP, Zonal, Archived File "07-2019", http://mis.nyiso.com/public/P-24Alist.htm.

[54] *Id.*

[55] *Id.*

prices for future generation capacity. These vary across regions and from year to year, but generally amount to a fraction of the total price paid for bulk power system services.[56]

Calculating the value of avoided generation capacity requires three sets of data points:

- the effective capacity of the DER across specified time periods, such as daily peak loads in a given zone or node for all four seasons;
- expected system capacity needs over the same time periods; and
- the expected *value* of future capacity, based on the prices assigned by the wholesale market for the relevant time-frame.

Armed with these data, it is possible to estimate how much the contribution of the DER in a given location will reduce local capacity needs and thereby lower capacity prices.

Transmission. In addition to transmission congestion and line losses, which are short term costs reflected in LMP, DERs can also potentially avoid the longer-term costs of transmission capacity additions. Those longer-term costs are substantially reflected in generation capacity prices and the congestion component of LMP, which captures what wholesale electricity purchasers are willing to pay over the short-term to overcome the transmission constraints in a particular location by buying electricity from accessible resources and routing it around the constraints. But relying on LMP can risk ignoring DERs' potential to avoid significant long-term costs.[57] A more focused calculation of the avoided cost of additional transmission can be done either by estimating the relationship between planned transmission capacity additions and their associated revenue requirements,[58] or by a more intensive modeling exercise that estimates the sensitivity of transmission capacity needs to incremental changes in load of the sort affected by the installation and operation of DERs.[59]

Ancillary services and other bulk power system costs. Even though the remaining bulk power system costs identified in Table 4 above tend to be small relative to generation and generation capacity, DERs' ability to avoid such costs can be valuable. In addition to being relatively small, however, these avoided costs are generally harder to calculate precisely—and extremely difficult to calculate for particular times and locations. This is why the tool that California utilities have been directed to use as the basis for the Locational Net Benefits Analysis of DERs simply calculates ancillary services as 0.9% of the value of generation.[60] Calculating the value of avoided fuel price volatility requires several analytical steps to translate from an estimated cost to a unit of marginal value made available by installing and operating a DER.[61]

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[56] David B. Patton et al., Potomac Econ., 2018 State of the Market Report for the New York ISO Markets 3 fig.1 (2019), https://perma.cc/V73H-3N2T.

[57] Clean Energy Parties, Proposal for Distribution and Transmission Value for Distributed Energy Resources (DERs) and DRV/LSRV Modifications, N.Y. Pub. Serv. Comm'n Case 15-E-0751, In the Matter of the Value of Distributed Energy Resources Working Group Regarding Value Stack 22-23 (June 7, 2018) https://perma.cc/BUA7-Z2GN.

[58] For an example of a regression analysis developed to estimate this value, see Reuben Behlihomji et al., Southern California Edison, Co., Phase 2 of 2018 General Rate Case Marginal Cost and Sales Forecast Proposals, Application No. A.17-06-030, Ex. SCE-02A, at 36-39 (Nov. 1, 2017), https://perma.cc/5RDP-N5L3.

[59] *See* Clean Energy Parties filing, *supra* note 57, at 23 (describing version of NYISO Reliability Needs Assessment that would detect the value of such incremental changes).

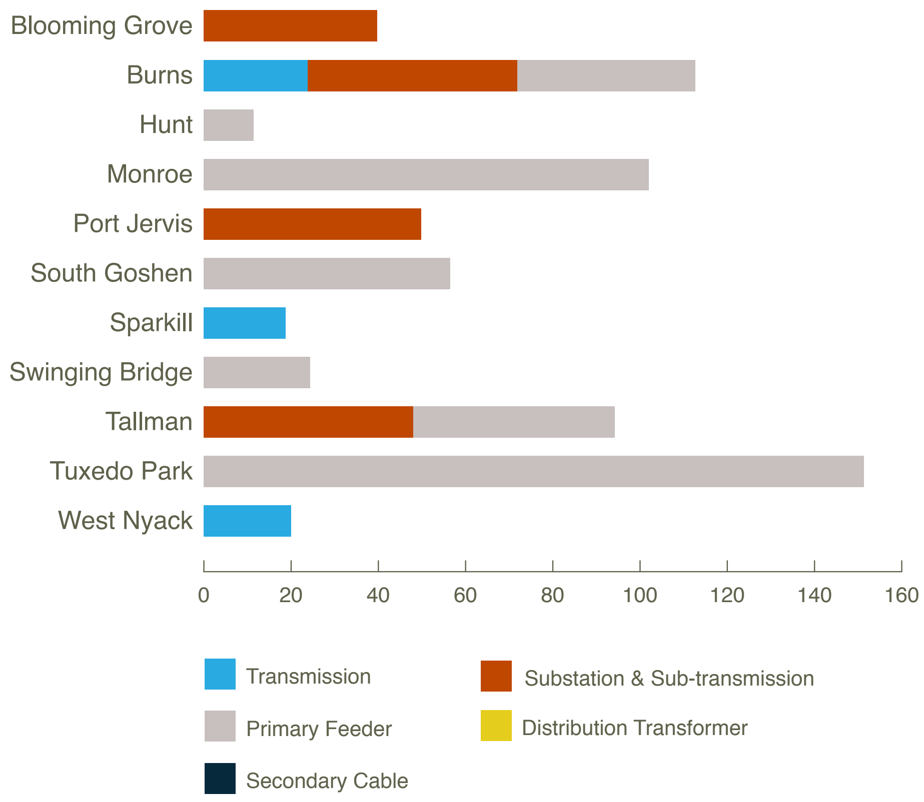
[60] Cal. Pub. Utils. Comm'n, Cost-effectiveness: 2019 Avoided Cost Calculator, ftp://ftp.cpuc.ca.gov/gopher-data/energy_division/EnergyEfficiency/CostEffectiveness/ACC_2019_v1b.xlsb ("General Inputs" tab) (accessed Aug. 25, 2019). That calculation also excludes the value of regulation "up" or "down" from its estimate. *Id.*

[61] For a description of one approach, *see* Daymark Energy Advisors (for Maryland Pub. Serv. Comm'n), Benefits and Costs of Utility Scale and Behind the Meter Solar Resources in Maryland 115-120 (2018), https://perma.cc/J3P9-UMU2.

Avoided distribution system costs

From a policymaker's perspective, determining the benefits of DERs to the distribution system only requires understanding the costs that DERs could avoid, like line losses and the marginal cost of adding distribution capacity. The Marginal Cost of Service Study commissioned by Orange & Rockland, a utility that serves the counties just northwest of New York City, describes the marginal costs of investments required to match expected load growth for each of the utility's 50 feeders.[62] The study breaks those marginal costs down into five "cost centers" or categories of infrastructure for each feeder. As shown in Figure 7, which depicts a characteristic sample of those 50 feeders, there is significant locational variation between services areas, and no costs are expected for two of those cost centers.

Figure 7. Marginal costs of planned capacity additions ($/kW) in sample of feeder areas in Orange & Rockland's service territory.[63]



According to its 2019 Marginal Cost of Service Study, Orange & Rockland does not plan to incur any capital costs for 28 of its 50 feeders over the coming decade. Nor does any feeder require upgrades or replacement of distribution transformer or secondary cable facilities in that time. But, as shown by Figure 7, maintaining service at the Burns location will require investments in transmission, substation, and primary feeder facilities; and at Tuxedo Park a very large investment in the primary feeder is necessary.

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[62] HANSER ET AL., *supra* note 40, at 16 tbl.8.

[63] *Id.*

Although line losses represent a small portion of the distribution costs that DERs can potentially avoid, they are still substantial.[64] Importantly, because line losses can vary significantly across a given utility's service territory and at different times,[65] using an average rate of line losses will likely distort any estimate of how much of that cost a DER could potentially avoid.[66]

Private decisions of DER developers and would-be owners about whether to install new DERs must also take into account available hosting capacity[67] and the compatibility of DER profiles with local "load shapes"—that is, the level and timing of local aggregate demand to understand whether it makes economic sense for them to install DERs. Compensating DERs for helping to avoid these sorts of costs sends a clear signal to DER developers and would-be owners about where to locate new DERs and what sorts of DERs to install there. In locations where a given DER's excess generation would help avoid distribution system costs by serving peaks in local load, a value stack will compensate that DER for providing a more cost-effective alternative to centralized system upgrades.

* * *

Taking the analytical steps described above results in an estimation of the value of particular DERs in a particular location. However, actually developing those DERs requires a degree of certainty about the compensation that will stem from that estimation. Due to the routine nature of wholesale market price patterns, many of the relevant avoided costs are predictable (including the value of avoiding wholesale generation, generation capacity, transmission, and other bulk power system costs). But local distribution system costs, as Orange & Rockland's Marginal Cost of Service Study shows, do not change on a uniform schedule and respond to changes in load, which are less predictable than the changes that inform bulk power system prices. This variability can undermine the usefulness of information provided by utilities to DER developers, if the DER compensation scheme employs a time horizon that is shorter than the amortization period used by the local utility for distribution infrastructure. Part III discusses options for balancing different stakeholders' interests and needs for accurate and predictable information about distribution system costs.

Avoided emissions of greenhouse gases and local pollutants

Potential benefits of DERs include avoiding emissions from centralized electricity generation. As with other benefits described above, the benefits of avoided emissions vary with time and place. With respect to greenhouse gas emissions—pollutants with global rather than local effects—that variation results from the different marginal emissions rates of whatever resources the DER's operation displaces. With respect to local air pollution, that variation owes to the marginal emissions rate of the displaced resource, location of populations near or downwind of that resource, and prevailing weather patterns.

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[64] *See, e.g.*, Xcel Energy Servs., Costs and Benefits of Distributed Solar Generation on the Public Service Company of Colorado System—Study Report in Response to Colorado Public Utilities Commission Decision No. C09-1223, at v & 31-34 (May 23, 2013), https://perma.cc/9F54-5RXB.

[65] Borenstein & Bushnell, *supra* note 51, at 12-14.

[66] Some states direct utilities to calculate and report line losses on a marginal basis. *See* Testimony of Chris Neme on behalf of the N. Carolina Justice Ctr. et al., N.C. Utils. Comm'n Docket No. E-2, SUB 1174, In the Matter of Application of Duke Energy Progress, LLC, for Approval of Demand-Side Management and Energy Efficiency Cost Recovery Rider Pursuant to G.S. 62-133.9 and Commission Rule R8-69, at 7, 30 (Sept. 4, 2018), https://perma.cc/7J6Y-NV6J. In states that allow utilities to report average rates, this small piece of a value stack is likely to be inaccurate. *See* Jim Lazar & Xavier Baldwin, Reg'y Assistance Project, Valuing the Contribution of Energy Efficiency to Avoided Marginal Line Losses and Reserve Requirements 3-5 (2011), https://perma.cc/TX57-GA6D (describing how averages understate line losses).

[67] Utilities generally charge DER developers the cost of expanding hosting capacity to accommodate a new DER installation.

Calculating the volume of emissions avoided requires detailed information about the type of pollution and marginal emissions rates of regional generation resources over the smallest possible intervals of time. Calculating the value of avoiding those emissions requires estimating the damage they would have done. For greenhouse gases, the best available tool for estimating the monetary value of damages from each increment of emissions is the Social Cost of Carbon, which was developed by the Interagency Working Group in 2010, and then updated in 2013 and 2016.[68] For local pollutants, several tools exist for estimating the monetary value of damage done, including BenMAP, EASIUR, AP2, and COBRA.[69]

Policy Integrity has previously described a five-step method for developing monetary estimates of emissions reductions attributable to DERs in *Valuing Pollution Reductions: How to Monetize Greenhouse Gas and Local Air Pollutant Reductions from Distributed Energy Resources*.[70] That report includes methodologies, data sources, and analytical tools for each of the following steps:

1. Determine what generation resource(s) will be displaced by a DER's installation/operation;
2. Quantify marginal emissions rates of the displaced generation;
3. Calculate in monetary terms the damages of relevant emissions generally, with attention to types of pollutants, their destinations, and the timing (seasonal and daily) of their emission;
4. Monetize the value of emissions avoided by displacing generation using the marginal emissions rates established by Step 2 and the per unit damages established by Step 3 (taking care to consider emissions priced fully or partly by existing policies and to adjust as needed to avoid double-counting);
5. Subtract from the result of Step 4 the value of any emissions directly attributable to operation of the DER.

Notably, Steps 3 and 4 are significantly easier to complete for greenhouse gas emissions than for ambient air pollution.

Improved resilience

Electricity system resilience is distinct from reliability.[71] Reliability focuses on high-probability, low-impact events, like downed tree limbs, and is concerned with preventing outages that might result. By contrast, resilience focuses on low-probability, high-impact events, like hurricanes or large-scale cyberattacks, and is concerned with resisting, absorbing, and recovering from the disruption they cause.[72] In addition, unlike with reliability, there is no single metric or set of metrics that indicate resilience to all types of hazard.[73] Instead, resilience is specific to a type of hazard, such that a system designed to be resilient to cyberattack *might* but will not necessarily also be resilient to hurricanes or wildfires. These features make it harder, but certainly not impossible, to calculate the resilience value of a DER.

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[68] Interagency Working Group on the Social Cost of Greenhouse Gases, Technical Update on the Social Cost of Carbon for Regulatory Impact Analysis (2016), https://perma.cc/UYX6-2W8M.

[69] For a summary description of each of these models and references to fuller descriptions, *see* Jeffrey Shrader et al., *supra* note 50.

[70] *Id.*

[71] NAS, Enhancing Resilience, *supra* note 42, at 9.

[72] *Id.* at 10 ("Resilience is not just about being able to lessen the likelihood that outages will occur, but also about managing and coping with outage events as they occur to lessen their impacts, regrouping quickly and efficiently once an event ends, and learning to better deal with other events in the future."); *see also* Order Terminating Rulemaking Proceeding, Initiating New Proceeding, and Establishing Additional Procedures, 162 FERC ¶ 61,012 P 22 (2018) (citing National Infrastructure Advisory Council's Critical Infrastructure Resilience Final Report and Recommendations 8 (Sept. 2009)).

[73] Standard reliability metrics include the System Average Interruption Frequency Index (SAIFI) and System Average Interruption Distribution Index (SAIDI), which measure different aspects of system performance and show no differences in sensitivity to different sources of disruption.

Over the past decade, resilience has become a greater priority for policymakers with responsibility for different segments of the electricity grid,[74] owing to increasingly frequent and severe climate-driven weather events, and recognition of the electricity grid's susceptibility to cyberattack.[75] However, determining the value of avoiding disruption, and, further, of particular investments that could achieve such avoidance, has proved challenging.[76] Policy Integrity's 2018 report, *Toward Resilience: Defining, Measuring, and Monetizing Resilience in the Electricity System*,[77] offers guidance on this issue. Drawing on the academic literature, it proposes calculating the resilience value of any investment or intervention using the following five analytical steps:

1. Characterize potential sources of disruption;
2. Specify metrics for resilience; each metric should—
    - Be measurable in terms of the consequences expected to result from particular threat types;
    - Reflect uncertainty (e.g., the expected consequence or the probability of the consequence occurring exceeds an acceptable level); and
    - Use data from computation models that incorporate historical experience or expert evaluation.
3. Quantify system resilience in a baseline scenario;
4. Characterize how the investment or intervention would modify system resilience; and
5. Compare the benefits and costs of the resulting resilience improvement.[78]

These steps are broadly consistent with approaches developed by other researchers to estimate the resilience value of DERs.[79]

This approach can also be supplemented by valuing community resilience.[80] This distinction is noteworthy because state-level policies adopted to promote resilience often aim at the communities and individuals that rely on public health and safety services, many of which rely on electricity.[81]

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[74] *See, e.g.*, Arthur Maniaci, NYISO, *2019 Climate Study – Draft Outline of Statement of Work for RFP* (Nov. 9, 2018), https://bit.ly/2HrKCJm; Order Approving Electric, Gas and Steam Rate Plans in Accord with Joint Proposal, N.Y. Pub. Serv. Comm'n Case 13-E-0030, Proceeding on Motion of the Commission as to the Rates, Charges, Rules and Regulations of Consolidated Edison Company of New York, Inc. for Electric Service (Feb. 21, 2014), https://perma.cc/6WAP-ATHM (directing ConEd to undertake a Climate Change Vulnerability Study and implement responses to its findings).

[75] NAS, Enhancing Resilience, *supra* note 42, at 10-12.

[76] Wilson Rickerson et al., Converge Strategies (prepared for NARUC), The Value of Resilience for Distributed Energy Resources: An Overview of Current Analytical Practices (2019), https://perma.cc/P7YZ-STEY.

[77] Unel & Zevin, *supra* note 46.

[78] As noted in Policy Integrity's report, these steps are a streamlined version of the steps and data requirements developed by Sandia National Laboratory as part of the DOE Metrics Analysis for Grid Modernization Project. *See* Eric Vugrin et al., Sandia Nat'l Labs., Resilience Metrics for the Electric Power System: A Performance-Based Approach (2017), https://perma.cc/CK3F-SF5A.

[79] *See* Rickerson et al., *supra* note 76.

[80] For the definitions of these two types of resilience, compare NAS, Enhancing Resilience, *supra* note 42, at vii, *with* Nat'l Acad. of Sci., Eng'g & Med, Building and Measuring Community Resilience: Actions for Communities and the Gulf Research Program 12-13 (2019), and Nat'l Inst. Sci. & Tech, Community Resilience Planning Guide for Buildings and Infrastructure Systems, vol. 1, at 13 (2016), https://perma.cc/68TB- 5B98.

[81] For a discussion of the challenges arising from improving not only the resilience of electricity services but also community resilience, *see* Justin Gundlach, *Microgrids and Resilience to Climate-Driven Impacts on Public Health*, 18 Houston J. Health Pol'y & L. 77 (2018); *see also* Rolon et al., *supra* note 46 (estimating resilience value to the city and county of San Francisco of adding solar plus storage installations to local shelters and libraries).

III. Reasons to move beyond net energy metering

NEM programs in many states, though not all, have enabled a significant amount of private investment in DERs—particularly solar PV. However, because NEM programs' compensation of DERs generally ignores temporal and locational value, NEM is at odds with this report's recommended approach to valuing DERs over the long-term, once a critical mass of DERs has been installed in a given utility service territory.

As explained below, the crux of the problem with NEM lies in its reliance on retail rates. Small retail electricity customers generally pay for electricity service through a monthly, two-part tariff. One part of that rate is fixed, meaning that it does not vary with the customer's electricity usage. The other part is volumetric, meaning that customers pay for the kWh of electricity they consumed during each billing period. The price multiplied by the customer's monthly kWh is "flat" across all the hours of the month. The vast majority of ratepayers are charged a bundled, flat rate for consuming electricity. The rates paid by larger commercial and industrial customers often also include a "demand charge" that reflects their peak demand during each billing period.

The shortcomings of net energy metering

Because NEM compensates DERs based on the net consumption of the customer, it relies on the underlying retail rates.[82] If these retail rates are bundled rates (and for most consumers they are), NEM does a poor job of capturing the benefits and costs of DERs in a granular way.

Reliance on partial and distorted price information

NEM's reliance on retail rates causes three types of problems: it distorts economic signals about efficient DER deployment and operation, it ignores important benefits and costs, and it shunts non-DG DER into a different set of compensation and planning processes, which also distorts economic efficiency.

Distorted economic signals. Nearly all retail utilities charge their customers based on the average cost of electricity service in the utility's territory over each billing period. As a result, most utilities charge a flat price of electricity service for that period, even though the *costs* of providing that service vary significantly across both time (minute, hour, day, season) and location (distribution system line and feeder, and bulk power system node and zone). This discrepancy between price and cost leads customers to not see accurate price signals about the underlying costs when they consume electricity, leading to economically inefficient consumption. Furthermore, because every customer pays the same retail rate regardless of where and when they consume electricity, those who use electricity during cheaper off-peak times cross-subsidize those who use electricity during more expensive peak times. Similarly, those who use electricity at less congested locations, cross-subsidize those who use electricity at congested locations.[83]

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[82] *See* Revesz & Unel (2017), *supra* note 8, at 60 (noting that 34 jurisdictions credited NEM participants at the retail rate in 2017).

[83] Distribution facilities experience increased wear and tear at near-peak times. Thus, flat pricing at near-peak times results in indifference to the capital costs of distribution system upkeep—costs that utilities generally seek to recover through charges that capture the coincidence of customers' maximum level of demand with maximum local demand on the distribution system ("coincident peak demand").

By basing compensation to DER owners on the flat retail rate, NEM creates for DER owners the same distortions that lead electricity customers to consume inefficiently. That is, DER owners receive an average price for their electricity even at times when its value to the centralized grid far exceeds (or falls below) the monthly average, and even in places where it alleviates (or creates) costs. As academic researchers and the New York State Energy Research and Development Authority (NYSERDA) found in one study, causing DERs to be deployed and operated at the wrong times and in the wrong places can lead NEM's costs to exceed its benefits.[84]

Ignored benefits and costs. Because it is based on retail rates, NEM only reflects the benefits and costs included in a utility's perspective on value. It ignores other benefits and costs, like public health benefits of avoided emissions, treating them as externalities to which electricity prices should be indifferent. Ignoring externalities like these causes decisions about electricity consumption and electricity system design—and DER installation and operation—to be needlessly net-costly to society. Notably, these benefits and costs also—like the system costs highlighted in the previous paragraph—generally depend on time and place.[85]

Fragmentary compensation for DER subcategories. The rules that currently govern compensation for DG and different types of non-DG DERs generally *prevent* direct competition among them by causing compensation to flow to different technologies through distinct channels at different rates. As a consequence, different resource types that provide comparable services often do not compete in a direct and meaningful fashion. As shown in table 6, there is little overlap among compensation mechanisms for different types of DER.

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[84] Sexton et al., *supra* note 9, at 3-4, 29-31; Kush Patel et al., Energy+Environmental Economics (prepared for N.Y. State Energy Research & Dev. Auth. and N.Y. State Dep't of Pub. Serv.), The Benefits and Costs of Net Metering in New York 51-62 (2015), https://perma.cc/3L5C-K73K.

[85] *See* Shrader et al., *supra* note 50, at 4.

Table 6. Compensation mechanisms for different DER categories.

Type of DER	Main compensation, cost recovery, and subsidy mechanisms
DG	NEM,[86] and numerous grant, rebate, tax credit, and other programs to reduce the costs of installation.[87]
Standalone BTM energy storage	Energy storage deployed by customers "behind the meter" is generally valued by its owners because it can help avoid consumption of grid-based electricity (along with associated demand charges for commercial and industrial customers), or provide backup power during an outage.[88] Subsidies for deploying energy storage vary by state. Some are grants that reduce the cost of deployment.[89] Others seek to encourage storage to reduce peak usage and to displace high-emitting generation resources, by compensating storage that charges at times when the marginal emissions rate of grid-based electricity generation is low and to discharge when it is highest.[90]
Demand response	Wholesale demand response programs compensate demand response resources like generation capacity and delivered generation, based on bids that clear in wholesale capacity and energy market auctions. Retail demand response programs compensate different demand response providers differently: residential customers subject to time-of-use rates save when they avoid higher-priced periods; residential customers subject to flat rates generally receive bill credits; and participating commercial and industrial customers might receive capacity or performance payments (similar to wholesale "capacity" and "energy") as either bill credits or monetary compensation.
Energy efficiency	Customers who invest in EE can recover their costs through reduced energy consumption. Utilities subject to legislative and regulatory mandates can often also recover the costs of making or subsidizing qualifying EE investments through rates and other regulatory mechanisms.[91] In addition, commercial consumers in at least 20 states (and residential consumers in three states and multiple localities) can access low-cost financing for EE investments through PACE programs[92] and recover payments through each participant's property tax bill.
Non-wires alternatives (NWAs)	As noted above, some states direct or authorize retail utilities to recover the costs of NWAs through rates, so long as the suite of DERs perform as needed over the relevant timeframe.[93]

Net energy metering and "fairness"

As explained above, NEM's earliest defining feature was that it enabled DER compensation without disrupting other aspects of providing centralized electricity services, such as metering, billing, and regulatory and tax treatment of flows of electricity and money. How NEM allocates benefits and costs, both between NEM program participants and other ratepayers, and between NEM program participants and utilities, has always been incidental to that more basic priority.

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[86] For a survey that provides summary descriptions of DG compensation schemes for all 50 states as of September 2018, see Memorandum from Juliet Homer & Alice Orrell, Pacific Nw. Nat'l Lab., to Stacey Donohue, Idaho Pub. Util. Comm'n, Distributed Generation Cost-Benefit and Ratemaking Considerations for Idaho 8 (Jan. 25, 2019), https://perma.cc/JK4K-4B4E.

[87] For a comprehensive list of state and federal level programs, see the "Programs" webpage of NC Clean Energy Technology Center's Database of State Incentives for Renewables & Efficiency, *supra* note 29, (accessed Aug. 27, 2019).

[88] Garrett Fitzgerald et al., Rocky Mtn. Inst., The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid 4 (2015), https://perma.cc/7MHL-2A8G.

[89] *See, e.g.*, Julian Spector, *New York's Energy Storage Incentive Could Spur Deployment of 1.8GWh*, GreenTech Media, Apr. 29, 2019, https://perma.cc/E9U4-CZ7Y; Sarah Shemkus, *Massachusetts Grants Help Get Energy Storage Projects off the Ground*, Energy News Network, Nov. 8, 2018, https://perma.cc/5G5R-9L4P.

[90] *See, e.g.*, Decision Approving GHG Emission Reduction Requirements for the Self Generation Incentive Program Storage Budget, Cal. Pub. Utils. Comm'n Rulemaking 12-11-005, Order Instituting Rulemaking Regarding Policies, Procedures and Rules for the California Solar Initiative, the Self-Generation Incentive Program and Other Distributed Generation Issues (Aug. 9, 2019), Mass. Dep't of Energy Resources, The Clean Peak Energy Standard: Draft Regulation Summary (Aug. 7 & 9, 2019), https://perma.cc/2ZT8-YDNZ.

[91] *See* Am. Council for an Energy Efficient Economy, Energy Efficiency Resource Standard, https://perma.cc/6YUQ-8XVC (accessed Oct. 22, 2019) (listing policies of various states).

[92] PACENation, *PACE Programs Near You*, https://pacenation.us/pace-programs/ (accessed Aug. 27, 2019).

[93] Brenda Chew et al., Non-Wires Alternatives: Case Studies from Leading U.S. Projects (2018).

And yet, even though fairness was never the main priority of the design of NEM programs, their "fairness" has received a great deal of attention by commentators and public service commissions in recent years.[94] Some discussions of NEM's fairness focus on whether NEM results in a "cross-subsidy" or "cost shift," whereby DER owners' patterns of electricity consumption and compensation for excess generation leads them to contribute disproportionately less to the revenues utilities rely on to cover the costs of providing centralized electricity services. As a result, so goes the argument, customers with no DER end up paying a disproportionately greater share of utility costs.[95] Other discussions of fairness focus on whether NEM is "fair" to utilities, which receive less in bill payments from NEM participants yet must maintain the infrastructure that supports those participants' continued access to centralized resources.[96]

This report does not attempt to define fairness or to articulate whether or how NEM could be made fair. Instead, it argues that the question of NEM's "fairness" arises from misplaced reliance on retail rates, which are necessarily based on an unduly narrow perspective on benefits and costs. The question of fairness can be best dealt with by adopting a broader perspective and allocating the benefits and costs encompassed by *that* perspective in accordance with principles of economic efficiency and cost causation—steps embodied in the value stacking mechanism described below. Taking these steps recognizes the value contributed by DERs and compensates those contributions for that value, but not more. Unfortunately, resolution of this sort is seldom if ever considered in arguments over whether NEM is unfair and in need of correction. Instead, demands for so-called fairness have given rise to tight caps on NEM eligibility and non-coincident demand charges for NEM program participants,[97] measures that establish more stable revenue streams for utilities[98] but do not cause DERs to be compensated more accurately in light of their benefits and costs to society.

* * *

NEM has enabled the initial deployment of renewable DERs in many jurisdictions,[99] but as those deployments have grown, state authorities have begun to re-examine NEM.[100] Indeed, many if not all states that allow DERs to interconnect and compete with centralized grid resources are either exploring or implementing changes to their original NEM programs (see callout box).[101] For the reasons presented above—some of them valid, others debatable—states want to move beyond NEM. Some also want to move to an approach centered on value stacking.

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[94] *See, e.g.*, Geffert & Strunk, *supra* note 11, at 37 (examining whether NEM is unfair to non-participants and utilities and concluding that it is unfair to both).

[95] *But see* Memo from Homer & Orrell, *supra* note 86, at 8. ("cost shifts can go both ways"); *see also* Barbose, *supra* note 28, at 30-31 (concluding that NEM often leads to cost shift but in de minimis amounts that do not materially affect ratepayers).

[96] *See, e.g.*, Lindsey Hallock & Rob Sargent, Shining Rewards: The Value of Rooftop Solar Power for Consumers and Society 15-16, tbl.2 & fig.1 (2015), https://perma.cc/2Y5P-E9PC (showing that sponsorship and methodology of 11 "value of solar" studies generally predicts conclusions about utility cost recovery from DER owners).

[97] For examples, see Melissa Whited et al., Synapse Energy Econ. (prepared for Consumers Union), Caught in a Fix: the Problem with Fixed Charges for Electricity 26-27 (2016), https://perma.cc/RJ33-B8X7.

[98] The Louisiana Public Service Commission's recently adopted net metering reform, which authorizes utilities to recover lost revenues due to excess generation exported to the grid by DER owners, is an especially clear example. Catherine Morehouse, *Louisiana Utilities to Pay Less for Rooftop Solar Power Under New Net Metering Rules*, UtilityDive, Sept. 13, 2019, https://perma.cc/2HGH-B6TL.

[99] Naïm R. Darghouth, Nat'l Renewable Energy Lab., Net Metering and Market Feedback Loops: Exploring the Impact of Retail Rate Design on Distributed PV Deployment 2 (2015), https://perma.cc/53G8-58PK.

[100] Herman K. Trabish, *Renewables: As Rooftop Solar Expands, States Grapple with Successors to Net Metering*, UtilityDive, Sept. 13, 2018, https://perma.cc/FU64-8RXA.

[101] Some states are simply retaining NEM. In Maine, the election of a Democratic Governor and legislature led to the reversal of plans to adopt a NEM replacement that would compensate excess generation based on a static value that reflected avoided utility costs only. Me. Rev. Stat. tit. 35-A, § 3209-A (West 2019) (codifying An Act to Eliminate Gross Metering).

The case for replacing net energy metering with a value stack

If implemented well, a value stack *can* improve on all aspects of NEM without sacrificing the certainty made available from NEM's simplicity. Whereas NEM fails to capture temporal and locational variations in value, a value stack uses them to inform stakeholders and optimize system planning by indicating where DERs can or cannot add value. Whereas NEM ignores values not reflected in retail rates, a value stack can reflect the wider array of values that materially affect stakeholders and system planning. And whereas NEM invites misguided debates over fairness, a value stack can remove the motive and need for such debates by demonstrably compensating program participants for the value they add and nothing more.

It is important to note, however, that a value stack mechanism is an interim and partial solution. The ultimate and complete solution would not stop with owners of DERs but would make the prices that *all* electricity customers pay for electricity services sensitive to costs that change across times and locations. This would level the playing field for investments that can only reduce behind-the-meter consumption such as energy efficiency, and investments that can reduce consumption and inject, such as solar PV. That solution would also expand the list of costs that factor into electricity prices to include emissions of greenhouse gases and ambient air pollutants. However, recognizing that interim steps are often inevitable (if not entirely necessary) to reach this ultimate goal, this report encourages regulators capable of doing so to begin compensating DERs using a value stack. This value stack should reflect temporal and locational differences and encompass more than just avoided utility costs.

NEM and post-NEM programs currently being implemented or considered

1. Retain NEM and ease eligibility limits to allow new categories of participants and larger volumes of participating capacity (example: Washington State).[102]
2. Retain NEM but put curbs on participant compensation (e.g., higher noncoincident demand charges for participants or caps on how much capacity can participate) to (a) offset the revenue utilities lose when DG owners buy less electricity and (b) eliminate cost-shift from participants to non-participants (example: Arkansas).[103]
3. End NEM and adopt a "NEM 2.0" program that employs time-of-use (TOU) rates and locational targeting for program participants (example: California).[104]
4. End NEM (for some or all customer classes) and establish a successor program that credits excess generation based not on retail rates but on a static value that is updated annually (example: Minnesota).[105]
5. End NEM and establish a successor program centered on a value stack whose components are dynamic and whose broad perspective encompasses pollution factors as well as avoided bulk power system and distribution system costs (example: New York).[106]

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[102] Wash. Rev. Code Ann. § 80.60.005 (West 2019) (codifying Solar Fairness Act).

[103] Ark. Code Ann. § 23-18-603 through 605 (West 2019). Decision Adopting Successor to Net Energy Metering Tariff, Cal. Pub. Utils. Comm'n Decision 16-01-044 (Jan. 28, 2016), https://perma.cc/DHZ9-U8NW.

[104] Decision Adopting Successor to Net Energy Metering Tariff, Cal. Pub. Utils. Comm'n Decision 16-01-044 (Jan. 28, 2016), https://perma.cc/DHZ9-U8NW.

[105] Minn. Stat. § 216B.164, subd. 10 (West 2019); *see also* Benjamin Norris et al., Clean Power Research (for Minn. Dep't of Commerce), Minnesota Value of Solar: Methodology (Apr. 2014), https://perma.cc/DE53-43R4.

[106] Stanton, *supra* note 4, identifies eight types of response by commissions to the increasingly obvious problems with NEM as the solution for compensating DER contributions to electricity service provision: NEM 2.0 or successor [included VDER]; comprehensive rate design review and update; changing rates for "net excess generation"; higher monthly fixed charges for mass market customers; creation of new DER customer class for separate treatment; authorizing third-party or utility ownership of DERs; authorizing community solar.

Table 7 below summarizes the dynamic components that can be combined by a value stack to inform the value of a DER's contributions—viewed from a societal perspective—to providing electricity services.

Table 7. Value stack components, their underlying dynamic metric(s), and their temporal and locational parameters.

Component	Metric and/or Units	Interval	Geography
Wholesale energy (including generation, congestion, and line losses)	LMP [$/MWh]	Hour	Wholesale market node (or zone)
Wholesale capacity	Installed capacity or "ICAP"[107]	*Varies by jurisdiction*	
Transmission	*Varies by jurisdiction;*[108] *LMP & ICAP capture some but not all capital and O&M costs of transmission*	Six months	
Distribution system capacity and line losses	Utilities' marginal costs of service	Decade	As local as possible: primary feeder, lateral feeder, transformer
Greenhouse gases	[CO_2e / MWh]	Hour	Wholesale market zone
Ambient air pollutants	[PM, SOx, NOx / MWh]	Hour	*As granular as is supported by available tools e.g., EASIUR, InMap*
Resilience	*Varies by jurisdiction*	*Varies by jurisdiction*	Distribution utility service territory

The Metric column contains items described in part II; the Interval column indicates how frequently those metrics should be updated to stay accurate; and the Geography column indicates where the metric pertains. In a "stack," these assembled metrics look like figure 8, below, which shows how they compare to the flat retail rate that informs NEM program compensation.

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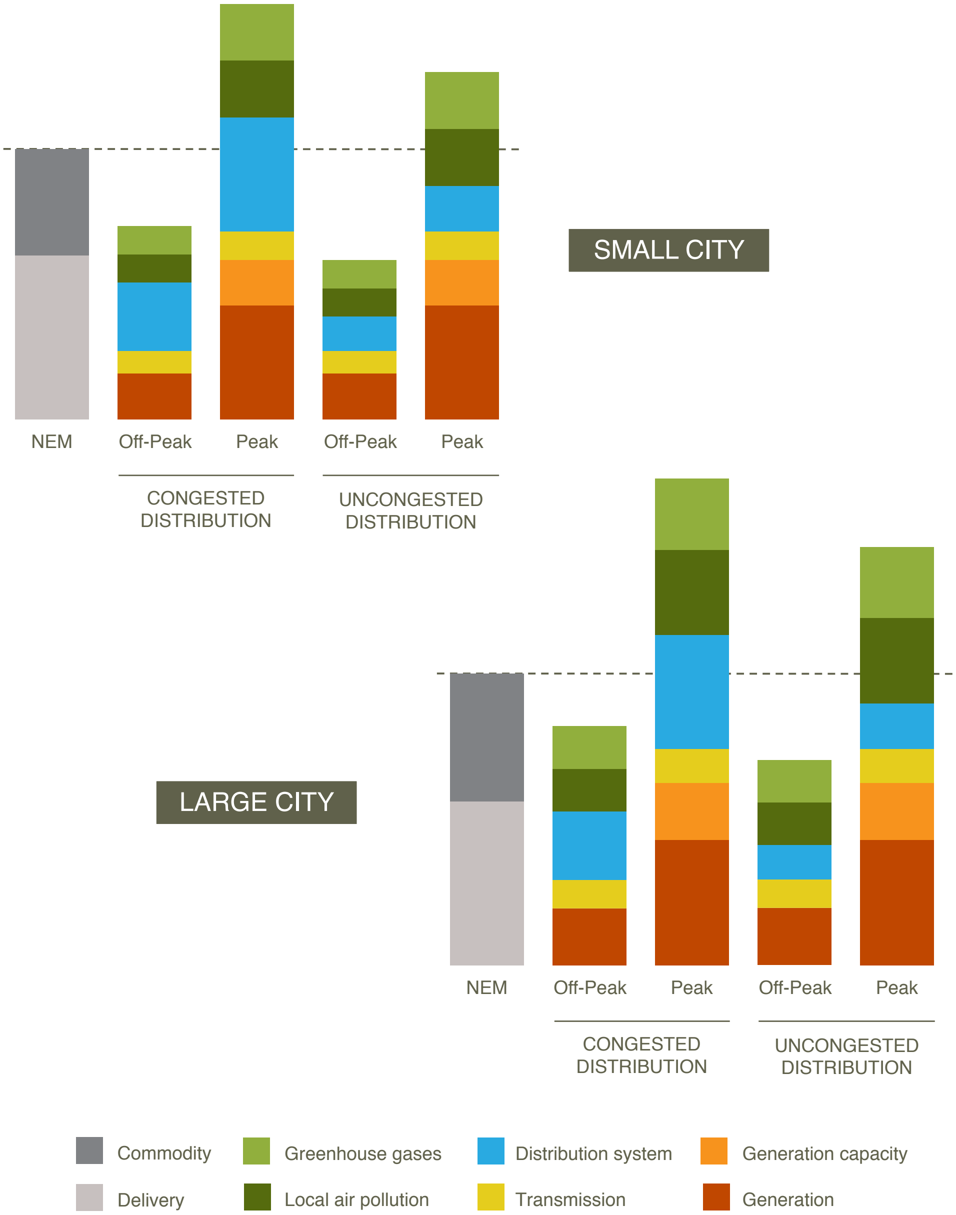
[107] A California Public Utilities Commission proceeding investigated two different use cases, one for the short term that uses a version of ICAP payments as a proxy for capacity value, and one for the long term that uses the cost of new entry (CONE). *See* Locational Net Benefit Analysis Working Group Long Term Refinements Final Report, Cal. Pub. Serv. Comm'n Rulemaking 14-08-013, at 49-52 (Jan. 9, 2018), https://perma.cc/4JXJ-BYZ8.

[108] *See, e.g.*, ConEdison, Benefit-Cost Analysis Handbook v.2.0, at 20-24 (2018), https://perma.cc/2GPL-5GL3; *see also* Paul Denholm et al., Nat'l Renewable Energy Lab., Methods for Analyzing the Benefits and Costs of Distributed Photovoltaic Generation to the U.S. Electric Utility System 34-37 (2014), https://perma.cc/F5XB-W5VH (listing three possible approaches to calculation).

Figure 8. Conceptual comparison of retail rate (and NEM) to value stack compensation across times (peak and off-peak) and locations (congested and uncongested distribution grid sections in a large and small city)



There is an important difference between what the NEM bars indicate and what the others do. The NEM bars' heights indicate what a DER would be compensated by a NEM program in each city over a full billing period. By contrast, the other bars' heights indicate how much a DER would be compensated by a value stack in select places and select times within a billing period.

Figure 8 illustrates how compensation for DERs in accord with this report's proposed value stack would respond to different settings and circumstances. Before exploring how the value stack bars in the figure reflect responses to those settings and circumstances, it is useful to first understand the delivery and commodity components of the NEM bars. As explained above, most retail rates do not reflect the costs of providing electricity services at particular times and locations. Instead, they reflect average values, arrived at by taking the utility's costs of providing electricity in an entire service territory for each billing period, summing those costs and then parceling them out to different classes of ratepayer as "flat" rates. Because NEM mirrors retail rates, NEM generally compensates DER owners based on these homogenized, "flat" values.

This is why, in Figure 8, the delivery component (light grey) in each city is proportionate to the average of the distribution system costs (blue) in the four different settings shown for that city. Even though distribution system costs might be higher in congested areas, the utility does not charge customers served by congested facilities more. And so, NEM compensation does not rise in congested areas or fall where there is no congestion. Similarly, the commodity component (dark grey) of the NEM bars is proportionate to the average of the bulk power system costs (yellow, orange, and red) in the corresponding value stack bars. Even though those costs differ significantly across both congested and uncongested areas and peak and off-peak times, retail rates flatten out these differences. And NEM compensation, which mirrors flat retail rates, ignores those differences too.

Unlike the NEM bar components, the value stack bars' components respond to changes in load (i.e., on- or off-peak), the presence of congestion in the local distribution system, the number of people exposed to air pollution released by nearby generation facilities, and the volume of greenhouse gas pollutants emitted.

Peak/Off-peak. At peak times, the bulk power system incurs costs to generate electricity and transmit it to load centers. And, because enough capacity to supply peak load must be maintained, the bulk power system also incurs capacity costs at peak times. At off-peak times, demand is lower, so energy costs are lower and capacity costs fall to zero. The value stack translates a DER's ability to help avoid costs at these times into commensurate compensation—more at peak times, less at off-peak.

Distribution system congestion. Congestion also makes a distribution system more expensive to operate and can spur expensive capital investments. So, as reflected in the value stack, a DER's ability to help avoid congestion is valuable at all times, and especially at times of peak load. It is important to note that the timing of this congestion may or may not correspond with the bulk power system peak.

City size. The public health costs of local air pollution are a function of the pollution's severity and the number and demographics of people it affects. It follows that those costs are higher in a large city because more people are affected, even if the volume of emissions is the same as that emitted near or in a small city. The value stack compensates a DER for its ability to help avoid these costs.

Greenhouse gas emissions. The generation fleet depicted in Figure 8 resembles those that operate in the NYISO and California ISO. There are no large, coal-fired generators, and the nuclear and renewable resources that supply most generation during off-peak times do not emit. At peak times, especially in cities with constrained transmission access, natural gas and dual-fuel resources operate as well. And so, both the volume of greenhouse gas emissions and the value of DERs' ability to avoid them tracks generation peaks. The large city is home to more load, higher peaks, and thus more emissions. In the PJM Interconnection region—which covers 13 states from the Midwest to the Mid-Atlantic and is home to much of the country's coal-fired generation capacity—these values would be quite different.

Figure 8 makes two important points especially clear. First, the different heights of NEM and value stack compensation in each scenario highlight that NEM programs often ascribe inaccurate values to DERs. Such inaccuracy in NEM-based compensation necessarily leads developers to put DERs in the wrong place, i.e., where they will add little or no value. The second point is that ignoring the costs imposed by emissions—and so ignoring the value of avoiding them—also leads to an under-valuation of DERs. Recognizing DERs' full value requires adopting a broader perspective on costs and benefits than that of a utility and its ratepayers.

Circumstances important to the effectiveness of a value stack

Administering a value stack effectively requires gathering and analyzing a great deal of granular information on an ongoing basis. And it requires regulatory authorities, utilities, and other stakeholders to work together to translate that information—particularly as it relates to various costs—into a single, dynamic price, on an ongoing basis, even as circumstances change. This means deploying AMI and pursuing integrated distribution system planning in a way that balances program design priorities.

When deciding how to compensate DERs, transparency and predictability can be as important as accuracy and precision. The primary goal of the compensation scheme should be the development of the right DERs in the right places, and the avoidance of unnecessary and unduly costly alternatives. Regulators and stakeholders in California and New York have both learned that implementing a value stack in a world rife with transaction costs and risk-aversion requires striking a balance between accuracy, transparency, and predictability.[109] New York's market for solar PV slowed in 2018 after compensation efforts prioritized accuracy without due concern for the other two priorities.[110] That slowdown followed the PSC's Value of Distributed Energy Resources Phase One Implementation Order, which directed that the distribution component of the value stack would be revised every three years based on input from utilities.[111] Investors and the DER developers that rely on them anticipated from this the elimination of revenue for any project beyond a three-year time horizon.[112] Regulators learned from this experience, and in 2019 adjusted the DER compensation scheme by (among other things) "locking in" the distribution component's value for 10 years—the same time horizon used by New York's retail utilities for amortizing distribution grid assets.[113]

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[109] *See* Herman K. Trabish, *Unnecessary Complexity? Assessing New York and California's Landmark DER Proceedings*, UtilityDive, Apr. 4, 2018, https://perma.cc/8N8H-3WGN.

[110] *See* John Weaver, *Community Solar Spurns New York's VDER, Seeks a Return to Net Metering*, PV Mag., June 20, 2018, https://perma.cc/Q9ED-XRKG.

[111] Order on Phase One Value of Distributed Energy Resources Implementation Proposals, Cost Mitigation Issues, and Related Matters, N.Y. Pub. Serv. Comm'n Case 15-E-0751, In the Matter of the Value of Distributed Energy Resources 11-13 (Sept. 14, 2017), https://perma.cc/52PH-X238.

[112] Jeff St. John, *Why Solar Advocates Are Crying Foul Over New York's Latest REV Order*, UtilityDive, Sept. 19, 2017, https://perma.cc/DM6F-3YZL; see also Comments of the Clean Energy Parties, N.Y. Pub. Serv. Comm'n Case 15-E-0751, Value of Distributed Resources Phase One Implementation Plans 5 (July 24, 2017), https://perma.cc/2VU7-ZCWY ("It is much harder to design customer products and finance projects if there are key values that are unpredictable, irretrievable, or subject to utility interpretation.").

[113] Order on Value Stack Compensation, N.Y. Pub. Serv. Comm'n Case 15-E-0751, In the Matter of the Value of Distributed Energy Resources 20-21 (Apr. 18, 2019), https://perma.cc/8NBD-FVKP.

Conclusion

The value of particular electricity resources to different stakeholders and to society as a whole depends on multiple factors, several of which are sensitive to where and how those resources operate. For instance, in a region where load growth is on pace to exceed the capacity of existing generation or transmission, DERs whose operation will reduce load peaks can help to defer or wholly avoid the costs of importing more electricity from other regions or developing new generation and transmission facilities. Similarly, in an area burdened by a congested distribution system, DERs that alleviate one or more sources of congestion can thereby reduce costs and, potentially, improve reliability. And DERs located in communities served by fossil-fueled generation facilities can displace those facilities' operation and thereby deliver environmental and public health benefits. If the displaced facilities burn coal or oil, the benefits of their displacement are likely to be especially large. Capturing these sorts of benefits requires adopting a perspective that recognizes them. Such a perspective must be broader than that of an electric utility and should be broad enough to recognize benefits and costs accruing to society as a whole, such as the benefits to public health of avoiding local pollution.

NEM programs generally do a poor job of translating these determinants of value into appropriate compensation for DERs. This deficiency owes to NEM programs' embodiment of a cramped perspective (that of a utility, rather than society) and reliance on flat retail rates that ignore the importance of timing and location to value. State regulators considering how best to compensate DERs should make those two features—a broad perspective on benefits and costs, and sensitivity to timing and location—basic to whatever programs they adopt. A value stack is the logical mechanism for translating these features into compensation for DERs, and thereby informing decisions about whether solar PV, energy storage, another type of DER, or no DER at all would add the most value in a given set of circumstances.

As several states have discovered, implementing a value stack requires commissions to strike a balance between the competing priorities of accurate valuation, transparent access to information about the local and regional electricity grid, and predictability with regard to sources of DER compensation. All three are indispensable, and ensuring that a DER compensation program embodies all three requires thoughtful engagement with stakeholders both before and after a commission adopts a value stack. Commissions just now undertaking to examine and possibly move beyond their NEM programs should look to both the processes and the outcomes in states that have led, even if they have sometimes stumbled along the way.

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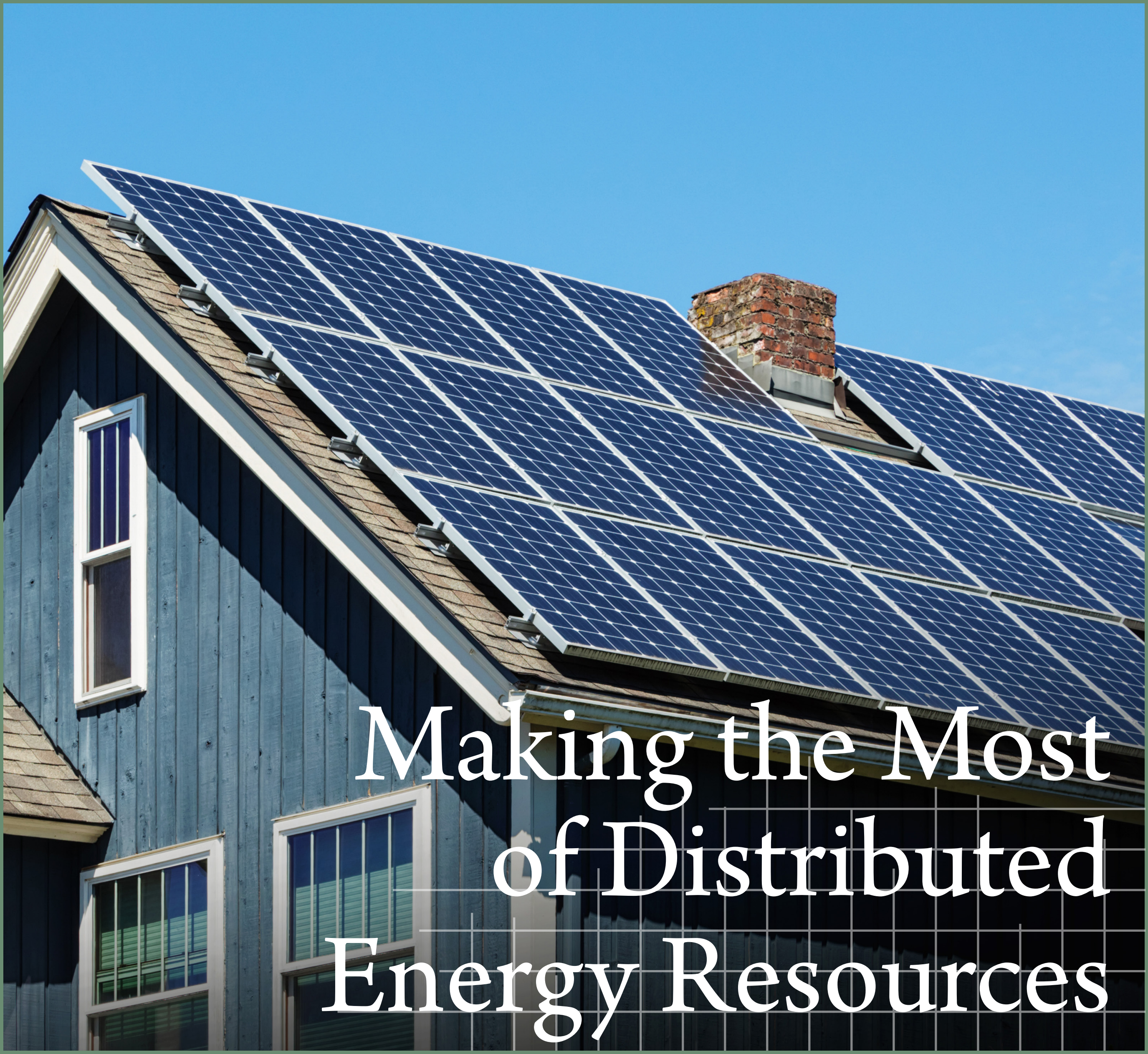

Making the Most of Distributed Energy Resources

Subregional Estimates of the Environmental Value of Distributed Energy Resources in the United States

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

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Figures and Tables

Executive Summary

Distributed Energy Resources (DERs), like rooftop solar and battery storage, have the potential to generate significant social benefits by displacing pollution-emitting electricity generators. Accurately compensating DERs for this environmental and public health value, which some regulators and experts call the "E-Value," is imperative for making the most out of DERs' potential. Doing so will ensure DERs are deployed, and used, when and where they create the most value for society. In practice, however, calculating the E-Value of DERs is difficult without a detailed model of the electric power sector because the benefits of avoided air pollution can vary significantly by location and time of day or time of year.

This report provides a new set of hourly E-Values for the whole United States, broken down into 19 subregions, using an open-source reduced-order dispatch model.[1] Critically, these granular estimates are shown to vary considerably by geography, hour, and season. The patterns uncovered by these estimates can help policymakers design economically efficient DER policies to reduce air pollution from electricity generators. Because these results come from an open-source model, they can be particularly useful for regulators with mandates to use publicly available data in their decisionmaking[2] or for those who desire to do their own analysis.

This report reveals three novel insights based on the hourly E-Values generated by the model. First, the E-Values of DERs depend crucially on the location of the DER, as some regions have more pollution-intensive electricity generators than others. Second, unlike the production cost savings of DERs (which are generally greater during periods of high electricity demand), there is no general and consistent pattern that can effectively characterize the E-Value of DERs throughout the day. Finally, the E-Value of DERs can be large – potentially greater than the benefits of avoided electricity production costs, and generally greater than what commonly used heuristics would suggest.

Policymakers can use these estimates and insights to create effective DER policies and programs. These findings highlight the need for more accurate and granular valuation of DERs, without which investments in DER technologies are likely to be either meager or misdirected. Policymakers using E-Value estimates in the design of DER compensation schemes or the assessment of other DER policies can rest assured they are making the most of DERs' potential to deliver social benefits in their jurisdiction.

The modeling results make clear four specific policy implications. First, the relative magnitude of E-Value can tip the scales in favor of DERs. Accounting for both the E-Value and the benefits of avoided energy of DER deployment nearly doubles the benefits of DERs in comparison to valuing the avoided energy alone. Ignoring the E-Value of DERs will therefore result in the deployment of fewer DERs than what is optimal.

Second, the E-Value can identify where in the country different DER technologies are most effective. For example, investing in energy efficiency lightbulbs create the most value where the nightly E-value is the largest, and likewise, efficient air-conditioning and rooftop solar should be directed towards the regions with a high E-Value during summer's midday. Policymakers should use the E-Value when deciding which technologies to support and where they should be deployed.

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Third, general policies rewarding DERs during certain times of day might not effectively capture the benefits of DERs because there is no general and consistent daily pattern in E-Values across all regions. Instead, policymakers interested in granular time-of-day policies must model the specific benefits of a DER's deployment within their region.

Finally, policies must account for both the climate and public health benefits of DERs when calculating the E-Value. Each component makes up roughly half of total E-Value's on average. Ignoring the either component of the E-Value will result in inefficient DER deployment even if the other component is accounted for.

This report proceeds by first establishing the elements that determine the E-Value of DERs, including marginal generators, marginal emissions, pollutant type, location, and timing. With that established, this report then briefly characterizes the model used to calculate the subregional E-Values of DERs and finally summarizes the modeling results. Before concluding, this report discusses the important role of E-Value in policymaking and the several policy implications. Interested readers are directed to Appendix A to learn more about the reduced-order dispatch model, and Appendix B for a table of average E-Values for each subregion, season, and time-of-day.

The Environmental Value of Distributed Energy Resources

DERs are small energy resources that can reduce or supply a portion of onsite demand for electricity.[3] Most DERs do not emit greenhouse gases or local air pollutants that can be harmful to human health and the environment.[4] When a pollution-free DER reduces the need for pollution-emitting bulk power generation, there are benefits – potentially large benefits – from the avoided pollution. These environmental benefits are fundamental to the characterization of a DER's overall value to society, and, when monetized, are referred to as the E-Value of a DER.

Businesses and individuals typically consider only the benefits of avoided electricity costs when deciding how to invest in and operate DERs. This means that they are bound to ignore the E-value of DERs when making their decisions in the absence of any policy intervention. Because they consider a limited scope of benefits, this behavior results in an underinvestment in DERs.

In response to this problem, some jurisdictions have implemented policies to encourage adoption of additional DERs for the purpose of decarbonizing the electricity grid; this trend is expected to continue as the need to decarbonize electricity grows.[5] However, as regulators strive to understand how to fit DERs into the larger electricity landscape, it is essential that they not only incorporate the E-Value of DERs, but do so accurately. If not, DERs could be deployed in an inefficient way that does not maximize the benefits they can provide or even work against state policy goals.[6]

Fortunately, there are readily available concepts and tools to help policymakers quantify the E-Value of DERs.[7] The rest of this section describes the determinants of the E-Value of DERs and the general procedure to calculate it.

Elements Determining the E-Value of DERs

Unlike the private benefits of DERs, such as avoided energy costs, which can be easily deduced from the price of electricity, calculating the E-Value of DERs requires multiple steps. These straight-forward steps to calculate the E-Value of DERs are summarized below, and the rest of this section goes into more detail on those different steps.

Marginal Generator and Marginal Emissions

A major determinant of a DER's E-Value is which electricity generator it displaces. Although many generators produce electricity simultaneously, usually only one responds to DER-induced changes in the demand for bulk-power electricity. The responding generator must adjust its production to match marginal changes in demand in real time. For this reason, the generator responding to DERs at any given moment is the **"marginal generator."**

Identifying the marginal generator displaced by a DER is the crucial first step in calculating the E-Value of a DER. The marginal generator could be a high-polluting oil plant or a relatively low-emissions natural gas plant, which means that a DER could displace either a larger or smaller amount of harmful emissions. The electricity grid operator, managing the balance of supply and demand in real time, determines which generator is marginal and can directly report this information to the public. Alternatively, because the market operator follows consistent rules to balance supply and demand, the marginal generator can be deduced from a simulation of the electric power sector.

The pollution emissions avoided when the marginal generator decreases its electricity production by a marginal amount are the **"marginal emissions"** of electricity in that moment.[8] The volume and type of pollutant avoided vary depending on the marginal generator's fuel type and other characteristics, like plant efficiency or pollution-control technology. Therefore, knowing only the generator type is not enough to accurately determine the environmental and public health effects. Instead, it is important to have direct observation of marginal emissions from the marginal generator.

Marginal Emissions vs. Average Emissions

The marginal emissions of electricity are different than average emissions of electricity. Marginal emissions capture how generators (and emissions) respond to DER-induced changes in electricity demand and supply. Average emissions, in comparison, represent all pollution from electricity divided by the quantity of electricity generated in a given time period. This means that average emissions fail to capture the true change in pollution due to DERs.

Pollutants, Location, and Timing

The environmental and public health effects of marginal emissions depend crucially on the type of marginal emissions, as well as the location and timing of those emissions. In particular:

(a) Different pollutants have different environmental and health effects. While greenhouse gases accumulate globally and cause global damages, some air pollutants remain local and cause harm relatively nearby. Local air pollutants, like sulfur dioxide, particulate matter, and nitrous oxides, contribute to serious human health consequences for populations near where they are emitted, like asthma and heart disease.[9] Policymakers can use a number of public health models to quantify how different doses of these pollutants affect human health.[10] They can then monetize these health effects using standard estimates, like the value of statistical life;

(b) Pollutants emitted in densely populated areas or near highly vulnerable populations, like low-income communities and communities of color, will cause more damage because of whom or how many people they harm; and

(c) Pollutants can have different effects depending on ambient weather conditions, like sunlight or temperature, so policymakers should know the precise timing of the marginal emissions.

Putting all of these elements together allows policymakers and stakeholders to quantify and monetize the E-Value of DERs. To do so accurately requires granular data on detailed marginal emissions rates and public health models.

Straight-forward Steps to Calculate the E-Value of DERs

1. **Identify the electricity generator on the margin.**
   This "marginal generator" is the last generator required to balance supply and demand. As a result, this generator (or group of generators) will reduce their output in response to DER-induced reduction in demand for bulk-power electricity.

2. **Quantify the marginal emissions from the marginal generator.**
   These are the pollution emissions per unit of additional electricity from the marginal generator. This varies by fuel type and electricity generator attributes (e.g. fuel, efficiency, and other technologies) and so is best measured directly (e.g. through EPA's Continuous Emissions Monitoring System (CEMS)).[11]

3. **Monetize the environmental and public health damages of the marginal emissions.**
   These monetized harms of pollution emissions depend on the type of pollutant, where the marginal emissions are located, and when the pollutants are emitted – both in terms of time of day and time of year. These public health effects can be quantified and monetized using several possible tools.[12]

4. **Calculate the benefits of avoided pollution per unit of DER deployment.**
   Multiplying the marginal emissions (tons/MWh) by the monetized damages per unit of emissions ($/ton) gives an economic value for the environmental benefit of avoided pollution per MWh reduction in bulk-power electricity.[13]

Trong Nguyen

General Model Description

This section presents a brief outline of the reduced-order dispatch model. Interested readers are directed to Appendix A for a more detailed description of the model and its application in this report.

The reduced-order dispatch model uses publicly available data on large fossil-fuel electricity generators to simulate historical hourly electricity production in a pre-specified geographic area.[14] For every week in the sample period, the model ranks electricity generators from lowest cost to highest cost.[15] This reflects the fact that low-cost electricity generators are typically called on to produce electricity before high-cost ones. With this weekly ranking, the model then identifies for every hour which electricity generators can be called upon to collectively produce enough electricity as was produced historically for the hour, but at the lowest possible total cost.

In this way, the model identifies the last electricity generator required to balance supply and demand as the marginal electricity generator. The pollution emitted from the marginal generator (in tons/MWh) represents the marginal emissions for that hour – the increase (or decrease) in pollution for a one-unit increase (or decrease) in the demand for fossil-fuel electricity.

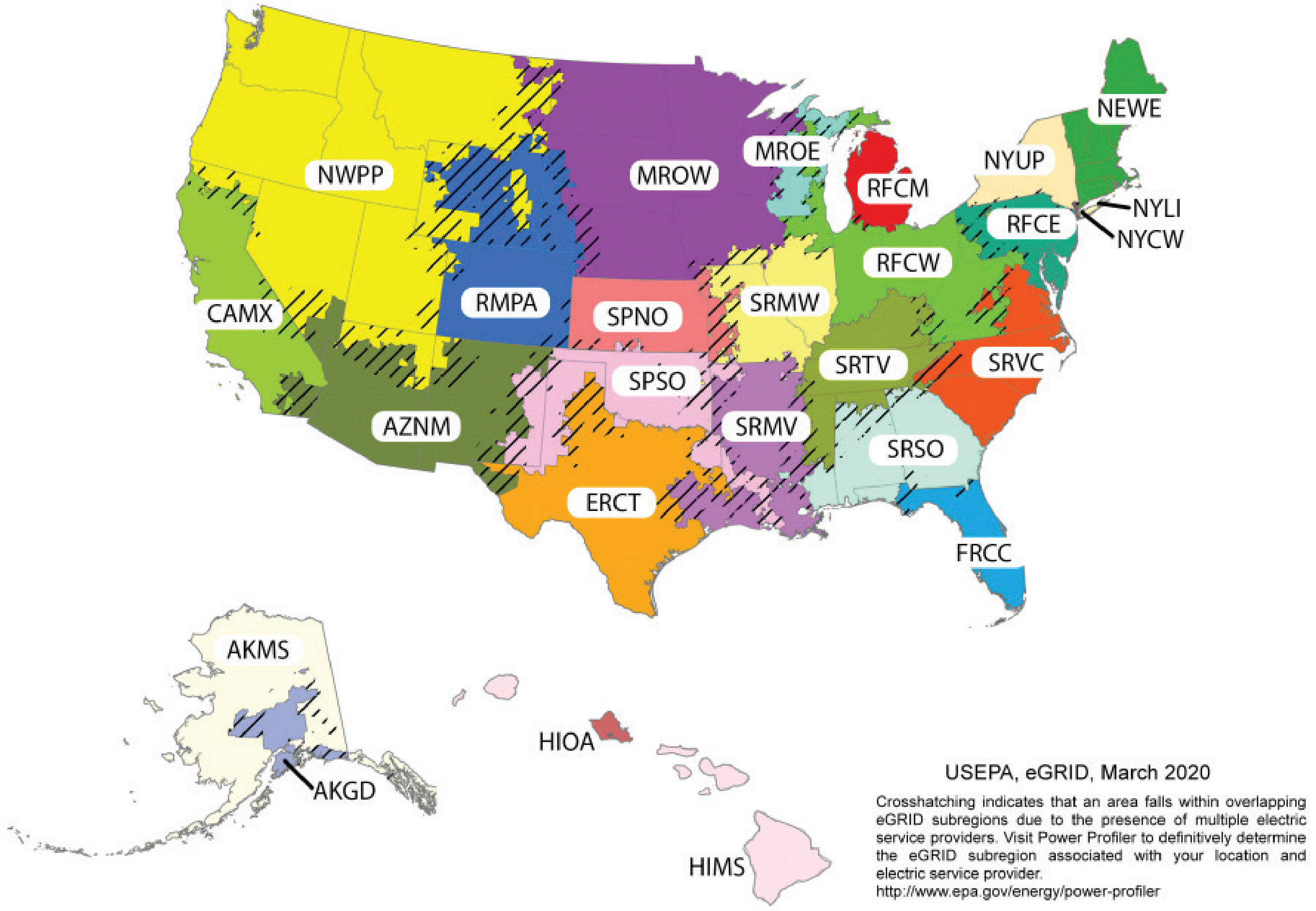
Although this model is relatively simple, it captures several of the complexities inherent in the electric power system, including the required downtime of thermal plants and weekly variation in plant efficiency and fuel prices. However, it does not capture transmission or distribution constraints, nor does it model non-fossil resources.[16]

This report presents results using the reduced-order dispatch model with data from the year 2018, and geographic regions based on EPA's Emissions & Generation Resource Integrated Database (eGRID) regions as displayed in Figure 1.[17] This modeling exercise directly outputs hourly marginal emissions of nitrogen oxides (NO_x), sulfur dioxide (SO_2), and carbon dioxide (CO_2) for each subregion, and therefore simultaneously completes steps 1 and 2 required to calculate the E-Value. For step 3, this report uses location-specific monetized damages of NO_x and SO_2 from the Estimating Air pollution Social Impact Using Regression (EASIUR) model, and monetized damages of CO_2 based on to the Social Cost of Carbon (SCC) developed by the federal Interagency Working Group (IWG).[18] Finally, in step 4, this report calculates the hourly E-Value by multiplying the marginal emissions and monetized damages for each pollutant and summing the resulting product across all pollutants measured.

Data limitations prevent this report from monetizing the damages of primary particulate matter pollution emitted from electricity generators (i.e., black carbon) because EPA's CEMS does not report primary particulate matter pollution data. Rather, the E-Value estimates in this report quantify only the damages of secondary PM2.5 that are produced from chemical interactions in the atmosphere involving SO_2 or NO_x. Because PM reductions are responsible for a significant portion of benefits from federal regulations of emissions from power plants, and so a "substantial portion of the benefits of all federal regulation,"[19] it stands to reason that the omission of this important data means that the E-Value estimates presented in this report are a lower bound.[20]

Evidence suggests that PM is a non-threshold pollutant, which means that it is harmful even at low doses.[21] Therefore, it is important to know the full magnitude of PM emissions. In order to incorporate the full effects of particulate matter into the subregional E-Values, hourly primary particulate matter pollution estimates must be imputed from annual measurements from electricity generators or modeled directly.[22] With these estimates, the E-Value can be updated to include total harms of particulate matter using location-specific monetized damages of primary particulate matter from the EASIUR model. Incorporating the total harms of particulate matter from the marginal electricity generator will increase the E-Value estimates in some regions and may change when and where the E-Value is the greatest.

Figure 1 – eGRID subregions defined by the EPA



USEPA, eGRID, March 2020

Crosshatching indicates that an area falls within overlapping eGRID subregions due to the presence of multiple electric service providers. Visit Power Profiler to definitively determine the eGRID subregion associated with your location and electric service provider.
http://www.epa.gov/energy/power-profiler

Note: NYUP, NYCW, NYLI, and NEWE are aggregated into a single region (NPCC) in the E-Value modeling exercise.

Results

The reduced-order dispatch model and monetization tools uncover the hourly environmental value of DERs for 19 regions in the continental United States. As a reference for policymakers, the season and time-of-day average E-Values are presented in Appendix B. The modeling results show the following conclusions.

The E-Value of DERs Varies by Region

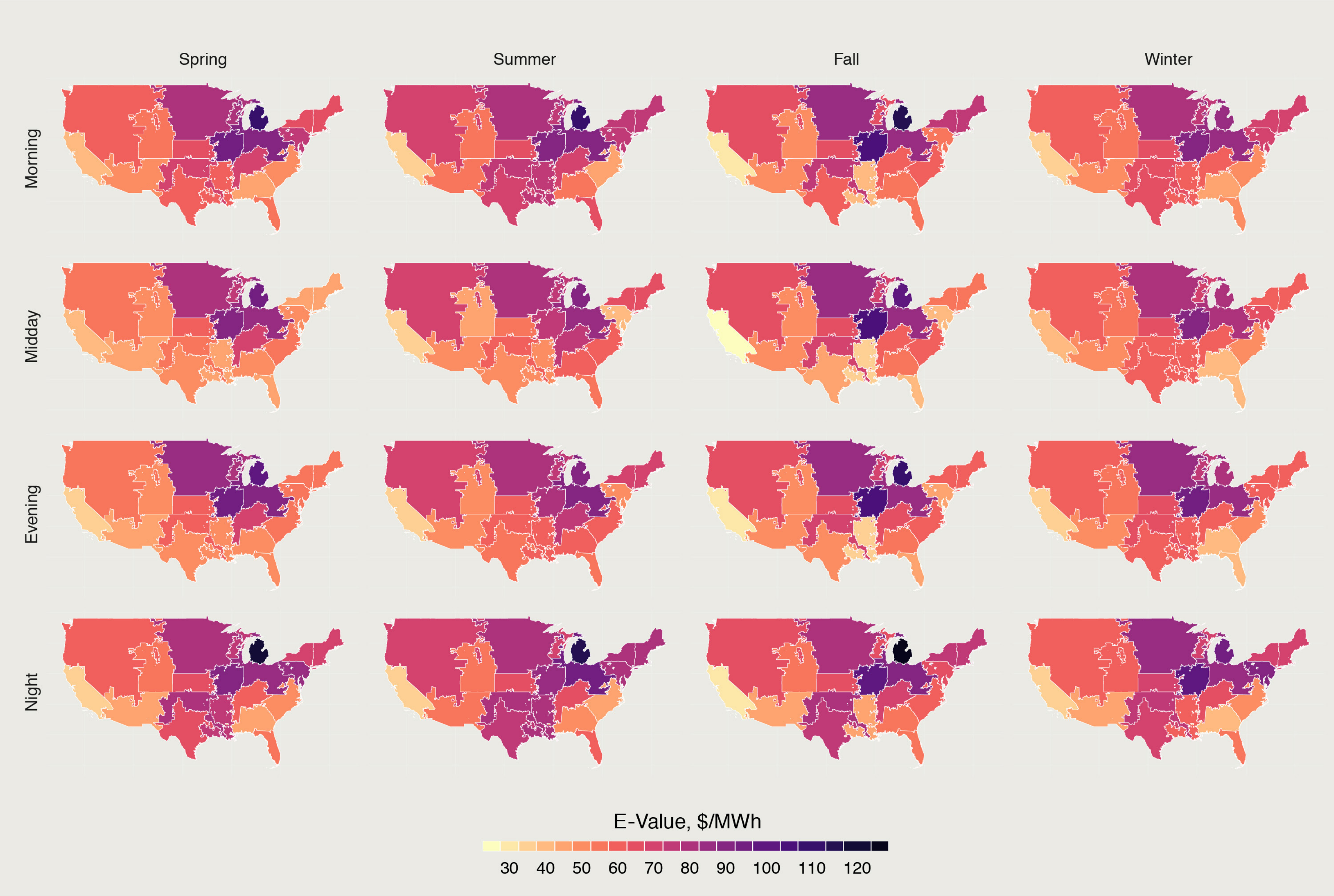
Results from the reduced-order dispatch model suggest the E-Values of DERs can vary significantly by subregion. Figure 2 displays hourly maps of the E-Value of DERs for each subregion averaged by season and time of day. This figure shows that the E-Value depends largely on the geographic region, and less so on the time of day and season. This variation is because some regions use more pollution-intensive fuels to generate electricity than others. For example, the Great Lakes and Ohio Valley regions are heavily dependent on coal electricity generators, which emit a large amount of CO_2 and SO_2 per MWh. The E-Value is relatively small in California where little-to-no electricity is generated by coal electricity generators.

Other than geographic location, population density can be a large determinate of the E-Value of DERs. Densely populated areas experience more damage from a given amount of pollution as more people are exposed. Results in Figure 2 show there are consistently higher E-Values in the Northeast compared to the Rocky Mountains, in part because the former is more densely populated than the latter. Analysis on the electric power sector done by the EPA illustrates this point in the context of PM2.5: a ton of PM2.5 released in the eastern region of the United States causes between \$130,000 and \$320,000 in damages, whereas the same ton in the western part of the United States causes \$24,000 to \$60,000 in damage.[23]

Heidi Besen

E-Values vary by geographic region because some regions use more pollution-intensive fuels to generate electricity than others.

Figure 2 – Map of Subregional Average E-Value by Season and Time-of-Day



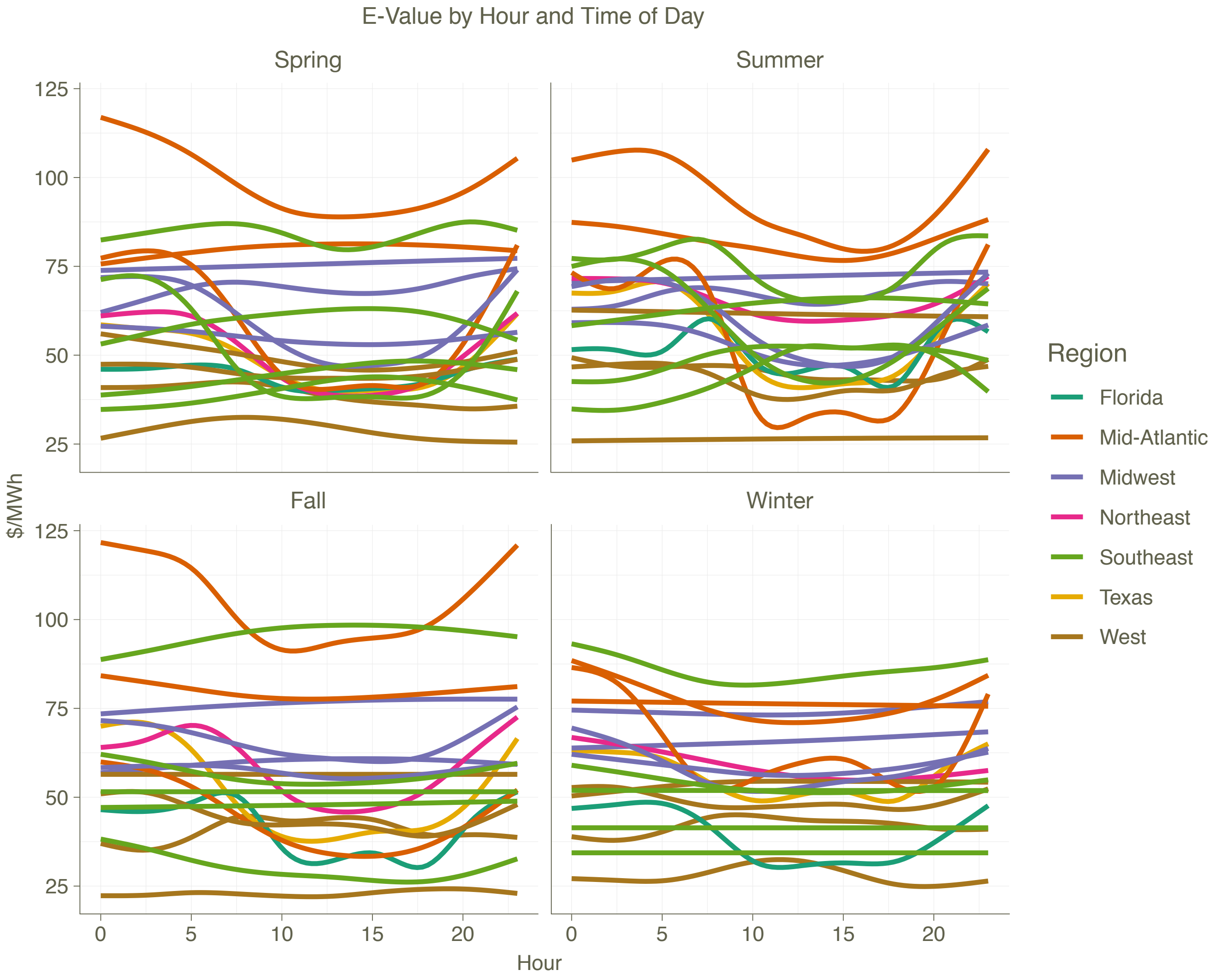
Seasons are defined according to equinoxes and solstices. Each time period is 6 hours long; Morning begins at 4 am, Midday at 10 am, Evening at 4 pm, and Night at 10 pm.

The E-Value of DERs Does Not Follow a General or Consistent Daily Pattern

Generally, the hourly E-Value can vary significantly throughout the day, as the marginal electricity generator, marginal emissions, and associated health benefits change hourly. If the hourly E-Value were to follow a consistent and general daily pattern, policymakers could use this information to better design DER compensation policies by, for example, compensating DERs the most during the time of day they generate the most social value.[24] But, if the E-Value does not follow a consistent and general pattern, policy makers would have to directly observe hourly marginal emissions or model the specific region to accurately compensate DERs for their intra-day variation in E-Value.

Figure 3 presents the average hourly E-Value for each subregion and season in an attempt to uncover whether there is any general pattern that can inform DER compensation policies that vary throughout the day. This figure shows there is no consistent and strong pattern throughout the day or season, especially in comparison to the variation among regions at a specific time of year. If anything, there is sometimes a pattern that is contrary to the pattern in energy costs: In some subregions, the E-Value of DERs is smaller in the middle of the day during "peak demand" periods. This is likely because a natural gas plant is the marginal generator during the day, and a relatively more pollution-intensive coal electricity generator is the marginal generator during the night.

Figure 3 – Smoothed Hourly Average E-Value of Subregions by Season

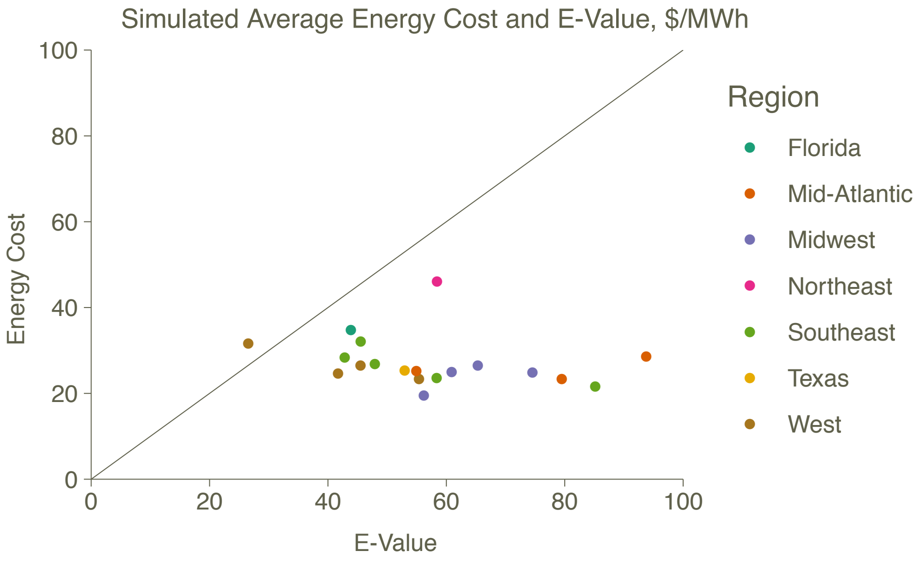


Each subregions color is based on the geography of the corresponding NERC region.[25]

The E-Value of DERs Can Be Large

The average E-Value of DERs, across all 8760 hours in a year and 19 geographic regions, was \$57/MWh (with a median of \$54/MWh). This value is nearly twice the average cost of electricity simulated by the reduced-order dispatch model (\$27/MWh), and greater than the national average wholesale price of electricity in 2018 (\$44/MWh).[26] Figure 4, which displays the simulated average production cost and average E-Value of DERs in every subregion, shows this relationship holds for every subregion except one.

Figure 4 – Simulated Energy Cost Compared to the E-Value of DERs

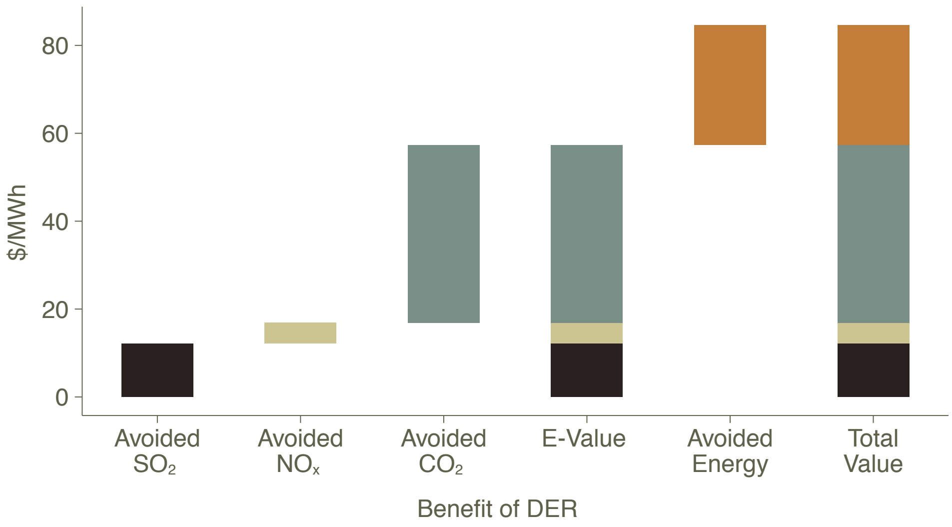


Each subregions color is based on the geography of the corresponding NERC region. The diagonal line represents equality between the two values, and subregions to the lower right of the diagonal lines have an average E-Value greater than average simulated energy cost.

Benefits from avoided greenhouse gas emissions make up nearly half of the E-Value. Decomposing the E-Value of DERs, as done Figure 5, shows the avoided CO_2 pollution is a large component of a DER's benefits on average across all regions and hours. By using the Social Cost of Carbon, the E-Values presented in this report capture, at least in part, the large future damages from climate change (including from coastal storms, extreme weather events, and human health impacts, such as mortality from heat-related illnesses induced by the use of fossil-fuels). Ignoring the benefits of avoided greenhouse gas emissions will provide an underestimate of the total benefits of DERs. For example, recent analysis by the EPA evaluating only the public health benefits of DERs, excluding avoided GHG emissions, range from \$17 to \$40/MWh on average.[27]

Finally, the E-Value of DERs are large relative to the estimated environmental value based on average pollution emissions from electricity production. This means that basing policy decisions on the commonly used heuristic of average pollution emissions instead of marginal pollution emissions leads to inefficient deployment. The divergence between the average pollution emissions and the marginal emissions depends on how the marginal electricity generator differs from the average electricity generator in terms of fuel-type, efficiency, location, and other technical features. The E-Value using the marginal emissions is greater than an E-Value equivalent based on average emissions when, for example, an oil plant is on the margin in a region composed largely of relatively cleaner natural gas electricity generators.

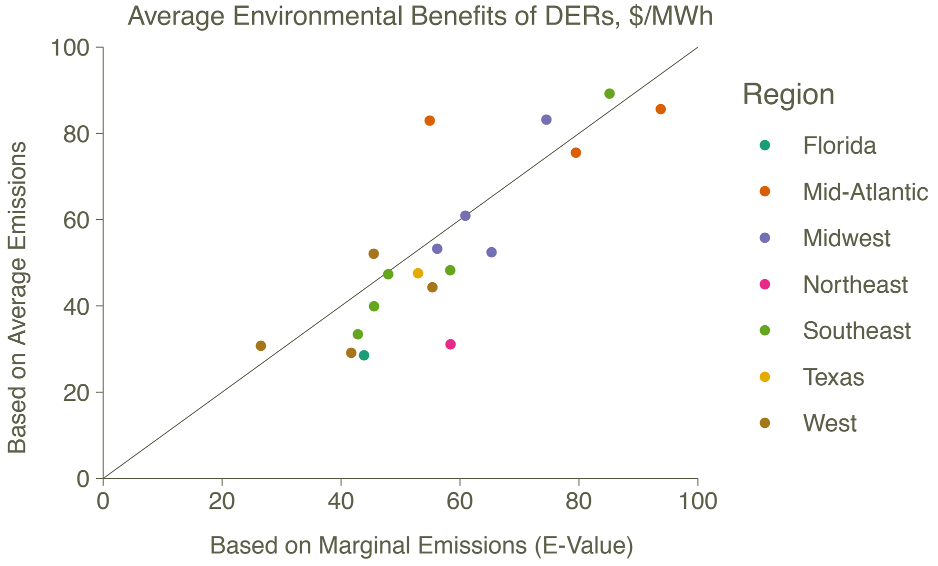
Figure 5 – Decomposition of a DERs' Benefits



Average hourly benefit of DERs across all hour-subregions in 2018. Avoided pollution (SO_2, NO_x, and CO_2) are monetized as described in the General Model Description section of this report. Avoided Energy represents the avoided fuel, operations, and management costs of bulk-power electricity by DERs. These benefits are not exhaustive; DERs can provide additional benefits not listed in this figure such as avoided line losses and avoided capital costs.[28]

The output of the reduced-order dispatch model shows an E-Value equivalent based on average emissions is less than the E-Value based on marginal emissions in 75% of hourly subregion observations. Figure 6 supports this statistic by showing the sample mean of each measure across all 19 subregions. Here, the E-Value of DERs is larger on average when it is based on marginal emissions. Because the reduced-order dispatch model does not include pollution-free resources like nuclear power and hydroelectric dams, the E-Value using actual average emissions (instead of simulated) would likely be even smaller – suggesting a heuristic based on average emissions could greatly undercount the benefits of DERs.

Figure 6 – Comparing E-Value Based on Average and Marginal Emissions



Like Figure 4, regions are defined according to the general geography of NERC regions and the diagonal line represents equality between the two values.

E-Value and Public Policy

DERs are becoming a fixture in the modern grid and policymakers have a variety of reasons for intervening to support DER deployment. First, policies that traditionally guide the electricity market are not designed to govern decentralized resources and so do not consider locational factors. Second, many longstanding policies overlook external costs that come with electricity production from thermal electricity generators, and so do nothing to correct a serious market failure which DERs can address. Third, newer policies to reduce greenhouse gas emissions can be complemented by – or even heavily rely on – greater deployment of DERs.

The E-Value can and should have significant bearing on how DER-focused policies are shaped. This section explores both the general importance of using the E-Value in DER policy and the implications of this report's specific findings.

The Importance of E-Value for DER Policy

Several states are adopting policies that support DER deployment as part of their emissions-reduction goals. Considering the E-Value for different DER technologies can help determine if DER-bolstering policies can achieve the desired pollution reductions. The E-Value can also highlight important policy impacts, such as whether DERs are providing the maximum possible social benefits or which type of DER offers the most benefits in a certain location. In practice, the E-Value can be applied anytime a DER reduces demand from the bulk-power system. The environmental and public health benefits the DER provides are applied in proportion to the number of MWh of bulk-power avoided. This information can ensure that the right type of DER is being deployed at the right time and location by sending the proper price signals.

The E-Value can help policymakers optimize policies that target specific DER technologies or programs, like distributed solar generation, battery storage, and energy efficiency. For example, a solar panel generating 1 MW of electricity reduces the demand for bulk-power electricity and so provides society the benefit of reduced air pollution, represented by the hourly E-Value at that point in time. So, if solar panels generate electricity when and where E-Value is highest, they can provide greater benefits to society. This is why establishing a tax credit offsetting installation costs of rooftop solar will benefit society more if it supports the deployment of solar that displaces an oil plant situated in a low-income community. Accounting for the E-Value when designing such a tax credit would accomplish exactly that.

DERs Policies Can Directly Incorporate the E-Value of DERs

The E-Value can not only inform DER investment, it can also be directly incorporated into policy design. For example, most rooftop solar is compensated a flat rate based on the retail rate of electricity through **net energy metering** policies. As an alternative, regulators can use a **value-stacking approach that is based on DERs' various attributes or services**. A value-stacking approach would compensate DERs for their avoided energy and their E-Value. This is more economically efficient than net energy metering because it accounts for all of the values DERs bring to the power grid.[29]

Similarly, if decisionmakers know the E-Value of charging (or discharging) an energy storage system at any given point in time, they can use this information to determine the values to bill (or compensate) energy storage assets in order to maximize their benefits. A battery discharging 1 MW of electricity generates environmental benefits that are best captured by the E-Value for that hour. If energy storage owners discharge their batteries when the E-Value is high and charge their batteries when the E-value is low, they can provide social benefits by decreasing environmental damages of electricity production.[30] Because energy storage technologies can more easily respond to price signals than most other DERs, it is crucial they are compensated and charged the E-Value accordingly.

Demand response is another similar case: Demand response that conserves 1 MW of electricity not only avoids the cost of electricity production but also provides society with the benefits of avoided pollution, an economic benefit equal to the E-Value for that hour. But, without the E-Value, customers might reduce their demand only when retail electricity prices are high, rather than when the sum of the E-Value and electricity prices are high. The latter approach produces greater social benefits.

The E-Value can also help demonstrate in what parts of the country implementing different energy efficiency policies can create the most benefit. Energy efficiency measures, like replacing incandescent lightbulbs with LEDs, provide greater social benefits when they are deployed in places that rely on electricity from more pollution-intensive electricity generators, like parts of the Midwest, or places with a higher nighttime E-Value.[31] Similarly, locations with a higher E-Value during summer's midday should potentially deploy more efficient air-conditioning before investing in energy efficiency lighting. Knowing the E-Value can also aid federal programs – like the Department of Energy's Weatherization Assistance Program – so that they direct energy efficiency investments towards regions with a higher E-Value on average.

The E-Value should be used in DER policy and can be applied across DER technologies. The next part of this section goes into greater detail about the specific policy implications of the subregional E-Values in this report's findings.

Policy Implications of Results

The Relative Magnitude of E-Value Can Tip the Scales in Favor of DERs

When decisionmakers know that E-Values can be relatively large compared to costs in the electric system, they are better equipped to set welfare-maximizing policies. The average E-Value of DERs across this report's findings was $57/MWh (with a median of $54/MWh). This value is nearly twice the average cost of electricity simulated by the reduced-order dispatch model ($27/MWh), and greater than the national average wholesale price of electricity in 2018 ($44/MWh).[32] The fact that the average E-Value exceeds production costs and wholesale electricity prices should clearly signal to policymakers and other stakeholders that DERs can be a worthwhile investment on their environmental merits alone. In states where DERs are being targeted by policies to reduce greenhouse gas emissions, this makes the case very clear cut. But even in states where investments in DERs are primarily weighed based on private costs and benefits, showing that the E-Value *can* exceed private costs creates a strong signal about optimal resource allocation.

E-Value Can Indicate Where Different DER Investments Are Most Effective

When E-Value is not a deciding factor in setting policy or making DER investments, these policies inevitably exclude considerations of location and scale. This is because absent a DER policy to account for each resource's E-Value, private investment and use of DERs is governed largely by their private benefit – avoided production costs, without regard for location. This suggests DER policies based only on the private production costs are ignoring most of the social value of DERs, and so will likely deploy DERs ineffectively. For example, DER investment based only on the cost of electricity would occur largely in the Northeast, whereas the environmental and public health benefits of DERs suggest they should be a higher priority in parts of the Midwest and Mid-Atlantic.

State policymakers can look at the results presented in this report and see if and when their state has a high E-Value. Though an E-Value of any magnitude should be accounted for in DER policy, states with high E-Values may choose to prioritize DER investment because the benefits can be so large.

General Time-of-Day Policies May Not Be Effective for DERs

Designing policies according to general patterns is common practice for setting retail electricity rates. For example, utilities, or policymakers, sometimes identify a "peak demand" period during the day and set rates higher during that period to disincentivize electricity use. These rates make sense in the context of electricity production. For example, periods of "peak demand" in the summer are generally associated with the highest production costs. If E-Values were to follow a similar daily pattern, smart policy design could compensate DERs for the hours of the day in which they generate the most benefits to society. For example, if the E-Value was consistently greatest in the early morning, retail rates encouraging the use of DERs in the morning would generate more benefits to society than a policy that ignores daily patterns in the E-Value.

However, the results show that even though the hourly E-Value can vary significantly throughout the day - as the marginal electricity generator, marginal emissions, and associated health benefits change – there is no general and consistent daily pattern of E-Values across all subregions. This means that even granular E-Value compensation policies that try to capture hourly variation could be ineffective unless they are based on real-time marginal emissions factors. Accordingly, policymakers that wish to accurately compensate DERs for the E-Value must conduct modeling specific to the location and DER technology under consideration. Blanket policies based on conventional wisdom might incorrectly compensate distributed energy resources the most when they are actually generating the least amount of environmental value.

DER Policies Should Monetize Avoided Climate Damages and Public Health Benefits

Finally, policymakers should ensure that they overlook neither the climate nor the public health aspects of the E-Value. The effects of greenhouse gases and local pollutants vary geographically, so although the greenhouse gas component of the E-Value is significant in some regions, it is outweighed by the public health component in others. Figure 5 shows that damages from CO_2 make up about half of the total E-Value on average. Internalizing the negative public health externalities from local air pollutants is necessary for properly valuing DERs, but it is not sufficient: excluding the negative environmental (i.e. climate) externalities would lead to a serious underestimate of the E-Value in some places. In addition, climate damages themselves reflect public health consequences that are not attributable to local air pollutants, like increased mortality from extreme weather events, so the picture of public health effects is not complete without them.

Luckily, there is a readily available tool that policymakers can use to monetize the benefits from avoiding a marginal ton of CO_2 emissions, the IWG's Social Cost of Carbon.[33] The Social Cost of Carbon should be used anytime a decision will affect greenhouse gas emissions, as is the case with many policies that affect DER deployment. In fact, because

DERs are often targeted by greenhouse gas reduction policies, using the Social Cost of Carbon in the E-Value makes the effectiveness of these policies more apparent.

In densely populated urban areas, it's possible the public health benefits of avoided local air pollution exceed the climate benefits of avoided greenhouse gas emissions. This is because the harms of local air pollutants, like particulate matter, increase in proportion to the number of people exposed to pollution. Monetizing the benefits of avoided greenhouse gas emissions is necessary for the reasons outlined above, but it is also not sufficient. DER policies must monetize both sets of benefits to ensure DERs are deployed at a scale that is economically efficient and provide the greatest possible benefit to society.

Conclusion

Policymakers looking to achieve efficient deployment of DERs in their jurisdiction must accurately compensate DERs for all of their benefits, including the E-Value. If they fail to do so, DERs are likely to be misemployed, meaning society misses out on important and cost-effective benefits of reduced air pollution. In practice, quantifying a DER's E-Value is difficult to do without specifically modeling or observing which electricity generators are displaced by DERs in any given hour and using a public-health model or other tool to monetize the benefits of avoided air pollution.

This report presents the average E-Value of DERs for 19 subregions in the United States using historical data from 2018. The results show that the E-Values are large relative to the benefits of avoided production costs, the public health benefits alone, and what hourly average pollution emissions would suggest. The most important factor in determining the E-Value of DERs is location. DERs in the Great Lakes and Mid-Atlantic region can provide benefits almost twice what they can in California. Finally, there is no general pattern of the E-Value of DERs throughout the day, suggesting policies that try to capture hour-to-hour benefits of DERs require real-time data on pollution from the electric power sector or modeling results specific to the region under consideration.

Although informative, these results paint only part of the picture. The E-Value presented in the report does not monetize the benefits of avoided primary PM2.5 pollution due to DERs. Incorporating these benefits of DERs can only increase the E-Value, possibly by a significant amount. In addition, modeling limitations prevent a more thorough analysis that considers how DERs might displace non-fossil resources like nuclear electricity generators or hydroelectric storage. Finally, as the grid transitions towards more utility-scale renewable generation and less pollution-intensive thermal resources, the E-Value of DERs is likely to change considerably. This suggests there are real benefits to updating E-Values used in policy making on a regular basis.

Appendix A: Reduced-Order Dispatch Model

This report uses an open-source reduced-order dispatch model to quantify the historical hourly marginal emission of electricity generation in a pre-specified region. This model uses publicly available data on historical fuel costs and electricity production to simulate which combination of electricity generators can generate the same electricity as was historically produced, for every hour, while minimizing production costs and respecting historical downtime requirements of thermal generators.

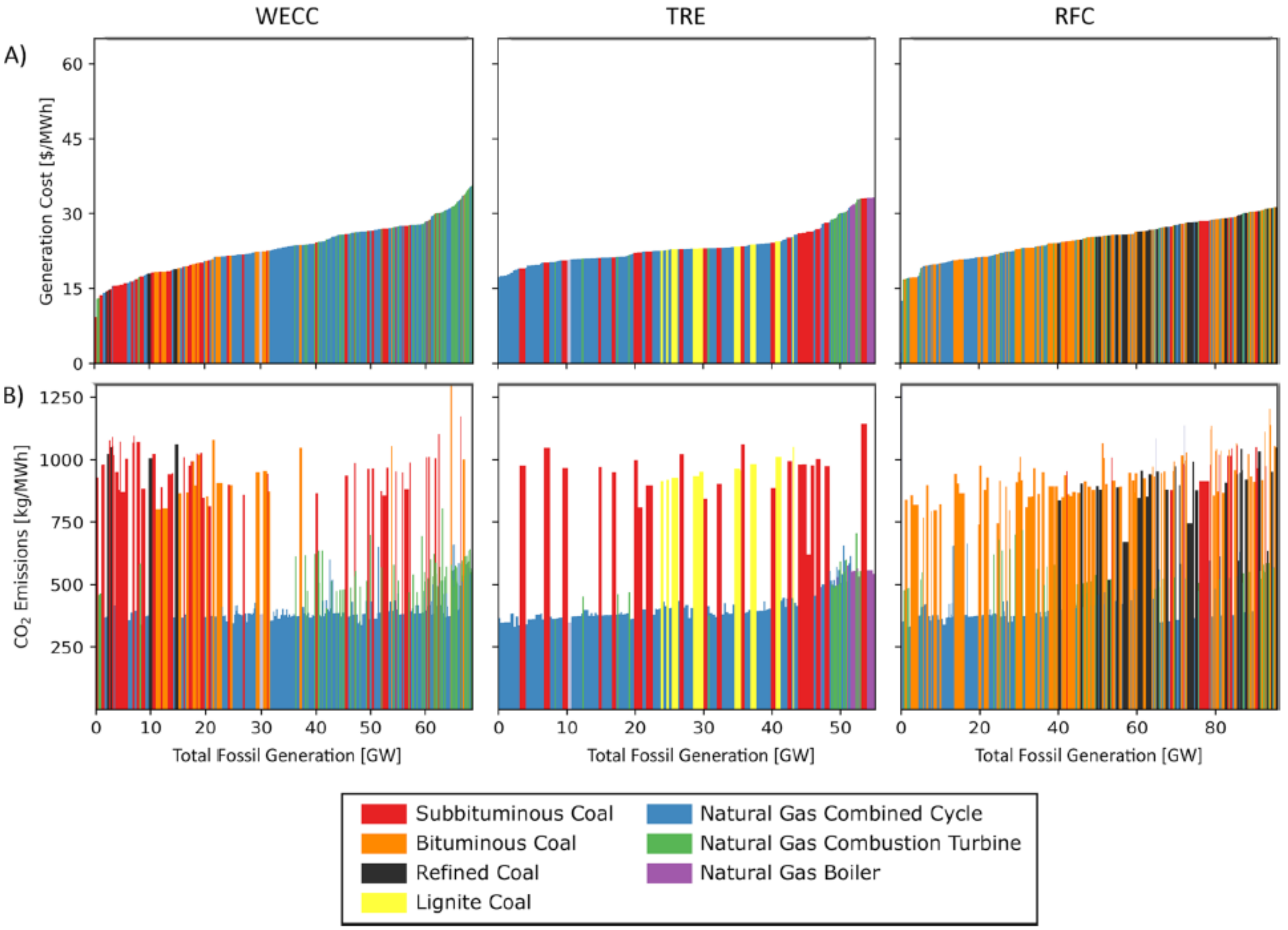
The model accomplishes this by constructing a "bid-stack" for every week on the sample year which ranks large fossil-fuel electricity generators according to their cost to produce electricity.[34] A separate set of bid-stacks are created for each subregion. This bid-stack varies week-to-week according to publicly available fuel prices and observed plant-specific efficiency rates. An electricity generator's costs includes fuel costs specific to the power plant when available, as well as general variable operations and maintenance costs based on the fuel type and power plant age. Figure 7 presents example "bid-stacks" for three regions for the first week in August of 2017 from Deetjen & Azevedo (2019). This figure also shows the weekly marginal emissions of CO_2 (per MWh) for each electricity generator in the bid-stack.

For every hour in the sample, the model determines which combination of resources could have produced the same quantity of electricity as historically produced by large fossil-fuel electricity generators, but at the lowest possible price by finding where the bid-stack intersects with the demand for electricity generated by large fossil-fuel electricity generators for that hour. In doing this, this model respects weekly limits on minimum and maximum output for each electricity generator, as well as required down time of larger fossil-fuel electricity generators. The last generator called upon to balance supply and demand for that hour is the marginal electricity generator, and the marginal emissions for that hour are based on the marginal emissions of that electricity generator.

Although the model is simple, it does a good job reconstructing the marginal electricity generator using historical data. Because it is a simulation, it allows for nuanced hourly emissions that might not be possible with regression-based estimates. In addition, it allows for counterfactual modeling exercises that can assess how pollution emissions would change if a carbon price were implemented in the electric power sector. The model could be improved upon, however, by incorporating non-fossil resources, transmission constraints, and the startup costs of electricity generators.

The Python code to run the reduced order dispatch model is publicly available.[35] For this report the code was modified to allow for more granular market definitions based on eGRID regions, as shown in Figure 1, and updated to more recent data from 2018. All the data required to run the model are publicly available, so the model can be updated in future years to reflect the changing electric power sector.

Figure 7 – Illustration of a Bid-stack and the Corresponding Marginal Emissions



The first figure from Deetjen & Azevedo (2019), supra note 1, showing example bid-stacks and the marginal emissions of each electricity generator in the bid-stack. Reprinted with permission from Reduced-Order Dispatch Model for Simulating Marginal Emissions Factors for the United States Power Sector, Thomas A. Deetjen and Inês L. Azevedo, Environmental Science & Technology 2019 53 (17), 10506-10513, DOI: 10.1021/acs.est.9b02500. Copyright 2019 American Chemical Society. Merit order – ascending in order of operation cost – for the first week of August for three NERC regions showing (A) generation cost and (B) CO_2 *emissions rates. Note that (A) and (B) have the same ordering of power plants.*

Appendix B: Environmental Value Reference Table

Table 1 – Average E-Value of DERs for 19 Subregions by Season and Time-of-Day

eGRID Region	Spring				Summer				Fall				Winter			
	Morning	Midday	Evening	Night	Morning	Midday	Evening	Night	Morning	Midday	Evening	Night	Morning	Midday	Evening	Night
AZNM	42.23	38.37	35.63	39.23	46.90	44.42	42.90	47.82	41.47	43.87	40.06	36.88	42.45	43.61	42.37	39.09
CAMX	32.00	30.32	26.05	27.26	25.69	27.20	26.82	25.92	22.91	22.34	24.04	22.57	28.00	31.70	25.52	26.62
ERCT	52.62	41.21	43.25	58.80	64.31	42.27	48.90	67.65	54.09	38.63	43.90	68.60	57.38	50.97	52.24	62.53
FRCC	46.25	39.96	43.80	46.74	55.59	46.03	49.09	52.91	47.75	33.21	36.20	47.61	43.85	31.33	34.20	47.04
MROE	70.74	67.79	70.60	66.08	68.24	65.44	69.40	64.93	59.99	60.35	60.98	57.45	66.25	63.74	68.59	64.77
MROW	74.92	74.39	78.24	74.67	73.33	71.83	72.95	70.23	76.03	77.25	78.13	73.86	74.94	71.23	75.52	75.26
NPCC*	57.10	39.55	45.25	60.38	69.06	59.21	61.52	72.05	66.63	47.06	54.83	66.47	63.80	53.94	54.71	63.14
NWPP	51.84	45.89	46.92	53.83	62.91	60.52	61.39	61.94	57.47	57.18	55.63	55.50	54.64	53.65	54.69	51.63
RFCE	66.70	41.41	46.86	77.81	69.36	32.53	41.29	71.94	48.95	34.72	37.30	56.17	60.46	58.76	54.83	80.76
RFCM	102.21	89.24	92.10	111.74	102.85	84.36	82.85	106.02	106.31	93.68	100.53	119.20	76.22	71.73	73.48	86.71
RFCW	80.31	79.88	82.16	76.87	82.34	78.40	80.72	86.78	79.12	78.20	79.41	82.32	77.31	73.41	77.66	76.83
RMPA	45.42	43.92	44.44	47.97	45.68	38.33	41.95	47.04	44.98	42.47	40.10	49.90	48.60	47.81	47.23	52.51
SPNO	56.62	53.13	53.65	57.07	56.96	47.76	50.89	58.48	59.29	55.14	57.05	58.45	59.55	55.49	58.06	61.74
SPSO	64.69	48.88	53.66	71.25	66.88	50.19	53.06	70.59	66.44	61.50	62.70	72.17	56.04	53.85	56.36	66.03
SRMV	53.15	38.39	41.98	69.20	66.78	44.94	51.74	73.21	30.37	28.30	26.11	35.75	52.17	50.34	50.94	54.14
SRMW	86.45	81.04	85.89	83.91	80.42	66.95	73.57	78.94	95.84	97.73	98.14	90.90	82.92	82.77	85.90	91.25
SRSO	37.57	42.83	42.20	35.89	48.63	51.97	52.08	44.56	47.61	47.32	49.03	47.61	36.22	33.23	34.00	33.97
SRTV	60.17	62.32	62.13	53.48	62.20	66.04	66.77	59.86	54.97	54.59	55.42	61.00	53.96	51.71	51.25	57.73
SRVC	42.57	45.42	49.40	40.97	39.13	50.91	51.30	37.00	53.03	51.21	51.17	50.77	41.57	40.64	41.59	41.78

*E-Value of DERs ($/MWh) for 19 subregions based on eGRID regions as defined in Figure 1. The cells in this table are shaded in proportion to E-Value for each time period and subregion. *Note "NPCC" represents an aggregation of the NYLI, NEWE, NYUP, and NYCW eGRID regions in the Northeast as shown in Figure 1.*

Endnote

[1] *See* Thomas A. Deetjen & Inês L. Azevedo. *Reduced-Order Dispatch Model for Simulating Marginal Emissions Factors for the United States Power Sector*, 53 Envtl Sci. & Tech. 10506 (2019). Appendix A of this report describes the application of this model in detail.

[2] *E.g.,* New Jersey's Clean Energy Act of 2018 requires that "[t]he methodology, assumptions, and data used to perform the benefit-to-cost analysis [for energy efficiency programs] shall be based upon publicly available sources." N.J.S.A. 48:3-87.9(d)(2)

[3] Examples include distributed electricity generators (i.e. modular solar panels or other small-scale electricity generators), energy storage (e.g. batteries that charge and discharge electricity onsite or with the grid), demand response practices (i.e. a system that can use battery storage, 'smart' residential or commercial appliances, and other technologies to reduce demand for electricity when called upon), and energy efficiency investments (i.e. efficient appliances, weatherization, and other technologies that reduce energy consumption onsite).

[4] Some DERs, like small diesel generators, do generate pollution. For others, the associated pollution is uncertain. For example, distributed battery storage can contribute to more pollution if the electricity generator charging the battery produces more pollution than the electricity generator the battery displaces when it is discharged. *See* Richard L. Revesz & Burcin Unel, *Managing the Future of the Electricity Grid: Energy Storage and Greenhouse Gas Emissions*, 42 Harv. Env't l L. Rev. 139 (2018). The E-Values in this report are still beneficial to policymakers so long as DERs are accountable for the pollution they induce (via electricity generation or otherwise).

[5] *See* Mass. Inst. of Tech., The Future of the Electric Grid 110 (2011).

[6] For example, without accounting for the E-Value of DERs it is possible that rooftop solar could end up displacing electricity generated from wind turbines, and areas with serious air pollution might not invest in energy efficiency or demand response programs at the scale that is best for society.

[7] *See* Jeffrey Shrader et al., Inst. for Pol'y Integrity, Valuing Pollution Reductions: How to Monetize Greenhouse Gas and Local Air Pollutant Reductions from Distributed Energy Resources (2018).

[8] Marginal emissions are measured as a rate, in mass of pollution (e.g. tons) per unit change in electricity demand (e.g. megawatt-hours (MWh)).

[9] *See* Shrader et al., *supra* note 7 at 19-21; *see also* Richard L. Revesz & Jack Lienke, Struggling for Air: Power Plants and the "War on Coal" 11 (2016).

[10] *See* Shrader et al., *supra* note 7, at 12-13.

[11] For other available tools to determine marginal emissions, *see* Shrader et al., *supra* note 7 at 14, Tbl. 2: Databases for Calculating Emission Rates.

[12] *See* Shrader et al., *supra* note 7, at 22-25.

[13] If the DER itself produces any emissions, the effects of those must be accounted for as well.

[14] *See* Deetjen & Azevedo, *supra* note 1. In this setting, large fossil-fuel electricity generators are greater than 25 MW in capacity and regularly report to EPA's CEMS.

[15] In this report, the sample period is the year 2018. An electricity generator's cost to produce electricity includes marginal fuel costs as well as variable operations and maintenance costs.

[16] Ignoring non-fossil resources will not bias the marginal emissions estimates so long as non-fossil resources are not marginal. This is typically the case for nuclear and renewable resources but not for load-following hydro resources.

[17] eGRID regions are defined by the EPA as partitions of more aggregate North American Electric Reliability Corporation (NERC) regions. Although there might be several market operators in a single eGRID region (e.g., NWPP) and perhaps a single market operator in multiple eGRID regions (both RFCW and RFCE are a part of the PJM RTO), eGRID regions are a fair approximation to granular market operators and transmission connections within the United States.

[18] *See* Jinhyok Heo, Peter J. Adams, & H. Gao, *Reduced-Form Modeling of Public Health Impacts of Inorganic PM2.5 and Precursor Emissions*, 137 Atmospheric Env't 80 (2016); *see also* Richard Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 Sci. 655, 655 (2017).

[19] Kimberly M. Castle & Richard L. Revesz, *Environmental Standards, Thresholds, and the Next Battleground of Climate Change Regulations*, 103 Minn. L. Rev. 1349, 1353 (2019).

[20] *See* U.S. Envtl. Prot. Agency, Regulatory Impact Analysis for the Clean Power Plan Final Rule ES-6 n. 2 (2015), https://www3.epa.gov/ttn/ecas/docs/ria/utilities_ria_final-clean-power-plan-existing-units_2015-08.pdf [hereinafter "CPP RIA"] (noting that benefits from directly emitted PM2.5 accounted for approximately 10% of total monetized health co-benefits).

[21] Castle & Revesz, *supra* note 19, at 1401.

[22] For example, the EPA National Emission Inventory report provides annual estimates of particulate matter pollution from electricity generators. And the EPA AVoided Emissions and geneRation Tool (AVERT) directly models particulate matter pollution from electricity generation in each state or county.

[23] CPP RIA, *supra* note 20, at 4-23.

[24] Alternatively, policymakers could compensate a DER more if it reduced the demand for bulk-power electricity during the time of day when the E-Value is largest on average.

[25] For example, Mid-Atlantic represents the RFC NERC region that consists largely of the PJM RTO.

[26] *See* U.S. Energy Info. Admin.. Wholesale Electricity and Natural Gas Market Data, https://www.eia.gov/electricity/wholesale/, (last visited on Aug. 28, 2020) (showing average hourly price across all nodes in 2018 was $44/MWh).

[27] *See* U.S. Envtl Prot. Agency, Public Health Benefits per kWh of Energy Efficiency and Renewable Energy in the United States: A Technical Report 25 (2019). https://www.epa.gov/sites/production/files/2019-07/documents/bpk-report-final-508.pdf. (showing the average low estimate of 1.7 cents per kilowatt hour ($17/MWh) and average high estimate of 4 cents per kilowatt hour ($40/MWh) for the public health benefits of DERs.) For comparison, the hourly marginal emissions of NO_x and SO2 from the reduced-order dispatch model described in this report correspond to public health benefits (not including GHG emissions) of $17/MWh on average across all regions, with the highest public health benefits in Michigan ($46/MWh on average).

[28] *See* Justin Gundlach & Burcin Unel, Inst. for Pol'y Integrity, Getting the Value of Distributed Resources Right: Using a Societal Value Stack 11 (Dec. 2019), https://policyintegrity.org/files/publications/Getting_the_Value_of_Distributed_Energy_Resources_Right.pdf. (showing a more complete characterization of DERs' potential benefits.).

[29] For more details on the value stacking approach to compensating DERs *see* Gundlach & Unel, *supra* note 28.

[30] *See* Revesz & Unel, *supra* note 4, at 163.

[31] *See* Natalie Mims, Tom Eckman & Charles Goldman, Time-Varying Value of Electric Energy Efficiency at ix fig. ES-1, 32–36 (2017) (quantifying value of carbon dioxide emissions reduction available from different forms of energy efficiency across different regions).

[32] *See* U.S. Energy Info. Admin., *supra* note 26.

[33] *See* Iliana Paul et al., Inst. for Pol'y Integrity, The Social Cost of Greenhouse Gases and State Policy: A Frequently Asked Questioned Guide (2017), https://policyintegrity.org/publications/detail/social-cost-of-ghgs-and-state-policy.

[34] In this setting, large fossil-fuel electricity generators are greater than 25 MW in capacity and regularly report to EPA's CEMS.

[35] The entirety of the Python code is available here: https://github.com/tdeetjen/simple_dispatch.

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Making Regulations Fair

How Cost-Benefit Analysis Can Promote Equity and Advance Environmental Justice

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Executive Summary

Since taking office earlier this year, the Biden administration has made "[a]ffirmatively advancing equity" a centerpiece of its policy agenda.[1] As President Biden has recognized, however, the agencies that administer federal regulatory programs currently lack the toolkit necessary to consistently and robustly assess the distributional impacts of their actions.[2] Without understanding how the costs and benefits of different regulatory options are distributed among subpopulations of particular interest, agencies cannot reliably ensure that their programs do not "perpetuate systemic barriers to opportunities and benefits for people of color and other underserved groups."[3]

Accordingly, in his Presidential Memorandum titled *Modernizing Regulatory Review*, President Biden called on the Office of Management and Budget ("OMB") to "propose procedures that take into account the distributional consequences of regulations, including as part of any quantitative or qualitative analysis of the costs and benefits of regulations, to ensure that regulatory initiatives appropriately benefit and do not inappropriately burden disadvantaged, vulnerable, or marginalized communities."[4]

Offering agencies "concrete suggestions" on how to assess distributional impacts and how to use those assessments in decisionmaking will be key to ensuring that the Biden administration's equity initiatives yield meaningful and long-lasting reform.[5] Prior presidential administrations instructed agencies to incorporate distributional concerns into regulatory cost-benefit analyses. But agencies received practically no guidance on *how* to do this, even though they have long had detailed instructions for approaching other aspects of cost-benefit analysis. Absent standardized, cross-agency benchmarks for assessing the quality of agencies' distributional analyses, questions of equity have received little formal attention from the White House Office of Information and Regulatory Affairs ("OIRA"), the office within OMB that is responsible for reviewing all significant agency regulations prior to proposal and finalization. As a result, cost-benefit assessments for major rulemakings typically focus on aggregate cost and benefit estimates, with little analysis—quantitative or otherwise—of how those costs and benefits are distributed.

This report makes four recommendations to OMB regarding the establishment of standardized procedures for conducting and acting on distributional analyses.

First, OMB should advise agencies to assess regulatory impacts on a more granular scale when practicable. With regard to environmental impacts, for example, OMB should promote the use of detailed spatial modeling to assess how different zip codes and census blocks are affected by changes in pollution, accounting for baseline exposure levels along with existing vulnerabilities and risk factors. This more granular approach will both facilitate more accurate assessments of a rule's total mortality and morbidity impacts *and* provide an informational foundation for distributional analysis.

Second, OMB should provide comprehensive guidance to agencies on how to disaggregate their total cost and benefit estimates to illuminate whether any economic or demographic group can be expected to disproportionately bear the regulatory burdens or receive the regulatory benefits. Such guidance should, among other things, standardize the groups upon which agencies' analyses should focus, as this will enable comparison and aggregation of distributional impacts across rulemakings and agencies. We note that the Biden administration has not yet defined "disadvantaged, vulnerable, or marginalized communities,"[6] and this report does not purport to identify which groups should be the focus of distributional analysis. However, we recommend that the administration undertake a robust stakeholder process to identify which groups merit particular consideration and what level of analytic granularity is needed to fully assess the impacts of federal action on those groups.

Third, OMB should provide more prescriptive guidance to agencies on incorporating the findings of their distributional analyses into decisionmaking. Currently, agencies are provided minimal guidance on how to weigh distributional effects against other regulatory impacts. Accordingly, agencies exhibit little consistency in their consideration of distributional impacts and frequently default to affording them little or no decisional weight. While precise recommendations on how agencies should balance distributional impacts are beyond the scope of this report, we survey the academic literature and identify approaches that OMB could consider.

Finally, we note that not all regulatory imbalances can or should be addressed on a rule-by-rule basis. The significance of some disparities may become clear only when viewed cumulatively across multiple rulemakings. And even where the distributional analysis of an individual rule reveals a significant disparity, changing the design of the rule may not always be possible or the most effective way to address that disparity; instead, compensatory action elsewhere in the executive branch may be warranted. Thus, our fourth recommendation is for OMB to develop coordinated, interagency strategies for identifying groups that are disproportionately burdened across the regulatory system and compensating those communities using agencies' regulatory and spending authorities. Regular reports from OMB on disparate impacts could help facilitate this process.

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Background: The Limits of Existing Guidance and Precedent

While executive orders and guidance documents have, for decades, advised agencies to consider equity and fairness when promulgating regulations and setting policy, agencies have not consistently incorporated distributional analysis into their regulatory cost-benefit analyses. This section explores that contrast at a high level, largely faulting the lack of detailed guidance focused on the assessment of distributional impacts or the consideration of those impacts when weighing regulatory alternatives.

This section first provides an overview of executive precedents on distributional analysis, and then discusses the sporadic implementation by agencies.

The Importance of Equity Considerations in Regulation

A common argument against considering distributional consequences in regulatory decisionmaking is that regulations should focus on efficiency (i.e., maximizing aggregate welfare), whereas distributional equity should be left to the tax-and-transfer system.[7] While a full assessment of this argument is outside the scope of this report, the argument elicits several common rejoinders. Most notably, scholars point out that the tax-and-transfer system, while theoretically better suited to address distributional concerns, is not, as a practical matter, designed to compensate regulatory "losers," particularly for non-monetary harms such as health risks.[8] Richard Revesz explores the limitations of the tax-and-transfer system in his 2018 article *Regulation and Distribution*, arguing that "perhaps the most important benefit of environmental, health, and safety regulation is the prevention of premature mortality, and the income tax system is poorly suited to deal with such distributional consequences that are not income-based."[9]

Additionally, because our society values distributional equity—and because distributional baselines and impacts can inform an assessment of aggregate welfare gains and losses—regulatory analyses that omit distributional impacts do not fully capture welfare effects and thus may not accurately measure efficiency.[10] In an early 2021 article, Zachary Liscow argues that the United States tax code achieves only one-ninth of "the redistribution needed to maximize welfare."[11]

A. Legal Framework for Equity Considerations in Regulatory Cost-Benefit Analysis

Distributional concerns have traditionally played a backseat role in regulatory cost-benefit analysis. While relevant executive orders expressly instruct agencies to consider distributional equity, OMB guidance on cost-benefit analysis offers few insights regarding the appropriate form of such an analysis. Additionally, a separate executive order from President Clinton calls on agencies to assess environmental justice impacts, but agencies have rarely integrated that assessment into their broader cost-benefit analysis.

Executive Order 12,866, issued by President Clinton in 1994, requires agencies to conduct cost-benefit analysis for major rulemakings.[12] While a prior executive order issued by President Reagan did call for some assessment of distributional impacts in regulatory analysis,[13] President Clinton's order more explicitly recognized that equity considerations are relevant in regulatory decisionmaking. Specifically, Clinton's order explains that agencies should select regulatory "approaches that maximize net benefits"[14] and explicitly recognizes that "distributive impacts[] and equity" are relevant to assessing net benefits.[15] The order thus unambiguously recognizes that agencies should incorporate equity considerations into their cost-benefit analyses and regulatory decisions. It does not, however, provide agencies with any instructions on how to do so.

In 1996, OMB convened an interagency working group on cost-benefit analysis that resulted in the publication of a best practices guidance document.[16] This document contained just a brief and mostly non-prescriptive section on distributional effects and equity.[17] For instance, the guidance advised agencies to assess important distributional effects "quantitatively to the extent possible, including their magnitude, likelihood, and incidence of effects on particular groups," but offered no further advice to agencies on how to conduct that assessment.[18] On the question of how to incorporate distributional considerations into decisionmaking, the guidance simply advised regulators that "[t]here are no generally accepted principles for determining when one distribution of net benefits is more equitable than another" and thus warned them to "be careful to describe distributional effects without judging their fairness."[19]

Under the George W. Bush administration in 2003, OMB refined and replaced the Clinton-era guidance through the publication of *Circular A-4*, which remains OMB's principal guidance document on cost-benefit analysis. *Circular A-4* recognizes that "removing distributional unfairness" can be a basis for regulation.[20] Like the 1996 guidance, however it offers limited technical instruction on assessing distributional effects. While *Circular A-4* advises agencies to "provide a separate description of distributional effects (i.e., how both benefits and costs are distributed among sub-populations of particular concern) so that decision makers can properly consider them along with the effects on economic efficiency," it does not explain how to conduct such an analysis or what demographic subpopulations to consider.[21] And, while *Circular A-4* echoes the Clinton-era guidance by advising agencies to describe distributional effects "quantitatively to the extent possible," it too lacks further direction on this front.[22]

In 2011, President Obama published Executive Order 13,563, which reaffirms the centrality of cost-benefit analysis in regulatory decisionmaking.[23] While noting the continued applicability of Executive Order 12,866,[24] President Obama's Order puts additional emphasis on agencies' ability to cite distributional concerns as grounds for regulatory action. Specifically, the Order directs that "[w]here appropriate and permitted by law, each agency may consider (and discuss qualitatively) values that are difficult or impossible to quantify, including equity, human dignity, fairness, and distributive impacts."[25] But the Order does not elaborate on how agencies should consider these impacts, nor did the Obama administration publish any related guidance documents to supplement *Circular A-4*'s instructions on this topic.

In addition to these executive orders and guidance documents on cost-benefit analysis, there is a parallel and largely distinct line of authority on environmental justice considerations in agency decisionmaking. Executive Order 12,898, issued by President Clinton in 1994, requires agencies to identify and seek to address adverse environmental and human-health impacts of all federal administrative programs (including regulations) on minority and low-income populations.[26] Guidance documents—issued by the White House Council on Environmental Quality under the Clinton administration[27] and the Interagency Working Group on Environmental Justice under the Obama administration[28]—provide detailed instruction on identifying and assessing a broad range of potential disparate impacts in environmental justice analyses conducted under Executive Order 12,898. But these documents offer sparse direction on how environmental-justice analysis for rulemakings should interact, if at all, with regulatory cost-benefit analysis.

The Environmental Protection Agency ("EPA") has released its own guidance documents on considering equity and environmental justice in cost-benefit analysis. The agency's *Guidelines for Preparing Economic Analysis* contains a chapter focused on assessing distributional considerations and incorporating them into a cost-benefit analysis.[29] In 2016, EPA issued a document building off of this chapter that provides the most detailed guidance to date on "methods for analysts to use when assessing potential environmental-justice concerns in national rules."[30] This EPA guidance recommends that analysts "estimate[] health and environmental risks, exposures, outcomes, benefits and other relevant effects disaggregated by income and race/ethnicity" whenever possible.[31] Among other issues, the document addresses key analytical considerations and provides technical guidance on assessing the distribution of both regulatory costs and benefits.[32] Published in the final months of President Obama's second term, however, this guidance was largely ignored during the Trump administration, and its recommendations have not been extended to other agencies.

B. Lack of Routine or Consistent Practice Across Agencies

In the absence of detailed guidance from the White House on distributional analysis, individual agencies have mostly failed to develop a consistent set of best practices for assessing the distributional outcomes of their regulations. Studies show that agencies rarely provide quantitative analysis of distributional considerations and hardly ever cite fairness and environmental justice as a basis for rulemaking.

Lisa Robinson, James Hammitt, and Richard Zeckhauser conducted what is perhaps the most comprehensive evaluation to date of the role of distribution in regulatory impact analysis, analyzing dozens of major regulations promulgated during President Obama's first term.[33] In their study, Robinson et al. find few consistent practices across agencies and across analyses, a lack of quantification of distributional impacts, and a general inattention to equity. For instance, the authors note that agencies "rarely quantify the distribution of health-risk reductions across [demographic] groupings" and "[i]n most cases . . . they simply certify that the regulation . . . does not adversely affect the health of minorities, low-income groups, or children" without detailed analysis.[34] The authors find even less attention to the distribution of compliance costs, with agencies regularly failing to estimate how profits, price changes, or payroll and employment impacts fall on different demographic groups.[35] In sum, the authors conclude, "[n]et tallies of costs and benefits for different groups are simply not available" and thus "it is not possible to estimate the distribution of net benefits" using existing agency analyses.[36] This conclusion largely mirrors the findings of an analysis by Carl F. Cranor and Adam M. Finkel, which concludes that agencies often "anecdotally mention[] the subpopulations and individuals who may bear disproportionate costs or reap disproportionate benefits" without providing quantitative analysis. These scholars note that particularly little attention is paid to assessing whether "the costs of regulations might be distributed either regressively or progressively."[37]

Analyses of Executive Order 12,898's impact similarly find that the Order has neither resulted in robust analyses nor substantially affected policy outcomes. For instance, one study finds that agencies typically either ignore Executive Order 12,9898 or satisfy its demands through "boilerplate rhetoric" that is "devoid of detailed thought or analysis."[38] Another survey concludes that interest in environmental justice has waxed and waned across presidential administrations and that agencies have sometimes passed off environmental-protection measures that they would have taken anyway as "environmental justice."[39] Given the lack of guidance on how to integrate the findings of an environmental-justice analysis with those of a broader cost-benefit analysis, moreover, agency findings under Executive Order 12,898 are typically not integrated into agencies' broader assessments of rules' economic impacts.[40]

There are a handful of cases in which agencies explicitly relied upon distributional equity as a basis for rulemaking. For instance, in 2014 the National Highway Traffic Safety Administration ("NHTSA") relied on equity and justice concerns in promulgating a regulation mandating backup cameras on all new vehicles.[41] Despite acknowledging that the rule's costs exceed its monetized benefits,[42] the agency nonetheless concluded that justice considerations (along with nonmonetized benefits) justified the regulation, highlighting the rule's beneficial outcomes for children, people with disabilities, and the elderly, who collectively are disproportionately the victims of back-over crashes.[43] But NHTSA's analysis, though laudable in many respects, was incomplete in others. In particular, the agency ignored the distribution of regulatory costs and offered a somewhat opaque explanation of how it balanced quantified costs and benefits with equity effects.

There are many other examples of agencies disregarding key distributional impacts. Under the Trump administration, in particular, agencies routinely ignored (or minimally considered) regressive regulatory impacts with limited discussion or quantitative analysis. In one egregious example, the Department of Agriculture finalized a regulation tightening eligibility for the Supplemental Nutrition Assistance Program that, by the agency's estimates, would cause 688,000 individuals to lose their food-assistance benefits.[44] Although the rule would substantially and almost exclusively burden low-income individuals, the Department of Agriculture provided just a short section on distributional impacts that briefly estimated the racial breakdown of disenrollees without acknowledging the rule's regressive economic effect.[45] Moreover, these important distributional concerns did not appear to factor into the agency's determination.[46]

Various scholars have argued that disregarding distributional impacts in cost-benefit analyses has led agencies to fail to remediate—and sometimes even exacerbate—existing inequalities. In their article *Pricing the Priceless*, for instance, Frank Ackerman and Lisa Heinzerling claim that agency cost-benefit analysis "has the effect of reinforcing[] patterns of economic and social inequality."[47] Building upon this critique, Melissa J. Luttrell and Jorge Roman-Romero argue that agency use of cost-benefit analysis frequently "maintains and worsens . . . racially inequitable disparities . . . by ignoring—or dramatically undervaluing—equity concerns, even when the statute at issue is meant to reduce disparities."[48] And other scholars and advocates have observed that the use of cost-benefit analysis in federal spending and grant programs can lead to money being inequitably directed to wealthier communities.[49]

In short, agency cost-benefit analyses rarely integrate distributional impacts in a meaningful fashion, and agencies have not developed consistent practices for considering equity as part of regulatory decisionmaking.

C. Signals of a New Approach

After vowing as a candidate to focus on environmental justice and racial equity,[50] President Biden began a process hours after his inauguration to reform regulatory review with the hopes of better incorporating distributional impacts.

In a Presidential Memorandum signed the afternoon of his inauguration titled *Modernizing Regulatory Review*, President Biden tapped OMB to lead an interagency process to identify "concrete suggestions on how the regulatory review process can promote public health and safety, economic growth, social welfare, racial justice, environmental stewardship, human dignity, equity, and the interests of future generations."[51] Among other directives, the Memorandum instructs OMB to develop practices to better "account [for] the distributional consequences of regulations" and "ensure that regulatory initiatives appropriately benefit and do not inappropriately burden disadvantaged, vulnerable, or marginalized communities."[52]

Also on the first day of his term, President Biden signed Executive Order 13,985, *Advancing Racial Equity and Support for Underserved Communities Through the Federal Government*.[53] The Order identifies how "[e]ntrenched disparities [have] denied . . . equal opportunity to individuals and communities," including those disparities created by public policy.[54] Accordingly, the Order calls on the federal government to "pursue a comprehensive approach to advancing equity for all, including people of color and others who have been historically underserved, marginalized, and adversely affected by persistent poverty and inequality."[55] Among other things, the Order tasks OMB with "assessing whether agency policies and actions create or exacerbate barriers to full and equal participation by all eligible individuals," assisting agencies in "assess[ing] whether underserved communities and their members face systemic barriers in accessing benefits and opportunities available pursuant to [federal] policies and programs," and "identify[ing] opportunities to promote equity in the budget that the President submits to the Congress."[56]

This Order also instructs the White House Domestic Policy Council to "coordinate efforts to embed equity principles, policies, and approaches across the Federal Government," including by "identify[ing] communities the Federal Government has underserved, and develop[ing] policies designed to advance equity for those communities."[57] In addition, the Order establishes an Equitable Data Working Group, which includes an OMB designee among its membership and which is tasked with reviewing existing data collection practices and providing recommendations for "expand[ing] and refin[ing] the data available to the Federal Government to measure equity."[58]

A week after signing Executive Order 13,985, President Biden issued a separate, sweeping executive order calling for widespread action to combat climate change.[59] Most relevant for this report, Executive Order 14,008 reaffirms "that environmental and economic justice are key considerations" for agencies and creates a White House Environmental Justice Advisory Council to identify avenues to "increase the Federal Government's efforts to address current and historic environmental injustice, including recommendations for updating Executive Order 12898."[60] It also calls on the Council on Environmental Quality to "create a geospatial Climate and Economic Justice Screening Tool and . . . annually publish interactive maps highlighting disadvantaged communities,"[61] which will facilitate agencies' abilities to use appropriately granular data. In May 2021, three working groups of the White House Environmental Justice Advisory Council,[62] released initial recommendations for the new tool, including that it should "be integrated and/or supplemented with local community knowledge," "be continually updated and improved as new data becomes available," and "be leveraged to track progress on [environmental justice] goals."[63]

Other relevant agencies and councils have also begun their work to implement President Biden's executive orders. In late March, the Environmental Justice Advisory Council held its first public meeting, at which members signaled a broad openness to numerous reforms to emphasize environmental justice in federal policymaking. And in early May, OMB put out a request for information seeking to identify "effective methods for assessing whether agency policies and actions . . . equitably serve all eligible individuals and communities, particularly those that are currently and historically underserved."[64] Among other queries, the request seeks guidance on "new approaches" that agencies could take to "conduct effective equity assessments" of proposed policies or regulations.[65]

RECOMMENDATION 1:

OMB Should Instruct Agencies to Assess Regulatory Impacts at a Granular Scale, Taking into Account Community Demographics and Existing Risk Factors

A critical first step in addressing the distributional impacts of regulation is to identify which groups and communities are affected by a rule and to what degree. Measuring impacts at aggregate scales can hinder this objective, as group averages often mask disparate effects across communities and fail to accurately capture total regulatory impacts. Thus, in order to improve quantification of total regulatory impacts and enable better identification and analysis of disproportionate effects, regulators should measure effects as granularly as possible, considering different levels of exposure and risk factors of affected communities. These granular measurements could lay the foundation for regulatory analyses that better account for distributional impacts, as discussed in the next section of this report. As noted earlier, this report does not attempt to identify which subpopulations should be examined in a distributional analysis. That list should be the product of a robust stakeholder engagement process. Relevant subpopulations would likely include, however, at least some of those demographic groups identified in Executive Order 13,985.[66]

This section explains how granular measurements could unmask disparities in the intensity of regulatory impacts, account for different risk factors of affected groups, and generate more accurate analyses of both regulatory benefits and costs. The examples in this section are drawn from air-quality regulations, where impacts are heavily determined by geographical space, and hence geographically granular measurements are required to best assess regulatory effects. However, the advantages of granular analyses in the measurement of distributional outcomes extend beyond air or even environmental regulation. Indeed, they apply to any policy whose disproportionate effects on vulnerable individuals or communities are masked by population averages. The Equitable Data Working Group—established under Executive Order 13,985 to disaggregate federal data sets by "race, ethnicity, gender, disability, income, veteran status, or other key demographic variables"—is already collecting much of the data that could be useful for such analyses,[67] and OMB should recommend that agencies make use of this data (and other available disaggregated data) whenever possible.

A. Geographically Granular Analyses Are Key to Unveiling Environmental Injustices

Recent research in public health and economics that applies novel modeling techniques and disaggregated demographic data highlights how a granular analysis of impacts might better reveal environmental injustices in ways that a coarser analysis cannot. For instance, a team of researchers led by Andrew L. Goodkind measure $PM_{2.5}$-related health damages at a fine geographical scale (down to one kilometer).[68] They find that a large share of damages[69] is borne by populations living very close to emission sources: a third of total damages happen within five miles of the source of pollution. As a result, health damages associated with one more unit of emissions can vary by an order of magnitude within a single county. Likewise, Janet Currie, Lucas Davis, Michael Greenstone, and Reed Walker find that toxic emissions from industrial plants cause low infant birthweight only in narrow areas surrounding a plant.[70] In those cases, a county aggregate—

let alone a state or national estimate—would obscure the disproportionate effects of those populations more directly affected by pollution. And, depending on the number and demographics of the individuals living within the proximate range of the relevant plants, larger aggregates could significantly under- or over-estimate the total regulatory effect.

More granular analysis could also be used to better assess the scope and distribution of more distant pollution harms. This is particularly important in the case of diffuse pollutants, such as fine particulate matter or arsenic contamination of drinking water, whose adverse effects can propagate through narrow paths across large spatial areas.[71] Hence, Goodkind et al., in their fine-scale analysis of $PM_{2.5}$ pollution damages, find that a sizable share of pollution harm is borne by populations living more than 150 miles from a pollution source.[72] Recent research also shows that 99% of coal plant emissions leave the counties from which they are emitted after only six hours.[73] These findings reveal that limiting the exploration of environmental injustices to nearby, "frontline" communities—even in cases of pollutants that are often considered "local," such as primary particulate matter—might be overly simplistic in certain cases. In actuality, pollution can affect distant narrow areas (as determined by wind patterns and atmospheric conditions, or water bodies). Granular analysis of pollution impacts, unlike aggregate county- or state-level analyses, allows for identification of geographic communities near and far from pollution sources that stand to suffer disproportionate harms.

To best assess impacts at a granular scale, agencies should exhibit a preference for census block data as opposed to larger geographic units such as census tracts. Choosing a larger geographic unit of analysis could result in a disadvantaged community being outnumbered by a surrounding population, masking its presence in the analysis. EPA has long cautioned against this potential outcome, pointing out that "pockets of minority or low-income communities, including those that may be experiencing disproportionately high and adverse effects, may be missed in a traditional census tract-based analysis."[74]

B. Granular Analyses Should Incorporate Varying Levels of Vulnerability

Besides identifying different levels of exposure, granular measurements would also enable better integration of the risk factors associated with affected communities (and subpopulations within those communities), allowing analysts to better translate pollution levels into public-health impacts. Populations with different socioeconomic characteristics can differ in their vulnerability to changes induced by regulation, as an additional unit of pollution more severely affects a more vulnerable population than a less vulnerable one.[75] As a result, granular analysis is critical not only to identifying the affected communities, but ultimately to accurately estimating the public-health impacts of the regulation that are influenced by the profile of the communities affected. Due to differing levels of vulnerability, a regulation could result in disproportionate effects even if all communities are equally exposed to the same levels of pollution (although such uniform exposure rarely occurs).[76]

Granular-level analysis that considers socioeconomic risk factors could reveal regulatory impacts that a county- or region-wide analysis would likely miss. To provide just one example, a study by Tatyana Deryugina and a team of researchers finds that more vulnerable elderly populations (e.g., those more frequently suffering chronic health conditions) are more susceptible to pollution increases than other elderly communities, yet they tend to live in areas with *lower* average pollution levels.[77] Hence, reducing pollution in highly polluted areas may not always maximize public-health gains, as community demographic risk factors are equally important to the assessment. Because vulnerable populations tend to be concentrated in particular, sub-county geographic areas, regulatory impacts estimated at the county level would fail to capture the disparate vulnerability levels of different communities and thus would not fully capture public-health impacts.

Considering local-level demographic risk factors would improve our understanding of both the aggregate and distributional impacts of many regulations. For instance, the average dose-response function between particulate matter concentration and mortality identified in a 2009 study of the American Cancer Society is widely used in the quantification of costs related to pollution exposure,[78] including by EPA's Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool.[79] However, that same study also shows that mortality risk from pollution exposure is negatively correlated with educational attainment: for instance, lung-cancer mortality risk associated with a change of 10 $\mu g/m^3$ $PM_{2.5}$ concentration is approximately 20% higher for those without post-secondary education. The use of disaggregated risk estimates would thus enable a more accurate estimate of pollution mortality and morbidity.[80] By doing so, it could reveal both efficiency and distributional impacts that might be overlooked when using average population risks.

C. Regulatory Costs Should Also Be Measured Granularly

To more fully assess distributional impacts, regulators should seek to granularly estimate costs as well as benefits.[81] Even environmental regulations that bring health-related benefits to some affected communities could impose disproportionate costs on these same communities if, for instance, they are dependent on the pollution sources for jobs or would face higher prices for common consumer goods. These costs might offset health-related benefits in some cases.[82] Hence, regulatory analysis should seek to assess both benefits and costs on a granular scale.

Assessing who bears regulatory costs due to changing energy prices or wages at a granular scale could be more challenging than granularly evaluating health-related impacts. As described above, health impacts could be estimated using readily available air-transport models[83] and census demographic data. However, the distribution of regulatory costs would usually depend on responses by firms and customers that are more complex to model (e.g., Would a firm pass costs incurred from a pollution-reducing policy to customers? Or would it rather decrease wages? How would customers/employees react to those changes?). For instance, regulations that cause a price increase in inferior goods (i.e., those for which demand decreases as consumer income rises) will tend to disproportionately burden low-income individuals and groups, whereas regulations that cause a price increase in normal goods (i.e., those for which demand increases as consumer income rises) will more heavily burden high-income individuals and groups.

Recent research has made advances in modeling these interactions. For instance, Dallas Burtraw, Maya Domeshek, and Amelia Keyes analyze how energy expenditures and income sources might change for populations with different income levels as a result of setting a federal carbon tax, showing that the details of implementation determine whether the policy is progressive or regressive.[84] When similar analytical models are not readily available, Lisa Robinson and her co-authors suggest performing a "bounding analysis" that assumes that costs are passed on "as changes in prices, wages, and/or returns to capital in both the short and long runs."[85] Comparing these different scenarios using disaggregated data on product purchases, wages by occupation, etc. would shed light on the potential distributional consequences of a policy, and consequently, allow a granular estimation of net benefits even when analysts are more data- or resource-constrained.

Case Study: Geographically granular analyses and environmental justice at EPA

EPA has long recognized the need to evaluate impacts at granular and disaggregated levels in order to address environmental justice, even if this recognition has not always been translated into policymaking. As early as 1995, and in response to Executive Order 12,898, EPA announced its goal that "no segment of the population, regardless of race, color, national origin, or income, as a result of EPA's policies, programs, and activities, suffers disproportionately from adverse human health or environmental effects."[86] However, in the decades following this statement, EPA's regulatory analyses were not typically carried out with a level of granularity to identify disproportionate impacts on different segments of the population. Indeed, most EPA analyses have incorporated environmental justice concerns only with "perfunctory, pro forma assertions," mostly stating that "a plan of environmental justice compliance was not needed because there would be no adverse impact."[87]

More recently, EPA has highlighted the importance of granular regulatory analysis in its detailed technical guidance issued during the last months of the Obama administration.[88] This guidance has the stated objective of assisting EPA's analysts in ensuring that "potential [environmental justice] concerns are appropriately considered and addressed in the development of regulatory actions."[89] Though it stresses that any analysis will be limited by the data available, the guidance highlights that a best practice is to "disaggregate data to reveal important spatial differences (e.g., demographic information for each facility/place) when feasible and appropriate."[90] In the case of air regulations, the guidance emphasizes that "finer-scale air quality, health, and socioeconomic data allow one to assess the distribution of air pollution impacts across key population groups of concern and to have greater confidence in the conclusions drawn from these data."[91] As noted in this section, such a granular analysis of pollution impacts should be feasible in most contexts using readily-available air transport models and census demographic data.

RECOMMENDATION 2:

OMB Should Provide Agencies with Detailed Guidance on Assessing the Distribution of a Proposed Regulation's Costs and Benefits Among Demographic Subgroups

Equipped with granular measurements of regulatory costs and benefits that consider different impact intensities and risk factors across subpopulations, a regulator could tally how those costs and benefits are distributed among discrete demographic groups. OMB should encourage agencies to provide such demographically disaggregated totals—in addition to aggregate calculations of costs and benefits—whenever possible. OMB should also publish guidance on conducting such an assessment, including a list of subpopulations to consider.

A. Disaggregated Totals Enable Agencies to More Rigorously Assess Disproportionate Impacts

As detailed in the Background section, executive orders and guidance on cost-benefit analysis have long called for agencies to quantify the distributional impacts of regulations, but these documents offer little direction on the form or contents of such an analysis.[92] To promote better and more consistent distributional analysis, OMB could provide more prescriptive and detailed guidance on this front. In particular, OMB could instruct agencies to provide disaggregated cost and benefit estimates, in addition to the population-wide estimates that agencies normally provide, that evaluate how both positive and adverse regulatory impacts are distributed across specified subpopulations.

Such analysis would enable regulators to assess not only how costs and benefits are dispersed among different subpopulations, but also whether the rule is more or less net-beneficial for those groups than it is for the remainder of the population. This would help regulators understand the magnitude of distributional consequences (including the distribution of benefits, costs, and net benefits) and potentially dispel false assumptions about their magnitude.[93] And by consistently disaggregating monetized cost-benefit totals along the same demographic lines, where possible, agencies (and OMB) could also assess whether subpopulations of particular concern are benefitted across the regulatory system, and consider whether disparate impacts of particular rules are offset or compounded by the effects of other rules. Such findings could be reported on a regular basis (e.g., yearly) as part of a suite of information that informs future actions.

Like good cost-benefit analysis itself, moreover, disaggregated estimates could also improve agency decisionmaking by "better inform[ing]" the public and decisionmakers on the regulation's distributional impacts and thereby "reduc[ing] interest group power over" the rulemaking process.[94] According to former OIRA administrator John Graham, advocates for low-income groups are underrepresented among lobbyists,[95] and so adding a "distributional test" to cost-benefit analysis would help ensure that "regulators . . . seriously consider the impact" of regulations on marginalized groups.[96] Clear, disaggregated data would also help engage stakeholders in the regulatory review process on distributional issues and facilitate dialogue between the public and the regulating agency on distributional impacts.

B. OMB Can Facilitate Consistent Disaggregated Analysis by Providing Guidance on Methodology and Approach

Despite not being widely implemented in regulatory analysis, the notion of disaggregating regulatory impacts along demographic lines is well-established in the academic literature.[97] But disaggregation can be very challenging. Without further guidance and standardization, agencies may continue struggling to assess distributional considerations in a rigorous and consistent fashion.

OMB should thus prepare guidance on methodologies for assessing distributional impacts. Such guidance should recommend methodologies for disaggregating and monetizing benefits, as well as methodologies for disaggregating and monetizing costs, and provide guidelines on the demographic subpopulations that agency analyses should consider. This section discusses those different elements, in that order.

For disaggregating benefits, EPA's 2016 technical guidance on incorporating environmental justice into cost-benefit analysis offers a useful starting point. In particular, that document provides detailed advice for analysts on disaggregating health impacts along geographic, and ultimately demographic, lines using mapping and data on exposure and baseline vulnerability.[98] As detailed in Recommendation 1, *supra*, regular usage of these state-of-the-art tools would enable agencies to better estimate both the scale and distribution of environmental benefits. As noted above, the Council on Environmental Quality is launching a new interactive mapping tool that would support the collection and consolidation of disaggregated data. Although OMB should broaden its guidance beyond environmental regulations, the core approach in EPA's guidance—incorporating scientific and demographic data to measure benefits at a granular scale—can be generalized and supplemented to facilitate disaggregated estimates of all benefits, both environmental and non-environmental.

As an example of using granular data to calculate benefits and costs on demographic subpopulations, Ronald J. Shadbegian, Wayne Gray, and Cynthia Morgan performed such an analysis in a paper looking at the impacts of EPA's sulfur dioxide trading program on various demographic subpopulations.[99] In their analysis, the authors began by looking at the distribution of sulfur-dioxide emission reductions by geographic area. They then looked at the demographic makeup of each geographic area to transpose geographic impacts into demographic effects. Specifically, the analysts assessed the rule's benefits and costs on five different demographic subpopulations based on race (Black and Hispanic), income (those below the poverty level), and age (children under 6 and the adults over 65).[100] While this analysis is from 2005 and does not make full use of high-resolution granularity now available, a more granular analysis would enable even more reliable translation of localized impacts into demographic assessments. In a 2014 assessment, for instance, a group of researchers from Resources for the Future performed a disaggregated cost-benefit analysis of several "smart growth" policies, analyzing their costs and benefits for numerous demographic subpopulations.[101]

As part of its guidance on disaggregating benefit estimates, OMB should provide particular guidance on how agencies should monetize health and welfare impacts that have been disaggregated along demographic lines. While some scholars have suggested using different willingness-to-pay values particular to each subpopulation,[102] one's willingness to pay is bounded by wealth and income and therefore does not fully reflect the value that one ascribes to a particular benefit. Especially if regulators assess benefits disaggregated by income groups, the use of particularized in-group willingness-to-pay values will thus undervalue benefits received by low-income groups and produce a skewed picture of regulatory impacts. Accordingly, the most defensible approach is to use the same monetized values for health and welfare benefits across all demographic groups.[103]

In addition to its normative advantages, using a constant value is also consistent with existing regulatory precedent, which could bolster its legal justification. For instance, EPA applies a constant value of a statistical life for all individuals, despite some empirical evidence suggesting that younger and healthier individuals may place a higher value on the avoidance of small mortality risks[104] (and the fact that ability to pay is higher among wealthier individuals[105]). And in the United Kingdom, cost-benefit analyses from the Department of Health apply demographic disaggregation while also using constant monetary valuations of health benefits across demographic groups.[106] OMB should provide clear guidance on the use of constant monetized values across demographic subpopulations to ensure consistent practices between agencies.

In addition to benefits, OMB should provide guidance on disaggregating regulatory *costs* along demographic lines, as "the distribution of health or environment effects alone," without disaggregated cost estimates, "might convey an incomplete—and potentially biased—picture of the overall burden faced by population groups of concern."[107] As detailed in Recommendation 1, frequently "data or methods may not exist for [a] full examination of the distributional implications of costs across population groups of concern."[108] Nonetheless, as noted therein, the distribution of costs could be assessed based on data such as the pass-through of compliance costs to consumers and the demographic makeup of the relevant consumer base and labor force.[109] Such cost data, to the extent available, could be disaggregated to estimate the breakdown of regulatory costs along different population subgroups. OMB could facilitate such analysis across the regulatory state by expanding on EPA's guidance to encompass cost considerations outside the environmental sphere.

OMB should also identify a manageable list of subpopulations for agencies' analyses to consider. Executive Order 12,898 targets the dimensions of income and race, with its focus on "minority populations and low-income populations."[110] Executive Order 13,985 lists a number of specific groups that have been historically underserved.[111] Other demographic characteristics such as age or health status may also be relevant, as illustrated by NHTSA's 2014 regulation involving backup cameras.[112] While all of these dimensions are important and merit consideration, disaggregating costs and benefits along demographic lines is challenging and time-consuming, and there is a risk that agencies may delay important regulations—or simply eschew recommended procedures for distributional analysis—if asked to perform quantitative analysis along numerous dimensions.

In providing guidance on the groups on which agency analyses should focus, OMB may wish to consider such factors as the prominence of different demographic indicators in concerns about distribution and equity, the availability of data, and the compatibility of different metrics with quantitative decisionmaking tools. Distributional breakdowns by income group fare especially well on the last criteria, as there is voluminous research translating income gains or losses into utility effects.[113] While disaggregated data based on race could also be highly informative regarding a regulation's racial or environmental justice impacts, agencies should exercise caution about factoring that data into regulatory decisionmaking since it could also implicate thorny constitutional issues.[114] As noted above, the federal government should engage stakeholders in identifying which groups to consider. Recommendations on which groups to choose are outside the scope of this report.

Whatever OMB recommends, it may wish to preserve flexibility for agencies to additionally consider a wide range of potential distributional considerations, either quantitatively or qualitatively, on a case-by-case basis (on top of the default analysis that OMB recommends). Important effects on particular communities—based on age or health status, for example[115]—could be considered in individual rulemakings even if it may not be feasible for agencies to quantitatively assess costs and benefits for that subpopulation in every rule.

RECOMMENDATION 3:

In Addition to Providing Guidance on How to Conduct Distributional Analysis, OMB Should Offer Suggestions for Incorporating the Results of Such Analysis into Regulatory Decisionmaking

Even if agencies gather detailed data on how costs and benefits are distributed among discrete demographic groups as described above, current authorities offer little guidance on what they should do with that data. For instance, *Circular A-4* instructs agencies to perform a distributional analysis but then says nothing about how to incorporate that analysis into the ultimate decision of which regulatory alternative to select. In other words, agencies have no guidance on how to weigh the desirability of a potential rule's distributional effects against other attributes of that rule, such as its total net benefits.

This section discusses three possible approaches to factoring distributional consequences into regulatory decisionmaking:

1. Qualitatively assessing the desirability of distributional outcomes from a disaggregated cost-benefit analysis.
2. Using quantitative tools that enable regulators to assess the desirability of distributional outcomes.
3. Using weighted cost-benefit analysis that directly incorporates distributional outcomes into aggregated cost and benefit totals.

The first option is premised on the status quo, where OMB grants agencies broad discretion to determine whether and how distributional desirability should affect their decisions.

The second is to recommend standardized metrics for scoring policies' distributional outcomes, which agencies could use to supplement a traditional cost-benefit analysis.[116] These approaches include inequality metrics and social welfare functions that enable agencies to "score," or assess the desirability of, different distributional outcomes. While this approach leaves agencies discretion as to how to use those scores when selecting among regulatory options, OMB could recommend that agencies treat these scores similarly to other nonmonetized effects.

The third option is to fully integrate distributional effects into the bottom line of a cost-benefit analysis by using distributional weights that reflect the diminishing marginal utility of income (recognizing that a dollar is worth more to a poor person than a rich one) or the diminishing marginal utility of well-being more broadly understood,[117] based on a utilitarian social welfare function. Alternately, OMB could recommend that agencies use weights that reflect an ethical choice to prioritize net benefits for worst-off individuals or groups, based on a prioritarian social welfare function. Rather than supplementing a traditional cost-benefit analysis, these metrics would effectively replace that traditional analysis.

OMB should use a consultative process to determine which of these approaches, if any, best meets the goals of stakeholders. Public input should also inform how the results of distributional analyses—and the data underlying those analyses—are presented, as not only agencies, but also community groups and other organizations may benefit from access. Whichever approach it chooses, we urge OMB to provide agencies with step-by-step guidance on how to implement that approach and assess—whether quantitatively or not—the magnitude or significance of distributional consequences relative to a proposed action's other effects (including aggregate monetized costs and benefits). We note that any approach to distributional analysis, including the status quo approach, requires a regulator to make explicit value judgments.[118] Transparency regarding such judgments is key to ensuring consistent and robust distributional analysis.

A. OMB Could Recommend that Agencies Qualitatively Assess the Results of a Disaggregated Cost-Benefit Analysis

Regulators could treat the findings of a disaggregated cost-benefit analysis the way they would treat a nonmonetized cost or benefit. Under this approach, an agency could use its discretion when evaluating the significance of a proposal's distributional effects and incorporating that evaluation into its regulatory decision. While this qualitative assessment resembles how agencies currently treat distributional impacts, agencies would now have quantitative support for their decisions from their disaggregated cost-benefit totals.

This would not be such a departure from current practice, as agencies are already making judgments like this when faced with important but nonmonetized risk reduction or health effects. Indeed, rules have been justified on the significance of their unquantified benefits in the past. For example, EPA promulgated a rule in 2015 on phosphoric acid manufacturing and phosphate fertilizer production despite finding that rule to be net-costly based on monetized impacts alone.[119] Though the agency relied on the nonmonetized benefits of mercury emissions reductions, EPA concluded that the rule was net-beneficial on the whole and therefore justified. Specifically, EPA explained that the rule "will mitigate future [mercury] emissions … by requiring compliance with numeric emission limits,"[120] thereby "result[ing] in improvements in air quality and reduced negative health effects associated with exposure to air pollution of these emissions."[121] However, EPA did not monetize the benefits of reducing mercury emissions because it lacked adequate data to do so.[122] Similarly, the Bureau of Land Management justified its 2015 hydraulic fracturing rule despite an absence of monetized benefits by concluding that not being able to put a number on the risk reduction associated with the rule "does not mean that the rule is without benefits."[123]

Circular A-4 also broadly endorses the consideration of nonmonetized benefits (and costs), explaining that "[w]hen there are important non-monetary values at stake," a regulator should "also identify them in [the] analysis so policymakers can compare them with the monetary benefits and costs."[124] Accordingly, regulators should "exercise professional judgment in determining how important the non-quantified benefits or costs may be in the context of the overall analysis."[125]

Agencies could treat the findings of their distributional analysis in the same manner. For instance, if a proposal has desirable enough distributional effects, those effects could allow a regulator to justify choosing this option even if it has lower net benefits than the other alternatives examined. Similarly, an agency could choose not to pursue the most net-beneficial option (according to aggregated, traditional cost-benefit estimates) if its distributional outcomes are undesirable. This ranking could be done by looking at the results of a disaggregated cost-benefit analysis and making normative judgments about the desirability of distributional outcomes—much like how regulators often consider other nonmonetized effects.

B. OMB Could Recommend that Agencies Use Quantitative Tools to Evaluate Distributional Outcomes

If a regulator is treating the results of a disaggregated cost-benefit analysis like a nonmonetized effect, it is important that those effects "be categorized or ranked in terms of their importance within the decision-making context."[126] Like with nonmonetized effects, the more underlying data to guide such an analysis, the better.[127] While distributional impacts could be ranked without further quantitative analysis, as discussed above, various quantitative methodologies to assess the results of a disaggregated cost-benefit analysis would greatly aid in the process of assessing and contextualizing different distributional outcomes.

If it pursues this approach, OMB should recommend standardized metrics for assessing distributional outcomes that regulators could then weigh against monetized costs and benefits. These metrics could be inequality metrics that are commonly used in the literature or they could be based on social welfare functions. The decisionmaker could also use this information to determine if some other quantitative analytical tool, like a breakeven analysis, would be useful. In breakeven analysis, if faced with a net-costly rule with nonmonetized benefits, the regulator tries to determine "[h]ow small … the value of the non-quantified benefits [would] be … before the rule would yield zero net benefits."[128]

The following subsections describe several analytical tools that could be used to more easily rank and compare policy proposals based on distributional outcomes or distributional desirability. As noted above, policymakers could treat their findings from these methodologies as they would a nonmonetized effect: the findings could factor into their decision, even to justify choosing a less net-beneficial alternative, but to what extent this information plays a role would be at the policymaker's discretion. In other words, these quantitative metrics could be presented alongside traditional cost-benefit analysis, with the regulator choosing how much weight to give each analysis in the decisionmaking process.

Quantitative Tools for Incorporating Distributional Considerations into Decisionmaking

Tool	Numerical Output	Possible Information[129]
Gini Coefficient	A number between 0 and 1. A higher value denotes greater inequality.	A ratio representing the projected distribution of an impact (e.g., cost or benefit) in a given policy scenario compared to an equal distribution of said impact.
Atkinson Index	A number between 0 and 1. A higher value denotes greater inequality.	A ratio representing the projected distribution of an impact in a given policy scenario compared to an equal distribution of said impact, reflecting societal preferences about inequality. The greater the societal aversion to inequality, the more sensitive the ratio is to unequal distribution of outcomes.
Theil Index	A number between 0 and infinity. A higher number denotes greater inequality.	A number representing how far the projected distribution of an impacts from a scenario where said impact is distributed equally.
Utilitarian Weighted Cost-Benefit Analysis	A dollar value for net benefits.	Aggregate costs and benefits of a rule if willingness to pay for a specific impact of the rule is weighted to reflect the diminishing marginal utility of income.
Prioritarian Weighted Cost-Benefit Analysis	A dollar value for net benefits.	Aggregate costs and benefits of a rule if willingness to pay for a specific impact of the rule is weighted so that improvements to the worst off are prioritized above other welfare impacts.

1. Inequality metrics

One option is for regulators to assess policy outcomes using inequality metrics. Inequality metrics take a range of inputs, like individual-, household-, or group-level characteristics (e.g., income, health status, or exposure to a particular pollutant), apply a formula that reflects certain assumptions about the regulator's priorities, and produce values that represent the level of inequality in a given scenario. Inequality metrics can be used to compare the status quo with the distributional outcomes of a specific policy scenario or to compare distributional outcomes across alternatives. The values produced by these metrics could allow regulators to rank different policy options based on distributional effects, enabling them to evaluate distributional outcomes alongside cost-benefit analysis to aid in decisionmaking process. Using these metrics requires a regulator to have already assessed the impacts of a rule on certain groups, so gathering and sorting the data by subpopulations of interest per Recommendation 1 and Recommendation 2 of this report are prerequisites for implementing inequality metrics.

Below are some examples of inequality metrics that OMB could suggest that agencies use. The Gini coefficient and Atkinson index have been used by researchers to measure health inequality and also "to evaluate changes in inequality resulting from environmental policy measures."[130] The Theil index is also widely used by researchers in the health context[131] and has been used to measure racial segregation.[132] The United States Census Bureau uses all three to assess income inequality.[133]

a. Gini Coefficient

The Gini coefficient was originally designed to measure inequality in distribution of income.[134] In the income context, the Gini coefficient takes the area between a given Lorenz curve, which shows income distribution, and an ideal Lorenz curve where income distribution is equal, and expresses that area as a proportion of the total area under the given Lorenz curve.[135] Gini himself proposed that the metric measured "the variability of any statistic distribution or probability distribution."[136] The result is a number between zero and one, "with higher values denoting greater inequality."[137]

The Gini coefficient can be deployed in other contexts by substituting other characteristics, like exposure to pollutants, for income. Thus, the Gini coefficient could be used to compare the effects of a proposed regulation with the status quo or the effects of a preferred regulatory alternative with other policy options.[138] If the Gini coefficient is near one for a proposed action but near 0.5 for a possible alternative, for instance, the regulator would know that the proposal would result in a more unequal outcome than the alternative.

b. Atkinson Index

The Atkinson index was also originally designed to measure inequality in the distribution of income. In the income context, the Atkinson index "is derived by calculating the equity-sensitive average income," which is "the level of per capita income which, if uniformly possessed, would make total welfare exactly equal to the total welfare generated by the actual income distribution."[139] The Atkinson index takes the status of an individual and the number of individuals in the population, and applies an inequality-aversion parameter.[140] The Atkinson index "explicitly incorporate[s] normative judgments about social welfare" by applying an aversion-to-inequality factor that is chosen by the analyst or regulator.[141] The inequality-aversion parameter reflects "societal preferences for equality."[142] Like the Gini coefficient, the Atkinson index could be used to compare the distributional effects of a regulatory proposal with those of the status quo or other regulatory alternatives.

c. Theil Index

The Theil index effectively measures how far away the population in a given scenario is from a state of equality.[143] The output is a number between zero and infinity, with higher numbers representing greater levels of inequality.[144] For example, a regulatory option with a Theil index of 5 would have a more equal distribution of impacts than one with a Theil index of 50. Some experts recommend that the Theil index only be used with other inequality metrics because certain aspects of its calculation lack intuitive appeal.[145]

Two research teams—one led by Jonathan Levy,[146] the other by Sam Harper[147]—provide useful overviews of these and other inequality metrics, which OMB may wish to consider. Levy et al. include a stylized example of how these three inequality metrics can be used in the context of an air pollution control policy.[148]

Inequality Metrics in the Literature

There are various notable papers that explore how to use inequality metrics for health and environmental justice considerations. Although this report does not endorse any particular metric (or the use of inequality metrics in general), this discussion highlights the rigor of these approaches and their prevalence in the literature.

In one paper, a team of researchers led by Sam Harper considers explicitly applying inequality metrics to regulatory decisionmaking.[149] The authors discuss twenty indicators of health inequality, including "quantification of the distribution of inequalities in health outcomes across social groups of concern, considering both within-group and between-group comparisons."[150] The authors note that regulators conducting distributional analyses using measures of well-being must make certain choices, including with respect to: reference groups or points for comparisons; whether they will look at relative or absolute dimensions of inequality; whether to consider ordinal groups (e.g., income quartiles or educational attainment) or nominal groups (e.g., ethnic or geographic groups) or both; and finally, any value judgments that belie possible weighting choices.[151] Finally, the authors caution that these measures "will…be interpretable only when they take account of baseline inequality and are evaluated in conjunction with [other] benefits."[152]

In another example of the application of inequality metrics, a team of researchers led by James Boyce uses different indicators of inequality—such as the Gini Coefficient, Theil Index/Generalized Entropy Measure, ratios of medians, and ratios of 90th percentiles—and census tract-level data to generate inter-state rankings according to inequality in exposure to air pollution. The authors look at both vertical inequality, which is inequality of exposure to air pollutants, and horizonal inequality, which is based on other characteristics like minority status and income.[153]

In the context of measuring inequality of health benefits derived from regulation, Levy et al.[154] compare different metrics, such as the Gini index, Atkinson index, and the Theil's entropy index. They analyze how these metrics behave with respect to what they consider an ideal set of criteria ("axioms").[155] They conclude that the Atkinson Index, an indicator originally developed to characterize income inequality, is the metric that best satisfies these axioms. In another paper, Neal Fann and his co-authors, for instance, use the Atkinson Index to assess distributional impacts of different air quality management approaches in the city of Detroit.[156]

In recent work, Erin T. Mansur and Glenn Sheriff[157] propose an alternative metric to the measures of inequality used by many other authors, wherein they draw from the Rawlsian veil of ignorance theory to rank emissions distributions resulting from different policy scenarios.[158] The authors use the premise that one policy is preferable for a specific subpopulation if that policy would be "chosen by an impartial agent who had an equal probability of receiving the exposure of any individual in that group." The authors caution that their approach allows the selection of a globally optimal policy only if there were consensus within groups about preferences. Specifically, they claim that their approach "informs a policy maker about how different policy options affect each group but leaves to her the decision of how to balance competing interests."[159]

* * *

Pending stakeholder input, OMB should consider inequality metrics as one set of available tools for agencies to incorporate distributional analysis into regulatory decisionmaking. Using inequality metrics alongside costs and benefits that have been disaggregated by demographic groups may give regulators important information about how evenly costs and benefits are distributed, which could help them contextualize a rule's distributional effects alongside other regulatory impacts.

2. *Weights based on social welfare functions*

Agencies could also assess the desirability of distributional outcomes by applying weights to costs and benefits that are based on a Social Welfare Function ("SWF") framework. SWFs are used to understand how social welfare changes as a function of the distribution of "utilities," or units of well-being,[160] in a given population.[161] Weights based on SWFs could be applied to disaggregated costs and benefits to rank policy options based on distributional desirability. Although SWFs typically are based on income or consumption, we note that it is also possible to define well-being using characteristics like health status or leisure.[162] **OMB should consult with stakeholders when evaluating whether an income-focused approach is appropriate and, if not, whether and how other attributes of well-being could be used to generate weights.**

Here we describe two types of distributional weights that could be applied to costs and benefits to proxy different SWFs: utilitarian and prioritarian. Utilitarian weights are typically constructed to reflect the fact that one dollar is more valuable for a low-income individual than a high-income one. They could also be constructed to reflect the diminishing marginal utility of well-being more broadly understood (e.g., an increase in environmental quality is more valuable to individuals with a lower baseline of environmental quality).[163] But using dimensions other than income requires additional analytical steps (e.g., determining how to measure environmental quality, including how a unit of environmental quality improvement or degradation can be compared). Under the prioritarian approach, weights go beyond incorporating the diminishing marginal utility of income (or other characteristics) and are constructed instead to integrate particular ethical and moral considerations of equity and fairness. Prioritarian weights assign "higher value to well-being increments that accrue to the worse-off than to identical well-being impacts that accrue to the better-off."[164] Under either approach, regulators could look at weighted cost-benefit assessments as another data point to inform their consideration of distributional concerns.

The economics literature underpinning social welfare functions is well-established. Proponents like Duke University law and economics professor Matthew Adler advocate for the use of social welfare functions in regulatory decisionmaking[165] by using analysis that applies weights in assessing costs and benefits.[166]

a. Utilitarian Weights

As currently conducted, traditional regulatory cost-benefit analysis monetizes regulatory impacts based on individuals' willingness-to-pay (which is largely based on ability to pay), and thus, does not account for the distribution of willingness-to-pay among individuals. Because those with higher income are able and willing to pay more for goods and services than those with lower incomes, a willingness-to-pay approach inherently favors those who are richer.

Diminishing marginal utility of income, however, considers that as income increases, the marginal benefit of each additional dollar to an individual's well-being decreases. Therefore, adjusting for diminishing marginal utility using income-based utilitarian weights could alleviate the inherent bias in the analysis. Such utilitarian weights translate income changes into well-being, or utility, changes. As a result, a certain monetized benefit for a low-income group is given greater value than the same monetized benefit for a high-income group, even when the monetization is based on a willingness-to-pay estimate. A regulatory analysis using this methodology would, in theory, show decisionmakers what regulatory option generates the greatest utility for society overall, offering policymakers a rigorous methodology to prioritize different distributional alternatives.

Utilitarian weights can be extended to reflect more complex definitions of well-being, rather than just equating well-being with income. For instance, well-being might be defined to include attributes like health status. In that case, utilitarian weights would reflect that the same health benefit increases the well-being of a sick person more than that of a healthier one.[167] However, constructing this type of utilitarian function would require that decisionmakers determine which attributes contribute to well-being. Relying on income rather than more complex definitions of well-being would be simpler, particularly given that the concept of diminishing marginal utility of income already underpins standard practices of cost-benefit analysis such as discounting.[168] Moreover, some attributes of affected communities that might be of interest to the regulator (such as race, gender, or labor occupation) cannot be incorporated into a utilitarian SWF. Hence, using utilitarian weights will not help in the analysis of distributional impacts along these dimensions.

Using income-based utilitarian weights is recommended by the British government for regulatory impact assessment.[169] The UK Green Book, which sets specific guidance on how to carry out cost-benefit analysis in the United Kingdom, even establishes precise values. Specifically, it states that a dollar to a person in the lowest income quartile is worth roughly twice as much as a dollar to a person in the highest income quartile in the British context.[170] Again, if a utilitarian-based analysis is presented alongside the results of a traditional cost-benefit analysis, regulators will have flexibility to assess what policy outcome is preferable considering different aggregate and distributional outcomes. In this context, the utilitarian analysis provides helpful perspective for the regulator but need not be the deciding factor.

In the context of a rule that controls air pollution, for example, utilitarian weighing might make the adjusted willingness to pay for health benefits of avoided exposure equal across income groups, even if the empirical willingness to pay differs between these groups (which it likely does because it depends on *ability* to pay). Or, such weighting might make such health benefits to low-income groups *even more* valuable than the same health benefits to groups with greater resources. Assuming that willingness to pay for health effects is uniform across social groups is not actually a deviation from standard practice, as we discuss in Recommendation 2. Alternately, using utilitarian weights might take identical costs to two groups and increase the magnitude of those costs to the lower income group, reflecting the fact that the same monetary cost has greater disutility to an individual with less ability to pay that cost.

b. Prioritarian Weights

A regulator could go one step further by applying prioritarian weights to inform an assessment of distributional outcomes. These weights can be used to proxy a prioritarian social welfare function—that is, a welfare function that recognizes a higher societal benefit to improving the utility of the worst-off than improving the utility of the best-off.[171] In essence, prioritarian social welfare functions assign larger weights to the welfare gains of the worst-off than weights based solely on marginal utility of income or other measures of well-being.[172] In giving priority to the worst-off, prioritarian weights reflect one possible (albeit common) idea of fairness. In the context described above, when considering a rule with air pollution effects, prioritarian weighting would necessarily give greater value to health benefits of the groups who are most vulnerable to those adverse effects (e.g., due to preexisting health conditions or lack of access to healthcare). Prioritarian weighting also means that if weights were applied to all effects of a proposed action (costs as well as benefits), costs to better-off groups would be weighted less heavily than the same costs to worst-off individuals, even after those costs were income-adjusted to reflect the declining marginal utility of consumption.

The parameters of a prioritarian social welfare function depend on the decisionmaker's normative determinations, including the evaluation of society's aversion to inequality. As a result, calculating prioritarian weights can be challenging. However, there are empirical estimates that a regulator could use to support such a calculation. For instance, society's distributional preferences and aversion to inequality, though nuanced,[173] can be measured empirically. One recent paper concludes that from a prioritarian standpoint, an improvement in air quality is eight times more advantageous when that improvement benefits someone with a lower baseline environmental quality, versus another individual whose environmental-quality baseline is twice as high.[174] However, this empirical measurement of inequality aversion depends, among other things, on the type of environmental good that is being considered (e.g., air quality versus soil quality). Calculating an aversion to inequality factor or coefficient can be a complex undertaking that is context-specific. Though OMB could provide guidance on the process for making such a calculation, agencies would potentially need to derive the aversion to inequality factor for each policy proposal.

Other studies of inequality aversion further demonstrate how an individual's well-being relative to others in a given population affects preferences for certain distributional outcomes.[175] In order to apply prioritarian weights practically, a regulator must make normative judgments and other decisions in order to select a methodology for determining the inequality aversion factor.[176] Once again, policymakers could consider an analysis using prioritarian weights alongside a traditional cost-benefit analysis, rather than assign it dispositive preference.

C. OMB Could Recommend that Agencies Calculate Net Welfare Using Weighted Cost-Benefit Analysis

Finally, in the biggest departure from common practice, a regulator could prioritize distributional outcomes by *replacing* traditional cost-benefit analysis with a weighted cost-benefit analysis. Under this approach, the results of a weighted cost-benefit analysis would be presented not alongside those results of a disaggregated cost-benefit analysis, but rather as the main or only result.

If it takes this approach, OMB should give explicit guidance on whether income will be the default measure of utility, and so the basis for weights, and if not, provide guidance on how regulators could use other measures of well-being in the place of income for generating weights. Also, as noted above, a utilitarian weighted cost-benefit analysis will not shed light on distributional impacts along some attributes that could be of interest to a regulator, such as race, while prioritarian weights could.[177] We note that though adopting SWF-based weights as the main decisionmaking tool has some theoretical and academic support,[178] it could pose a challenge from a practical and legal perspective (in addition to the limitations mentioned above).

First, weighting may be an unnecessary step to achieve more equitable outcomes. Some argue that using traditional cost-benefit analysis could lead to progressive (greater benefits to the worse off) rather than regressive (greater benefits to the better off) policies. In a forthcoming paper, Daniel Hemel argues that using traditional weighted cost-benefit analysis is particularly appropriate when assessing policies that are designed to save lives.[179] Hemel is not alone in concluding that regulators should stick with traditional cost-benefit analysis. David Weisbach draws the same conclusion in a 2015 paper, though for different reasons. Essentially, Weisbach argues that agencies exist to "perform specialized tasks," and that within that narrow scope of responsibility, agencies cannot achieve "desirable distributive policies." Therefore, he argues that regulatory decisionmakers should continue to use traditional cost-benefit analysis, with redistribution occurring primarily through the tax-and-transfer system.[180]

If OMB determines that weighting is the appropriate approach for agencies to meet both efficiency and distributional goals, there are a number of considerations that OMB would have to take into account before choosing this route. For example, employing a social welfare function requires regulators to make political decisions that they may not be empowered to make.[181] This may be particularly true when using prioritarian weights, as designating the "worst-off" group in any given scenario is an inherently value-laden judgment that may not fully capture all determinants of fairness. Although regulators have long purported to consider distributional concerns,[182] they may be ill-equipped to determine policy so explicitly and fundamentally based on distributional considerations. And insofar as regulations are justified primarily based on distributional benefits rather than more traditional benefits, courts may be concerned that agencies are relying too heavily on factors outside their core statutory mandate.

There are other possible practical and legal hurdles to adopting weighted cost-benefit analysis as the primary basis for regulatory decisions. For example, traditional cost-benefit analysis is widely applied across the federal government and well understood by courts. While agencies are given broad deference by courts and surely have latitude to make methodological choices, fundamental changes to cost-benefit analysis of this sort may draw judicial ire (justified or not).[183] It is certainly possible that case law could come to embrace the use of social welfare functions in cost-benefit analysis just as it has traditional cost-benefit analysis.[184] Indeed, agencies are generally empowered by sufficiently open-ended statutory frameworks to choose their preferred methodology and balance different regulatory priorities.[185] However, this may be a risk that the federal government does not wish to take. Indeed, even Adler, one of the biggest proponents of social welfare functions, argues that because applying distributional weights (both utilitarian and prioritarian) is "value-laden," agencies should "undertake standard [cost-benefit analysis] alongside distributionally weighted [cost-benefit analysis] with some range of weights," as we have discussed in the previous subsection.[186]

* * *

Addressing distributional concerns in regulation involves more than showing how the costs and benefits of a particular regulatory option accrue to different groups. It also requires taking this information into account when deciding whether and how to regulate. Agencies have a range of methodological options for considering distributional impacts alongside other regulatory effects. Clear guidance from OMB on how agencies can contextualize the magnitude or significance of distributional consequences will be critical to ensure robust and consistent consideration of distributional impacts across agencies.

RECOMMENDATION 4:

OMB Should Lead a Whole-of-Government Approach to Implement Measures to Mitigate Adverse Distributional Impacts Through Interagency Coordination

Regardless of how agencies account for distributional outcomes in regulatory decisionmaking, there will likely be some undesirable distributional outcomes resulting from otherwise desirable rules. Executive Order 13,985 has already tasked the Domestic Policy Council ("DPC") with "coordinat[ing] efforts to embed equity principles, policies, and approaches across the Federal Government."[187] OMB could join forces with the DPC and specifically coordinate among agencies to provide guidance on how agencies can mitigate potential adverse distributional outcomes.[188]

As noted in the previous sections, OMB could give agencies guidance to help them to identify adverse distributional outcomes during the rulemaking process. Agencies could then consider other avenues within their statutory authority to address or minimize undesirable distributional outcomes. For example, the Department of the Interior could prioritize fossil-fuel-dependent communities for the siting of renewable energy projects to redress potential lost revenue in those places due to more stringent leasing and production policies.[189] This type of policy accounts for lost income to some groups, an adverse distributional consequence, by providing new income-generating opportunities for those same groups. OMB could consult with agencies on a rule-by-rule basis to identify avenues to mitigate adverse distributional impacts.

If mitigating the adverse distributional effects of an otherwise cost-benefit-justified rule is outside the statutory authority of the rulemaking agency, then the lead agency could work with other agencies to create remediation plans. The DPC or OMB could act as a liaison between agencies. Additionally, OMB (or specifically OIRA) could provide oversight over distributional issues in decisionmaking, including by regularly reviewing distributional analyses across rules and across agencies to assess cumulative distributional effects. As part of such oversight, OIRA, along with the DPC, could convene an interagency working group to provide coordination across the federal government aimed at addressing adverse distributional outcomes. As a first step, **the administration should solicit public input and establish a robust stakeholder process to inform how it implements a whole-of-government approach to improving equity.**

A. OMB and the Domestic Policy Council Should Coordinate Between the Lead Agency and Other Agencies to Address Inequitable Effects

Many adverse distributional outcomes cannot be efficiently solved within the lead agency's authority, nor can any one agency alone work to solve longstanding distributional disparities suffered by certain groups. In this event, it may be appropriate for two or more agencies to work together to correct distributional imbalances. OMB and/or the DPC should provide coordination in this regard.

In a law review article on this topic, Richard Revesz discusses when it may be desirable for a second agency (other than the rulemaking agency) or multiple other agencies to design the redistributive mechanism.[190] Revesz goes into detail about a real-life example, the Partnerships for Opportunity and Workforce and Economic Revitalization (sometimes known as POWER) Initiative, which was designed to compensate displaced coal industry workers.[191] This initiative was in part a way of addressing the disproportionate effect of environmental regulations like the Clean Power Plan on coal communities.[192] Although EPA was responsible for the regulations in question, the Economic Development Administration, Department of Labor, Appalachian Regional Commission, Department of Commerce, and Department of Agriculture all worked with EPA on the POWER Initiative.[193]

Similar to the multiagency cooperation in the POWER Initiative, Executive Order 13,990 establishes the Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization.[194] This tasks numerous agencies and offices with "coordinat[ing] the identification and delivery of Federal resources to revitalize the economies of coal, oil and gas, and power plant communities," among other things.[195] A similar group of agency heads could come together to direct resources towards compensating groups adversely affected by a specific regulation or set of regulations.

Such cooperation could be a model for future efforts. OMB oversight and coordination could facilitate these types of joint ventures across the federal government.

OMB and the DPC Could Initiate a Pilot Program to Study Compensatory Mechanisms

Agencies have limited resources, including limited capacity for cross-agency engagement, but such coordination is essential to identify and implement compensatory mechanisms for groups and communities that have faced disproportionate adverse effects from federal action (and inaction). In fact, the Biden administration has already created one interagency working group aimed specifically at remediating inequitable harms against a particular community, and could create other interagency working groups to benefit other discrete, disadvantaged populations.

Executive Order 14,008 established an interagency working group on Coal and Power Plant Communities and Economic Revitalization.[196] This working group is tasked with addressing the economic costs that these communities have faced due in part to rules aimed at protecting public health and the environment by limiting the use of fossil fuels. In April, the group released a report,[197] per the executive order, that identifies the "mechanisms, consistent with applicable law, to prioritize grantmaking, federal loan programs, technical assistance, financing, procurement, or other existing programs"[198] to support these communities that may have suffered localized adverse impacts from federal actions. The report was informed by stakeholders and advocacy groups, and is but the first step of the working group.

A similar group could be established that addresses the cumulative adverse environmental harms faced by the communities living in Cancer Alley. Cancer Alley is not only in great need of remediation but is also a useful counterpart to coal and power plant communities because it has been affected by the regulatory status quo in very different ways. Whereas coal and energy communities have disproportionately felt the economic burdens of environmental and public health regulations, the communities of Cancer Alley have disproportionately suffered the costs of insufficient or altogether absent health and safety regulations.

Like the coal and power plant communities working group, the Cancer Alley working group could begin by gathering information on how those communities could be compensated (through grantmaking, financing, technical assistance, procurement, and other programs) to address the harms they have suffered due to government action and inaction.

B. OMB and the DPC Should Provide Systemwide Oversight

Beyond addressing the adverse distributional impacts of individual rules, OMB and/or the DPC could also facilitate assessment, and potentially remediation, of distributional inequities across the regulatory system. For instance, regulatory actions—or inactions—may routinely impose disparate impacts on the same groups. Conversely, some groups may experience disproportionate costs under some policies but enjoy offsetting disproportionate benefits under others. In order to identify these cumulative effects, the federal government would benefit from an approach that considers the whole universe of agencies and their actions, rather than looking at each agency or action in a vacuum. This will require systemwide oversight and data collection, which OMB (and OIRA in particular) could lead.[199]

As noted above, President Biden has already charged the DPC with leading an interagency process on improving equity across the federal government. Similarly, President Biden has given OMB a number of interagency coordination duties with respect to the climate crisis that the Office could carry out with careful attention to regulatory equity. For instance, President Biden's executive order *Tackling the Climate Crisis at Home and Abroad* (Executive Order 14,008) directs the Director of OMB to work with the National Climate Advisor to first identify fossil fuel subsidies provided by various agencies and to then take the necessary steps to ensure that "[f]ederal funding is not directly subsidizing fossil fuels."[200] As part of this role, OMB could help identify the nature and magnitude of disparate impacts resulting from fossil-fuel subsidies, and work with agencies to ensure that federal funding does not contribute to adverse distributional impacts. This same executive order also tasks OMB with reviewing and assessing agencies' Climate Action Plans to ensure these plans are consistent with policy established by the Order. OMB could similarly request plans from agencies that detail how the agencies intend to address equity in their upcoming actions.

OIRA, an office within OMB, is already responsible for carrying out some tasks that could be translated into the context of distributional analysis. For example, since agencies already provide regulatory impact analyses to OIRA for review, OIRA would be the perfect candidate to oversee a systemic review of agencies' distributional analyses.[201] First, it could collect data from agencies on their distributional analyses. This might include setting up an online database that is accessible to agencies and interested stakeholders alike that includes distributional effects for specific rules. This information could be aggregated in the database and organized by rule or action, year, agency, subpopulation, etc. Then, OIRA could look at the net effects on specific groups across agencies and across rules.

Using its expertise in assessing the consequences of regulation, OIRA could work with agencies to formulate an appropriate response to distributional consequences of proposed rules.[202] Given its understanding of the regulatory landscape, OIRA would also be well suited to advise agencies on when the distributional impacts of their regulations are significant and merit corrective action, similar to the agency's function in assessing whether a regulation is "significant" under Executive Order 12,866 triggering a detailed regulatory impact analysis. In the event that OIRA identifies a number of actions with potentially adverse distributional impacts affecting the same group, it could establish an interagency working group to address these impacts.

Finally, again due to its unique position overseeing the significant actions of all agencies, OIRA would be well positioned to assess cumulative distributional issues resulting from many actions. This could be done in partnership with or under the advisement of the DPC and the White House Environmental Justice Advisory Council. OIRA could, for example, incorporate other distributional issues into the environmental justice scorecard prescribed by Executive Order 14,008,[203] or generate separate scorecards to capture how well agencies are addressing equity in their decisionmaking.

OIRA could also use the unified agenda process to facilitate review of distributional analyses. Under this approach, agencies would flag potential adverse distributional outcomes early in the regulatory process. If possible, agencies could include preliminary distributional findings as part of their semi-annual submission to the unified agenda.[204] With this information, OIRA would be able to better guide agencies through the rulemaking process to address distributional concerns from the early stages, rather than waiting for notice and comment on each action. Similarly, OIRA, along with the DPC, could connect agencies to address distributional inequities. Moreover, providing this information early allows for further stakeholder engagement and input into the upcoming year's rulemaking process across agencies.

In its annual review and report to Congress, OIRA could assess distributional outcomes (both of key rules and across rules) and report whether any particular groups were adversely impacted by the year's regulatory actions.[205] Understanding the effects on specific groups from the entire universe of regulations in a given period of time is key to addressing longer-term inequities. Such information could also provide a baseline from which to consider the distributional effects of the following year's regulatory agenda.

OMB generally, or OIRA in particular, along with the DPC, could also convene an interagency working group to address the distributional outcomes of regulatory actions. This group could be tasked with "facilitat[ing] the organization and deployment of a Government-wide approach" to equity, the way the newly formed National Climate Task Force is tasked with taking such an approach to addressing climate change.[206] This could be housed within the existing Interagency Working Group on Environmental Justice or it could subsume the Equitable Data Working Group to minimize duplication of efforts, or could operate as a distinct body. Among other important tasks, such an interagency working group on distributional impacts could help OIRA assess the collective distributional impacts across regulations and across agencies to include in OIRA's annual report to Congress.[207]

The interagency working group could also be responsible for taking stock of methodological shortcomings of existing distributional analyses, such as identifying unquantified effects that have important equity implications for further research,[208] in partnership with the Equitable Data Working Group established by Executive Order 13,985. In this regard, it would have similar responsibilities to the Interagency Working Group on the Social Cost of Greenhouse Gases. Because interoperable, systematic distributional analysis would be new, there would inevitably be room for continuous improvement within and across agencies. An interagency working group could lead research efforts and contribute to OIRA's methodological guidance on established best practices. As Jason Schwartz has recognized, "[o]nce a set of best practices is established by the interagency working group, it will become less costly for agencies to conduct their distributional analyses, because they can refer back to established practices rather than trying to reinvent a new methodology each time."[209]

Wicked Problems, Systems Thinking, and Distributional Analysis

Social policy problems, like environmental injustice and other issues of inequity, can be seen as "wicked problems":[210] they are not lone problems in and of themselves, but in fact the product of a constellation of issues involving many stakeholders.[211] Wicked problems are defined by ambiguity, so there can be disagreement not only about the nature of the problem and its solutions, but also more abstract concerns about what constitutes a public good or how to define key elements like equity and justice.[212] There is also not necessarily a clear end point at which a wicked problem can be considered resolved, which is perhaps the most important characteristic for the purposes of this report.[213] Rather, wicked problems need to be looked at from multiple perspectives and each element of the problem must be considered along with all the others. This is why it may not be sufficient for a federal agency to act alone, or even in partnership with other individual agencies, to address distributional concerns that are the product of regulatory actions. Instead, distributional concerns should be considered across the entire regulatory system.

The existing siloed structure of the executive branch dampers our ability to see federal agencies—and their actions—as components of a broader system.[214] Specialized agencies operate exclusively within statutorily prescribed policy silos and only rarely undertake joint rulemakings and analyses.[215] Moreover, while OIRA's review of significant rules constitutes a form of systemic oversight, it is limited to furthering efficiency objectives. OIRA does not take this same type of bird's-eye-view with respect to other aspects of regulatory actions. Systems thinking, which has established methodologies and tool kits, can help policymakers "to identify and understand critical linkages, synergies and trade-offs between issues generally treated separately and thus to reduce unintended consequences."[216]

Using a systems thinking approach to distributional effects could be particularly effective for several reasons. First, some groups face historic and systemic inequities that are the product of decisions made across policy arenas. Second, the same groups may be losers (i.e., suffer net harms) from a given set of contemporary regulations. Third, decisionmakers may 'speak a different language' (i.e., operate from a different point of view) than affected individuals/communities or regulated industry, and so miscommunication between decisionmakers and stakeholders can be prevalent; systems thinking takes the perspectives of the various stakeholders into account.[217] Fourth, as noted above, there are often tradeoffs—but also unidentified synergies—in trying to address distributional concerns that agencies cannot address on their own. Fifth and finally, because social problems like environmental justice are often wicked problems, there is no single solution, but rather many solutions must be assessed and implemented.

Conclusion

The federal regulatory system could play an important role in addressing inequality and promoting fairness and environmental justice. Greater oversight and clearer guidance from OMB will be critical to creating long-lasting change on this front. As this report has outlined, OMB should provide detailed guidance to agencies on conducting granular analysis, assessing costs and benefits for a manageable number of demographic subgroups, and weighing distributional concerns alongside other regulatory impacts. Additionally, OMB and the DPC should facilitate coordination between agencies to promote equity throughout the regulatory system.

Endnotes

[1] Exec. Order No. 13,985 § 1, 86 Fed. Reg. 7009 (Jan. 20, 2021).

[2] *Id.* § 4(a) (requiring study of "best methods . . . to assist agencies in assessing equity").

[3] *Id.* § 1.

[4] Modernizing Regulatory Review § 2(b)(ii), 86 Fed. Reg. 7223 (Jan. 20, 2021). Notably, the memorandum does not define "disadvantaged," "vulnerable," or "marginalized" communities. Executive Order 13,985 does, however, provide a non-exhaustive list of "underserved communities that have been denied [consistent and systematic fair, just, and impartial] treatment," which includes "Black, Latino, and Indigenous and Native American persons, Asian Americans and Pacific Islanders and other persons of color; members of religious minorities; lesbian, gay, bisexual, transgender, and queer (LGBTQ+) persons; persons with disabilities; persons who live in rural areas; and persons otherwise adversely affected by persistent poverty or inequality." Exec. Order No. 13,985 § 2.

[5] *Id.* § 2(a).

[6] *See id.*

[7] Richard L. Revesz, *Regulation and Distribution*, 93 N.Y.U. L. Rev. 1489, 1500–11 (2018) (presenting, but then criticizing, this "orthodox view").

[8] *Id.* at 1512–18; *see also* H. Spencer Banzhaf, *Regulatory Impact Analyses of Environmental Justice Effects*, 27 J. Land Use & Env't L. 1, 14 (2011) ("[A]ctual compensations for the distributional effects of government projects and regulations are exceedingly rare, if not an outright fiction.").

[9] Revesz, *supra* note 7, at 1511–12.

[10] *See* Banzhaf, *supra* note 8, at 14 (stating that "if redistribution is a national objective, then any regulatory action that promotes this objective, ceteris paribus, is obviously preferable to one that does not").

[11] Zachary Liscow, *Redistribution for Realists* 6 (2021), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3792122.

[12] Exec. Order No. 12,866, 58 Fed. Reg. 51,735 (Oct. 4, 1993).

[13] Exec. Order No. 12,291 § 3(d)(1)–(2), 46 Fed. Reg. 13,193 (Feb. 17, 1981) (calling on agencies to "identif[y] . . . those likely to receive the benefits" and "those likely to bear the costs" of each regulation"). However, this Order does not advise regulators on how to incorporate such a distributional analysis into its assessment of net benefits. Instead, the Order advises agencies that "[r]egulatory objectives shall be chosen to maximize the net benefits to society," suggesting that distributional and justice considerations merit scant consideration. *Id.* § 2(c).

[14] *Id.* § 2(c).

[15] Exec. Order No. 12,866 § 1(b)(5).

[16] Office of Mgmt. & Budget, Economic Analysis of Federal Regulations Under Executive Order 12,866 (Jan. 11, 1996), https://georgewbush-whitehouse.archives.gov/omb/inforeg/riaguide.html.

[17] *Id.* § III(A)(8).

[18] *Id.*

[19] *Id.*

[20] Office of Mgmt. & Budget, Circular A-4, Regulatory Impact Analysis 3 (2003) [hereinafter "Circular A-4"].

[21] *Id.* at 14.

[22] *Id.*

[23] Exec. Order No. 13,563, 76 Fed. Reg. 3821 (Jan. 18, 2011).

[24] *Id.* § 1(b).

[25] *Id.* § 1(c).

[26] Exec. Order No. 12,898 § 1-101, 59 Fed. Reg. 7629 (Feb. 11, 1994) ("To the greatest extent practicable and permitted by law, . . . each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations . . . ."); *accord id.* § 3-302(a). Executive Order 12,898 does not define "minority populations" or "low-income populations. "

[27] Council on Env't Quality, *Environmental Justice: Guidance Under the National Environmental Policy Act* (Dec. 10, 1997), https://www.epa.gov/sites/production/files/2015-02/documents/ej_guidance_nepa_ceq1297.pdf.

[28] Fed. Interagency Working Grp. on Env't Just., *Promising Practices for EJ Methodologies in NEPA Reviews* (2016), https://www.epa.gov/sites/production/files/2016-08/documents/nepa_promising_practices_document_2016.pdf.

[29] EPA, Guidelines for Preparing Economic Analyses 10-1 to 10-23 (last updated 2014) [hereinafter "EPA Guidelines"].

[30] EPA, Technical Guidance for Assessing Environmental Justice in Regulatory Analysis (2016), https://www.epa.gov/sites/production/files/2016-06/documents/ejtg_5_6_16_v5.1.pdf [hereinafter "EPA Technical Guidance"].

[31] *Id.* at 13.

[32] *See, e.g., id.* at 11–14 (describing key analytical considerations); *id.* at 41–59 (offering guidance on assessing distribution of benefits and costs in regulatory impact analysis).

[33] Lisa A. Robinson, James K. Hammitt & Richard Zeckhauser, *The Role of Distribution in Regulatory Analysis and Decision Making* (Mossavar-Rahmani Ctr. for Bus. and Gov't, Harvard Kennedy Sch., Working Paper No. 2014-02, 2014), https://www.hks.harvard.edu/sites/default/files/centers/mrcbg/files/Zeckhauser_final.pdf.

[34] *Id.* at 9.

[35] *Id.* at 10–12.

[36] *Id.* at 12.

[37] Carl F. Cranor & Adam M. Finkel, *Toward the Usable Recognition of Individual Benefits and Costs in Regulatory Analysis and Governance*, 12 Reg. & Governance 131, 131 (2018) (emphasis added).

[38] Elizabeth Ann Glass Geltman, Gunwant Gil, & Miriam Jovanic, *Beyond Baby Steps: An Empirical Study of the Impact of Environmental Justice Executive Order 12898*, 39 Family and Cmty. Health 143, 143 (2016); *see also* Revesz, *supra* note 7, at 1540 ("[O]f the nearly 4,000 rules the EPA promulgated during the Obama administration, the agency referred to only seven as ones taking environmental justice concerns into account.").

[39] Denis Binder et al., *A Survey of Federal Agency Response to President Clinton's Executive Order No. 12898 on Environmental Justice*, 31 Env't. L. Rep. News & Analysis 11133 (2001).

[40] *See* Banzhaf, *supra* note 8, at 5–6 ("[W]hen it has incorporated even these limited environmental justice objectives into its [cost-benefit analyses], EPA has tended to stop at perfunctory, pro forma assertions that it is not creating or exacerbating an environmental injustice.").

[41] Federal Motor Vehicle Safety Standards; Rear Visibility, 79 Fed. Reg. 19,178 (Apr. 7, 2014).

[42] *Id.* at 19,184.

[43] *Id.* at 19,236.

[44] USDA, Regulatory Impact Analysis: Supplemental Nutrition Assistance Program: Requirements for Able-Bodied Adults Without Dependents 2 (2019), https://www.regulations.gov/document?D=FNS-2018-0004-19016. This analysis was conducted in support of Supplemental Nutrition Assistance Program: Requirements for Able-Bodied Adults Without Dependents, 84 Fed. Reg. 66,782 (Dec. 5, 2019).

[45] *Id.* at 49–51.

[46] The U.S. District Court for the District of Columbia found this regulation to be arbitrary and capricious, citing, among other reasons, the agency's failure to meaningfully evaluate distributional impacts. *D.C. v. United States Dep't of Agric.*, 496 F. Supp. 3d 213, 256–57 (D.D.C. 2020). This case represents a rare judicial rebuke of an agency's distributional analysis.

[47] Frank Ackerman & Lisa Heinzerling, *Pricing the Priceless: Cost-Benefit Analysis of Environmental Protection*, 150 U. Pa. L. Rev. 1553, 1573 (2002).

[48] Melissa J. Luttrell & Jorge Roman-Romero, *Regulatory (In) Justice: Racism and CBA Review*, Yale J. on Reg. (Oct. 27, 2020), https://www.yalejreg.com/nc/regulatory-injustice-racism-and-cba-review-by-melissa-j-luttrell-and-jorge-roman-romero/.

[49] *See, e.g.,* Anne N. Junod, Carlos Martín, Rebecca Marx, & Amy Rogin, *Equitable Investments in Resilience: A Review of Benefit-Cost Analysis in Federal Flood Mitigation Infastructure*, The Urban Institute (2021) (explaining how use of cost-benefit analysis often directs federal flood mitigation funding to wealthier communities by focusing on home values). Although this report focuses on the use of cost-benefit analysis in federal regulation, its recommendations on how to improve upon those analyses are also applicable for cost-benefit analyses performed for other purposes, such as federal grantmaking.

[50] *See generally* Joe's Vision, Joe Biden, https://joebiden.com/joes-vision/.

[51] Modernizing Regulatory Review, *supra* note 4, § 2(a).

[52] *Id.* § 2(b)(ii).

[53] Exec. Order No. 13,985.

[54] *Id.* § 1.

[55] *Id.* The Order defines two terms: "equity" and "underserved communities." It defines "equity" as "the consistent and systematic fair, just, and impartial treatment of all individuals, including individuals who belong to underserved communities that have been denied such treatment, such as Black, Latino, and Indigenous and Native American persons, Asian Americans and Pacific Islanders and other persons of color; members of religious minorities; lesbian, gay, bixsexual, transgender, and queer [] persons; persons with disabilities; persons who live in rural areas; and persons otherwise adversely affected by persistent poverty or inequality." It defines "underserved communities" as "populations sharing a particular characteristic, as well as geographic communities, that have been systematically denied a full opportunity to participate in aspects of economic, social, and civic life, as exemplified by the list in the preceding definition of 'equity.'" *Id.* § 2.

[56] *Id.* §§ 4(a), 5, 6(a).

[57] *Id.* § 3.

[58] *Id.* § 9(c)(ii).

[59] Exec. Order No. 14,008, 86 Fed. Reg 7619 (Jan. 27, 2021).

[60] *Id.* §§ 219, 221(b).

[61] *Id.* § 222(a).

[62] These working groups are: The Justice40 initiative working group, the Climate and Economic Justice Screening Tool working group, and the Executive Order 12,898 Revisions working group.

[63] White House Environmental Justice Advisory Council, *Interim Final Recommendations for Justice40, Climate and Economic Justice Screening Tool, & Executive Order 12898 Revisions* 65 (May 13, 2021), https://www.epa.gov/sites/default/files/2021-05/documents/whejac_interim_final_recommendations_0.pdf.

[64] Methods and Leading Practices for Advancing Equity and Support for Underserved Communities Through Government, 86 Fed. Reg. 24,029, 24,029 (May 5, 2021).

[65] *Id.* at 24,030.

[66] Exec. Order 13,985 § 2(a).

[67] *Id.* § 9.

[68] Andrew L. Goodkind et al., *Fine-Scale Damage Estimates of Particulate Matter Air Pollution Reveal Opportunities for Location-Specific Mitigation of Emissions*, 116 Procs. Nat'l Acad. Scis. 8775 (2019).

[69] Here, damages are defined as the monetary valuation of premature mortality attributable to exposure to fine particulate matter.

[70] Janet Currie et al., *Environmental Health Risks and Housing Values: Evidence from 1,600 Toxic Plant Openings and Closings*, 105 Am. Econ. Rev. 678 (2015).

[71] Banzhaf, *supra* note 8; *see also* Ellen S. Post, Anna Belova & Jin Huang, *Distributional Benefit Analysis of a National Air Quality Rule*, 8 Internat'l J. Env't Res. & Pub. Health 1872 (2011).

[72] Goodkind et al., *supra* note 68.

[73] John M. Morehouse & Edward Rubin, *Downwind and Out: The Strategic Dispersion of Power Plants and Their Pollution* 47 (Ctr. for Growth & Opportunity at Utah State U. Working Paper, 2021).

[74] EPA, F*inal Guidance for Incorporating Environmental Justice Concerns in EPA's NEPA Compliance Analyses* 16 (1998).

[75] Qian Di et al., *Air Pollution and Mortality in the Medicare Population*, 26 New Eng. J. Med. 2513 (2017).

[76] Solomon Hsiang, Paulina Oliva & Reed Walker, *The Distribution of Environmental Damages*, 13 Rev. Env't Econ. & Pol'y 83 (2019); *see also* Banzhaf, *supra* note 8.

[77] Tatyana Deryugina et al., *Geographic and Socioeconomic Heterogeneity in the Benefits of Reducing Air Pollution in the United States* (Nat'l Bur. of Econ. Res. Working Paper Series, 2020).

[78] Daniel Krewski et al., *Extended Follow-up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality* (Health Effects Inst. Rsch. Rep., 2009).

[79] CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool, Data and Tools, EPA, https://www.epa.gov/statelocalenergy/co-benefits-risk-assessment-cobra-health-impacts-screening-and-mapping-tool (last updated June 26, 2017).

[80] Neal Fann et al., *Maximizing Health Benefits and Minimizing Inequality: Incorporating Local-Scale Data in the Design and Evaluation of Air Quality Policies*, 31 Risk Analysis 908 (2011).

[81] Banzhaf, *supra* note 8.

[82] Jonathan I. Levy, *Accounting for Health Risk Inequality in Regulatory Impact Analysis: Barriers and Opportunities*, 41 Risk Analysis 610 (2021); *see also* EPA, Final Guidance For Incorporating Environmental Justice Concerns in EPA's NEPA Compliance Analyses (1998).

[83] Goodkind et al., *supra* note 68.

[84] Dallas Burtraw, Maya Domeshek & Amelia Keyes, *Carbon Pricing 104: Economic Effects Across Income Groups*, Resources for the Future (May 4, 2020), https://www.rff.org/publications/explainers/carbon-pricing-104-economic-effects-across-income-groups/.

[85] Lisa A. Robinson, James K. Hammitt & Richard J. Zeckhauser, *Attention to Distribution in U.S. Regulatory Analyses*, 10 Rev. Env't Econ. & Pol'y 308 (2016).

[86] EPA, EPA Environmental Justice Strategy 3 (Apr. 3, 1995), https://www.epa.gov/environmentaljustice/epa-environmental-justice-strategy-1995.

[87] Elizabeth Glass Geltman, Gunwant Gill & Miriam Jovanovic, *Beyond Baby Steps: An Empirical Study of the Impact of Environmental Justice Executive Order 12898*, 39 Fam. & Cmty. Health 144 (2016).

[88] EPA Technical Guidance, *supra* note 30.

[89] *Id.* at 1.

[90] *Id.* at 14.

[91] *Id.* at 47.

[92] *See supra* notes 12–46 and accompanying text.

[93] *See* Robinson et al., *supra* note 33, at 21.

[94] Cass R. Sunstein, *The Cost-Benefit State* 22–23 (Coase-Sandor Institute for Law & Economics Working Paper No. 39, 1996).

[95] John Graham, *Savings Lives Through Administrative Law and Economics*, 157 U. Pa. Law. Rev. 395, 520 (2008).

[96] *Id.*

[97] As discussed above, a 2016 EPA guidance document recommends that analysts quantify the distribution of costs and benefits as part of their regulatory analysis. Many legal and economic scholars also support the practice. *See supra* notes 30–32 and accompanying text. Many legal and economic scholars also support the practice. *See, e.g.,* Banzhaf, *supra* note 8, at 9 n.35 (collecting sources).

[98] *See* EPA Technical Guidance, *supra* note 30, at 41–57.

[99] Ronald J. Shadbegian, Wayne Gray & Cynthia Morgan, *Benefits and Costs from Sulfur Dioxide Trading: A Distributional Analysis*, (Nat'l Ctr. for Env't Econ. Working Paper 05-09, 2005).

[100] *Id.* at 15–18.

[101] Winston Harrington et al., Resources for the Future, *Distributional Consequences of Public Policies: An Example from the Management of Urban Vehicular Travel* (Resources for the Future Discussion Paper 14-04, 2014).

[102] *See, e.g.,* Daniel Hemel, *Regulation and Redistribution with Lives in the Balance,* U. Chi. L. Rev., at 2 (forthcoming, manuscript available at March 2, 2021), https://papers.ssrn.com/abstract=3796235) ("Incorporating distributive objectives into cost-benefit analysis of lifesaving regulations while maintaining equal dollar [values of a statistical life] for rich and poor will potentially produce perverse outcomes that—according to standard economic thinking—actually redistribute from poor to rich.").

[103] Applying uniform benefit estimates across demographic groups is effectively a form of utilitarian weighting, which is described further in Recommendation III, *infra*.

[104] EPA Guidelines, *supra* note 29, at B-4 to B-6. *But cf.* Richard l. Revesz & Michael A. Livermore, Retaking Rationality: How Cost-Benefit Analysis Can Better Protect the Environment and our Health 80–81 (2008) (discussing evidence that older individuals place a higher value on each remaining life-year).

[105] EPA Guidelines, *supra* note 29, at B-4 ("[T]he income elasticity of [willingness to pay] to reduce mortality risk is positive . . . .").

[106] David Glover & John Henderson, *Quantifying Health Impacts of Government Policies: A How-To Guide to Quantifying the Health Impacts of Government Policies*, UK Dep't of Health 12 (2010) (advising that "the health gains to any two individuals should be valued the same regardless of their income"); *see also id.* at 10–12 (endorsing disaggregating assessment of regulatory impacts).

[107] EPA Technical Guidance, *supra* note 30, at 57.

[108] *Id.* at 58.

[109] *Id.* at 57–59; EPA Guidelines, *supra* note 29, at 10-8 to 10-9.

[110] Exec. Order No. 12,898 § 1-101.

[111] This includes "Black, Latino, and Indigenous and Native American persons, Asian Americans and Pacific Islanders and other persons of color; members of religious minorities; lesbian, gay, bixsexual, transgender, and queer . . . persons; persons with disabilities; persons who live in rural areas; and persons otherwise adversely affected by persistent poverty or inequality." Exec. Order 13,985 § 1.

[112] *See supra* note 43 and accompanying text.

[113] *See, e.g.,* Matthew Adler, Measuring Social Welfare: An Introduction 16 (2019) [hereinafter Measuring Social Welfare] ("If income indeed has declining marginal well-being impact, then an equal distribution of a fixed total 'pie' of income among otherwise identical individuals generates a bigger sum total of well-being, as compared to an unequal distribution of the same 'pie.'"). Social welfare functions are discussed in further detail in Recommendation 3.

[114] Earlier this year, for instance, a divided panel of the U.S. Court of Appeals for the Sixth Circuit enjoined the Small Business Administration from prioritizing applications for relief funding based upon the race or sex of the applicant. *Vitolo v. Guzman*, 999 F.3d 353 , 366 (6th Cir. May 27, 2021). Two weeks after that decision, a federal judge in the Eastern District of Wisconsin issued a temporary restraining order blocking the Department of Agriculture from administering a loan-forgiveness program based on the applicant's race. *Faust v. Vilsack,* 2021 WL 2409729 (E.D. Wis. June 10, 2021).) A federal judge in the Middle District of Florida also enjoined the same program less than two weeks later, on similar grounds. *Wynn v. Vilsack*, 2021 WL 2580678 (M.D. Fla. June 23, 2021).In general, federal courts are skeptical of mathematical analyses involving "suspect classifications" such as race. *See, e.g., Gratz v. Bollinger*, 539 U.S. 244, 279 (O'Connor, J., concurring) (concluding that university-admission process relying on racial "point allocations" violates the Equal Protection Clause because it "ensures that the diversity contributions of applicants cannot be individually assessed"). *But see Grutter v. Bollinger*, 539 U.S. 306 (permitting university-admission process that considers racial diversity as a "soft variable[]" in a holistic analysis).

[115] *See, e.g., supra* note 43 and accompanying text.

[116] We refer to traditional cost-benefit analysis to differentiate the status quo from cost-benefit analysis where utilitarian or prioritarian weights are applied to the costs and benefits of different groups before aggregation, as described below.

[117] *See* below in the discussion of utilitarian and prioritarian weights that income is the default, but not necessarily the only, basis for weights. Weights could also consider attributes like health status. *See infra* p. 31–32.

[118] *See* e.g., Marc Fleurbaey & Rossi Abi-Rafeh, *The Use of Distributional Weights in Benefit-Cost Analysis: Insights from Welfare Economics*, 10 Rev. Env't Econ. & Pol'y 286, 289 ("Interpersonal comparisons have long been considered problematic because they are associated with difficult value judgments. Although the Pareto principle, which is so popular in economics, is itself a value judgment, it seems easy to defend. In contrast, dealing with the conflicting interests of winners and losers involves defining who is worse off, or more deserving, and this is clearly no simple task.").

[119] Phosphoric Acid Manufacturing and Phosphate Fertilizer Production RTR and Standards of Performance for Phosphate Processing, 80 Fed. Reg. 50,386 (Aug. 19, 2015).

[120] *Id.* at 50,430.

[121] *Id.*

[122] EPA determined this rule to not be significant under Executive Order 12,866. *Id.* at 50,431.

[123] Oil and Gas; Hydraulic Fracturing on Federal and Indian Lands, 80 Fed. Reg. 16,188 (Mar. 26, 2015).

[124] Circular A-4, *supra* note 20, at 3.

[125] *Id.* at 2. The Circular uses nonmonetized and unquantified somewhat interchangeably, noting that "[a] non-quantified outcome is a benefit or cost that has not been quantified or monetized in the analysis." *Id.* at 3.

[126] Lisa A. Robinson et al., *Reference Case Guidelines for Benefit-Cost Analysis in Global Health and Development* xviii (2019), https://cdn1.sph.harvard.edu/wp-content/uploads/sites/2447/2019/05/BCA-Guidelines-May-2019.pdf.

[127] *See* Circular A-4, *supra* note 20, at 27 (encouraging agencies to assess "detailed information on the nature, timing, likelihood, location, and distribution of the unquantified benefits and costs").

[128] *Id.* at 2.

[129] The inequality metrics discussed in this section can be applied in a variety of ways. This table merely illustrates the type of information each metric could provide that would be useful to a policymaker.

[130] Sam Harper et al., *Using Inequality Measures to Incorporate Environmental Justice into Regulatory Analyses*, 10 INT'L J. ENV'T RES. PUB. HEALTH 4039, 4042 (citing Jonathan Levy et al., *Quantifying the Efficiency and Equity Implications of Power Plant Air Pollution Control Strategies in the United States*, 115 ENV'T HEALTH PERSPECT. 743 (2007)); Jonathan Levy et al., *Evaluating Efficiency-Equality Tradeoffs for Mobile Source Control Strategies in an Urban Area*, 29 RISK ANALYSIS 34 (2009); Neal Fann et al., *Maximizing Health Benefits and Minimizing Inequality: Incorporating Local-Scale Data in the Design and Evaluation of Air Quality Policies*, 31 RISK ANALYSIS 908 (2011).

[131] Harper et al., *supra* note 130, at 4041.

[132] E.g., Urban Inst., *Segregation Measures*, https://www.urban.org/research/data-methods/data-analysis/quantitative-data-analysis/segregation-measures (last visited June 28, 2021).

[133] U.S. Census Bureau, *Income Inequality Metrics*, https://www.census.gov/topics/income-poverty/income-inequality/about/metrics.html (last visited June 28, 2021).

[134] *See* Robert Dorfman, *A Formula for the Gini Coefficient*, 61 REV. ECON. STAT. 146 (1979); FRANK COWELL, MEASURING INEQUALITY (1995).

[135] *Id.* at 147.

[136] *Id.* (citing Corrado Gini, *Variabilità e Mutabilità*, J. ECON. INEQ. (1912)).

[137] James Boyce et al., Measuring Environmental Inequality, 124 ECOL. ECON. 114, 118 (2016).

[138] *See, e.g.,* Daniel L. Millimet & Daniel Slottje, *Environmental Compliance Costs and the Distribution of Emissions*, 42 J. REGUL. SCI. 105 (2002) (using Gini coefficient to assess how uniform increases in federal environmental standards impact the distribution of environmental hazards).

[139] Jonathan Levy et al., *Incorporating Concepts of Inequality and Inequity into Health Benefits Analysis*, 5 INT'L J. EQUITY HEALTH 1, 10 (2006).

[140] *See* Harper et al., *supra* note 130, at 4052 for a detailed discussion on the Atkinson Index.

[141] Levy et al., *supra* note 139, at 10. We note that other tools discussed in this section incorporate those judgments implicitly (e.g., by excluding a factor that represents societal preferences about inequality).

[142] *Id.*

[143] *See* U.S. Census Bureau, *Theil Index*, https://www.census.gov/topics/income-poverty/income-inequality/about/metrics/theil-index.html (last visited June 28, 2021) ("The Theil index measures an entropic 'distance' the population is away from the 'ideal' egalitarian state of everyone having the same income.").

[144] *Id.*

[145] *Id.*

[146] Levy et al., *supra* note 139.

[147] Harper et al., *supra* note 130.

[148] Levy et al., *supra* note 139, at 10–12.

[149] Harper et al., *supra* note 130, at 4041 (2013) ("We are primarily concerned with characterizing the degree of inequality across social groups in defined health outcomes and how that inequality changes as a function of regulatory measures targeting environmental exposures.").

[150] *Id.* at 4039.

[151] *Id.* at 4043–46.

[152] *Id.*

[153] Boyce et al., *supra* note 137, at 115.

[154] Levy et al, *supra* note 139.

[155] According to these axioms, the metric should: "avoid value judgments about the relative importance of transfers at different percentiles of the risk distribution; incorporate health risk with evidence about differential susceptibility; include baseline distributions of risk; use appropriate geographic resolution and scope; consider multiple competing policy alternatives"; and satisfy the Pigou-Dalton transfer

principle (that an indicator "should not decrease when risk is transferred from a low-risk to high-risk person, and it should decrease when risk is transferred from a high-risk to low-risk person") and subgroup decomposability (an indicator "should be able to have total inequality divided into its constituent parts").

[156] Neal Fann et al., *Maximizing Health Benefits and Minimizing Inequality: Incorporating Local-Scale Data in the Design and Evaluation of Air Quality Policies*, 31 Risk Analysis 908 (2011).

[157] Erin T. Mansur and Glenn Sheriff, *On the Measurement of Environmental Inequality: Ranking Emissions Distributions Generated by Different Policy Instruments*, 8 J. Assoc. Env't & Res. Economists 721 (2021).

[158] *Id.* at 1.

[159] *Id.*

[160] In his 2019 book, Matthew Adler dedicates a chapter on how to define/measure a unit of well-being. Measuring Social Welfare, *supra* note 113, ch. 2.

[161] Fleurbaey & Abi-Rafeh, *supra* note 118.

[162] *See, e.g.,* Matthew Adler & Koen Decancq, *Measuring Well-Being and Respect for Preferences*, in Prioritarianism in Practice (Matthew Adler and Ole Frithjof Norheim, eds., forthcoming).

[163] *Id.*

[164] Maddalena Ferranna et al., *Addressing the COVID-19 Pandemic: Comparing Alternative Value Frameworks* 19, (National Bureau of Economic Research, Mar. 29, 2021).

[165] Measuring Social Welfare, *supra* note 113.

[166] Matthew D. Adler, *Factoring Equity into Benefit-Cost Analysis*, Regul. Rev. (Apr. 26, 2021), https://www.theregreview.org/2021/04/26/adler-factoring-equity-benefit-cost-analysis/ [hereinafter Factoring Equity].

[167] *See, e.g.,* Ferranna et al., *supra* note 163, at 6 (constructing weights considering that well-being depends on "consumption/income, longevity, and health status").

[168] *See, e.g.,* Tamma Carleton & Michael Greenstone, *Updating the United States Government's Social Cost of Carbon* 25 (2021); Circular A-4, *supra* note 20, at 35 (explaining that one rationale for discounting is that "if consumption continues to increase over time, as it has for most of U.S. history, an increment of consumption will be less valuable in the future than it would be today, because the principle of diminishing marginal utility implies that as total consumption increases, the value of a marginal unit of consumption tends to decline").

[169] Her Majesty's Treasury, T*he Green Book: Central Government Guidance on Appraisal and Evaluation* (2020), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938046/The_Green_Book_2020.pdf [hereinafter UK Greenbook].

[170] *Id.* at 97.

[171] *See* Matthew D. Adler, *Benefit-Cost Analysis and Distributional Weights: An Overview*, 10 Rev. Env't Econ. & Pol'y 264 (2016) [hereinafter BCA and Distributional Weights]; Factoring Equity, *supra* note 165.

[172] Adler explains the family of prioritarian social welfare functions at length, but very simply, they are tools that can be used when a decisionmaker places value on improving the well-being of the worst-off, even if that leads to larger decreases in well-being to the best-off. Measuring Social Welfare, *supra* note 113, at 88.

[173] *See, e.g.,* Raymond Fisman, Ilyana Kuziemko & Silvia Vannutelli, *Distributional Preferences in Larger Groups: Keeping up with the Joneses and Keeping Track of the Tails*, 19 J. Euro. Econ. Assoc. 1407 (2021).

[174] Frank Venmans & Ben Groom, S*ocial Discounting, Inequality Aversion, and the Environment*, 109 J. Env't Econ. & Mgmt. 1 (2021).

[175] For instance, Fisman et al., *supra* note 172, use different models to understand what value an individual may place on greater equality. The authors also discuss aversion-to-inequality models more generally. This study in particular looks at "the role of others' payoffs in choosing distributional outcomes." *Id.* at 1409. In other words, the authors can "distinguish, for example, whether individuals put more weight on reducing inequality at extreme income levels such as the top and bottom, or focus on inequality nearer to the subject's own income." *Id.* Their findings explain some anecdotal evidence regarding society's aversion to inequality, like why the top one percent of earners are an easier target than those who are extremely well-off but lower down on the income scale for higher tax rates. *Id.* at 1408.

[176] *See* BCA and Distributional Weights, *supra* note 170, at 271 (explaining that defining the inequality aversion parameter can also reflect "the moral preferences" of a decisionmaker).

[177] As we note above, using race as a factor in decisionmaking may raise constitutional issues. *See supra* note 114 and accompanying text.

[178] *See, e.g.,* Fleurbaey & Abi-Rafeh, *supra* note 118, for a brief overview of this literature.

[179] Hemel, *supra* note 102.

[180] David A. Weisbach, *Distributionally Weighted Cost-Benefit Analysis: Welfare Economics Meets Organizational Design*, 7 J. Legal Analysis 151 (2015).

[181] *See, e.g.,* BCA and Distributional Weights, *supra* note 170, at 278 ("The use of distributional weights does raise questions of institutional role. An unelected bureaucrat might feel that it would be legally problematic, or democratically illegitimate, for her to specify weights."); *see also* Fleurbaey & Abi-Rafeh, *supra* note 118, at 289.

[182] *See, e.g.,* Robinson et al., *supra* note 33.

[183] In a new working paper, Harvard Professor and former OIRA administrator Cass Sunstein argues that "courts . . . should tread lightly" when making determinations about whether the use of a social welfare function-based approach to regulatory analysis is arbitrary. Cass R. Sunstein, *Arbitrariness Review (With Special Reference to the Social Cost of Carbon)* (Harvard Kennedy School working paper, June 26, 2021), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3874312.

[184] Measuring Social Welfare, *supra* note 113, at 213.

[185] *Id.* at 214 (arguing that the law likely enables agencies to choose between a social welfarist approach and a traditional cost-benefit analysis approach).

[186] Factoring Equity, *supra* note 165.

[187] Exec. Order 13,985 § 3.

[188] This section draws significantly from Revesz, *supra* note 7, and Jason Schwartz, Inst. for Pol'y Integrity, *Enhancing the Social Benefits of Regulatory Review* 11–12 (2020), https://policyintegrity.org/files/publications/Enhancing_the_Social_Benefits_of_Regulatory_Review.pdf.

[189] *See* Jayni Hein, Inst. for Pol'y Integrity, *A New Way Forward on Climate Change and Energy Development for Public Lands and Waters* 12 (Sept. 2020) (proposing that Interior "identify renewable resource generation potential in areas that have experienced or are expected to experience a decline in fossil fuel production" and potentially prioritize those areas for such renewable development).

[190] Revesz, *supra* note 7, at 1573.

[191] *See Investing in Coal Communities, Workers, and Technology: The POWER+ Plan* 2–3 (2015), The President's Budget, https://obamawhitehouse.archives.gov/sites/default/files/omb/budget/fy2016/assets/fact_sheets/investing-in-coal-communities-workers-and-technology-the-power-plan.pdf.

[192] Revesz, *supra* note 7, at 1550.

[193] *Id.* at 1551.

[194] Exec. Order No. 14,008 § 218.

[195] *Id.* Membership in this interagency working group is comprised of the Secretaries of the Treasury, Interior, Agriculture, Commerce, Labor, Health and Human Services, Transportation, Energy, Education, the Administrator of the EPA, the Director of OMB, the Assistant to the President for Domestic Policy and the Director of the Domestic Policy Council, and the federal co-Chair of the Appalachian Regional Commission.

[196] Exec. Order No. 14,008 § 218.

[197] Interagency Working Group on Coal and Power Plan Communities and Economic Revitalization, *Initial Report to the President on Empowering Workers Through Revitalizing Energy Communities* (April 2021), https://netl.doe.gov/sites/default/files/2021-04/Initial%20Report%20on%20Energy%20Communities_Apr2021.pdf.

[198] Exec. Order No. 14,008 § 218 (B)(ii).

[199] *See* Revesz, *supra* note 7, at 1556–68 for a detailed argument for why the Office of the President is an appropriate conduit for these considerations.

[200] Exec. Order 14,008 § 209.

[201] *See* Revesz, *supra* note 7, at 1570–72 for a discussion of why OIRA is a suitable candidate to oversee federal government-wide distributional issues.

[202] *Id.*

[203] Exec. Order No. 14,008 § 220 (d),

[204] Schwartz, *supra* note 187.

[205] *Id.*

[206] *See* Exec. Order No. 14,008 § 203.

[207] Schwartz, *supra* note 187, at 12.

[208] *Id.*

[209] *Id.*

[210] *See* Horst Rittel & Melvin Webber, *Dilemmas in a General Theory of Planning*, 4 Pol'y. Sci. 155, 160–61 (1973).

[211] *See* Kreuter et al., *Understanding Wicked Problems: A Key to Advancing Environmental Health Promotion*, 31 Health Ed. Behavior 441, 443 tbl.1 (2004) (providing a breakdown of what makes a problem "wicked").

[212] *Id.*

[213] *Id.*

[214] *See* OECD, *Systemic Thinking for Policy Making – The Potential of Systems Analysis for Addressing Global Policy Challenges in the 21st Century* at 3 (Gabriela Ramo & William Hynes eds., 2019), https://www.oecd.org/naec/averting-systemic-collapse/SG-NAEC(2019)4_IIASA-OECD_Systems_Thinking_Report.pdf ("[O]ur established approaches to analysis and policy are heavily based on the Western scientific tradition of reductionism—where we separate complex realities into specialized disciplines, fields of research, agencies and ministries, each focused on a part of the overall truth. We are then confronted by the need to pull all these disparate views together in order to organize an effective policy response.").

[215] There are, of course, exceptions. For instance, EPA and NHTSA have jointly promulgated fuel-efficiency and greenhouse gas emission standards for motor vehicles in recent years.

[216] Ramo & Hynes, *supra* note 213, at 3.

[217] *See, e.g.,* Jeroen van der Heijen, *Systems Thinking and Regulatory Governance: A Review of the International Academic Literature* 15–16, (State of the Art in Regul. Governance Rsch. Paper 2020).

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The Social Cost of Greenhouse Gases

A Guide for State Officials

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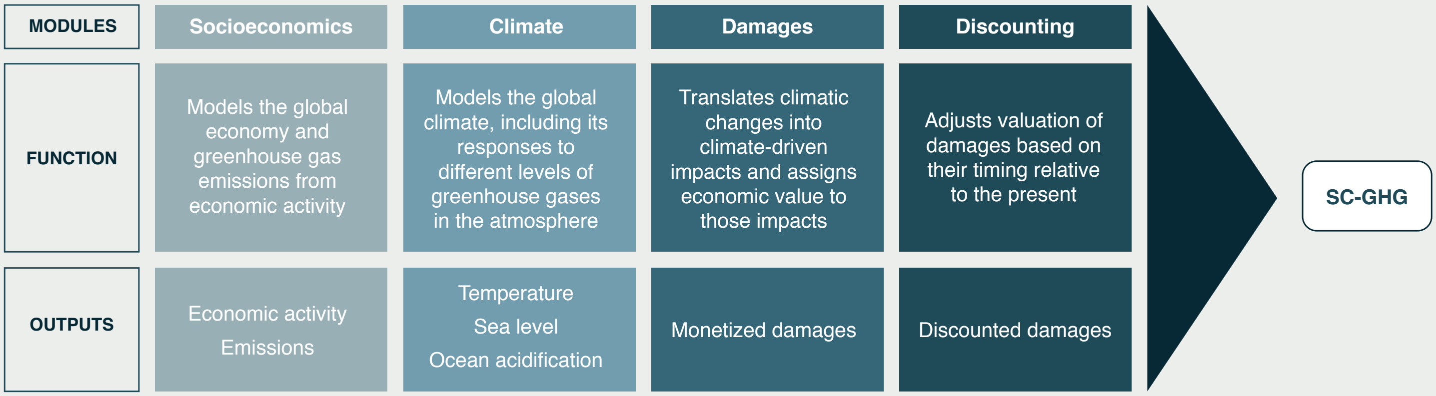
[1] The SC-GHG can also be used to determine the climate damages resulting from emissions of other greenhouse gases. *See infra* Section 2.3.

Figure ES-1. SC-GHG Components



MODULES	Socioeconomics	Climate	Damages	Discounting
FUNCTION	Models the global economy and greenhouse gas emissions from economic activity	Models the global climate, including its responses to different levels of greenhouse gases in the atmosphere	Translates climatic changes into climate-driven impacts and assigns economic value to those impacts	Adjusts valuation of damages based on their timing relative to the present
OUTPUTS	Economic activity Emissions	Temperature Sea level Ocean acidification	Monetized damages	Discounted damages

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.

Table of Contents

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)*	●	●								●				
	Electric Utility IRPs	●	●					●	●			●	●		●
	Gas Distribution System														
	Planning Info.		●												
	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).

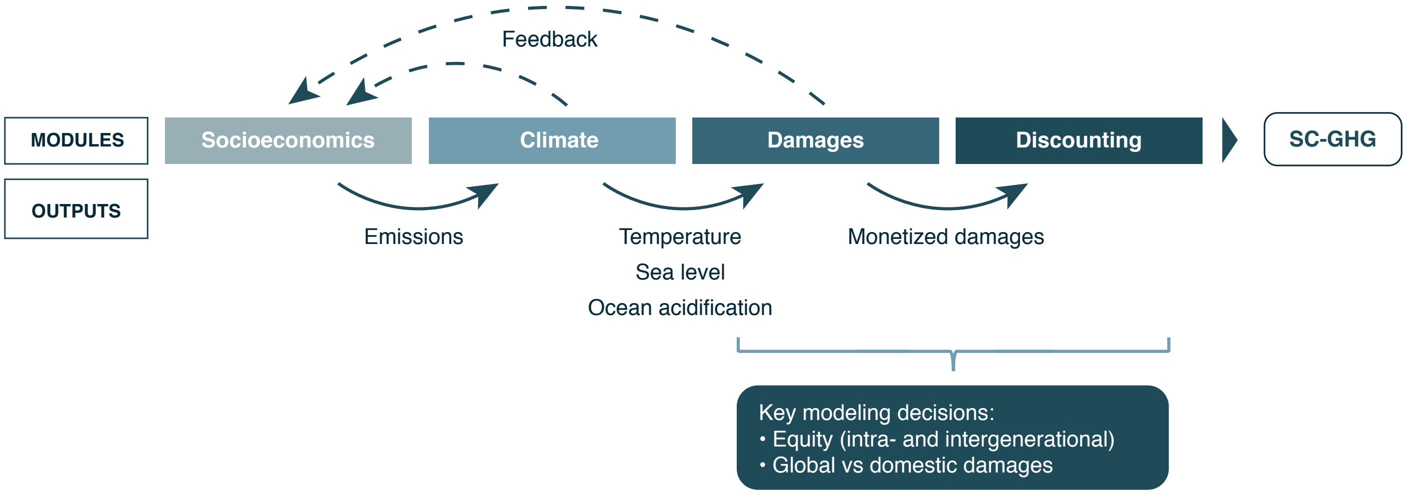
2. Key Concepts and Features

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]

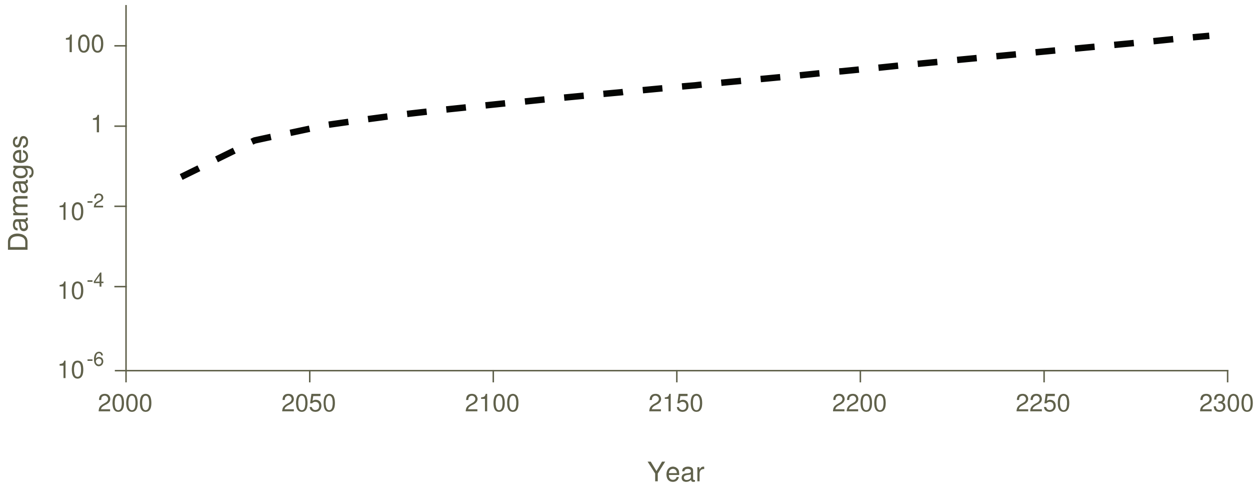
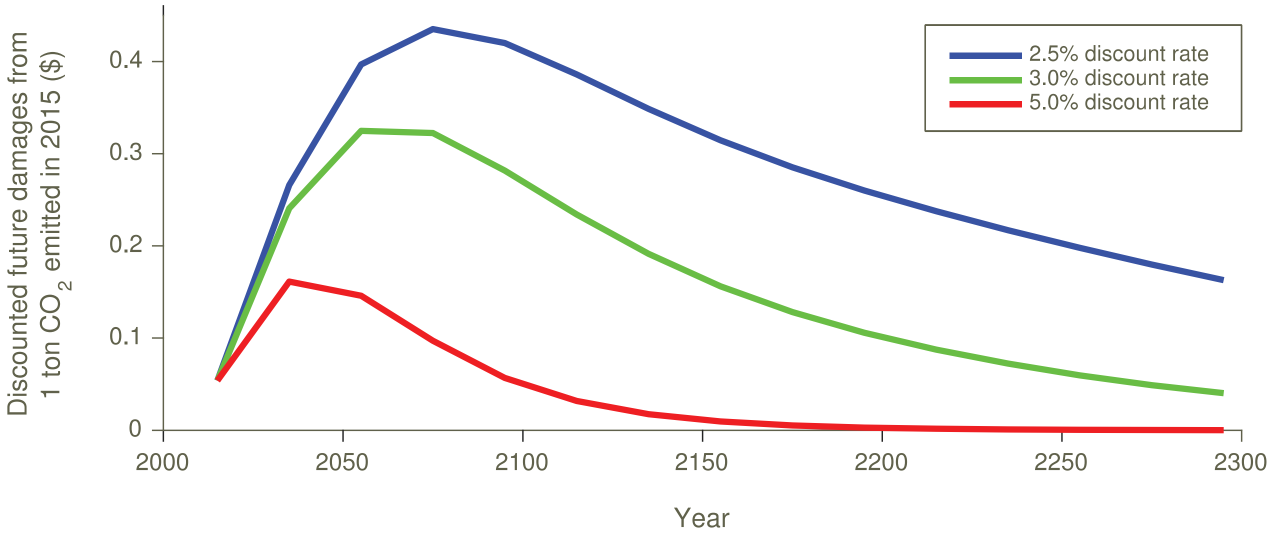


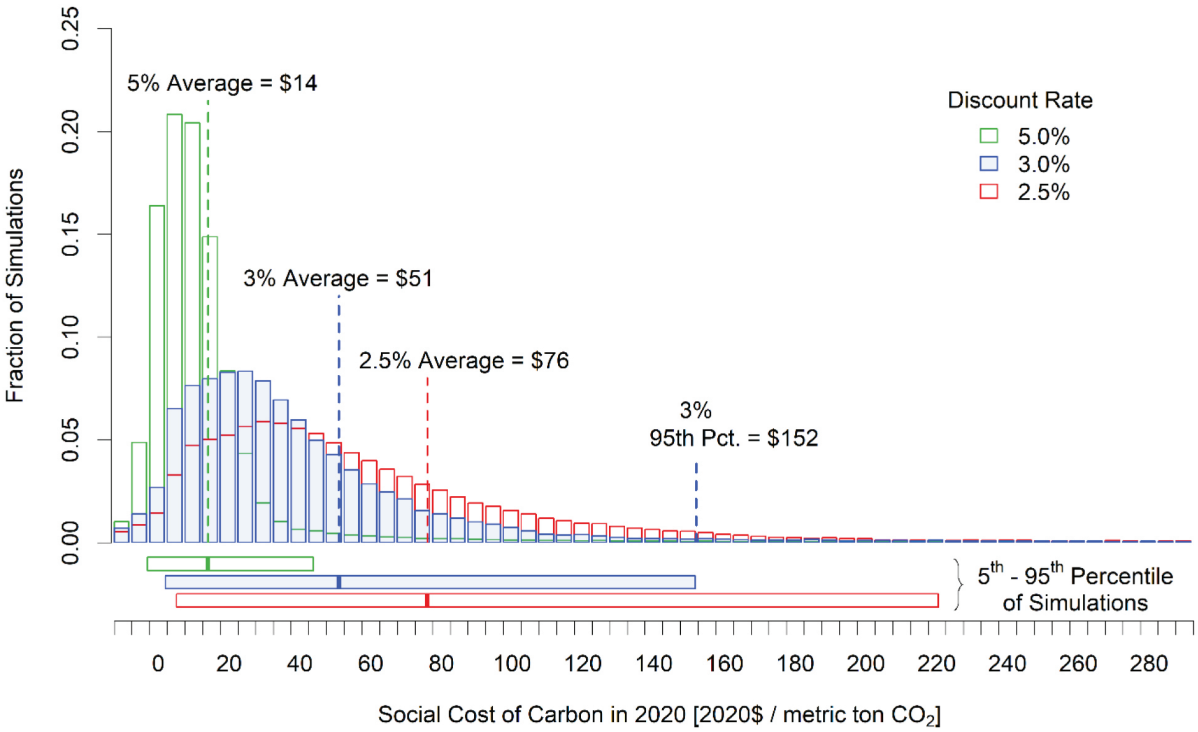
Figure 2-2. Annual Damages from Emissions of 1 Metric Ton of CO_2 Discounted Using Three Different Discount Rates.[58]



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.

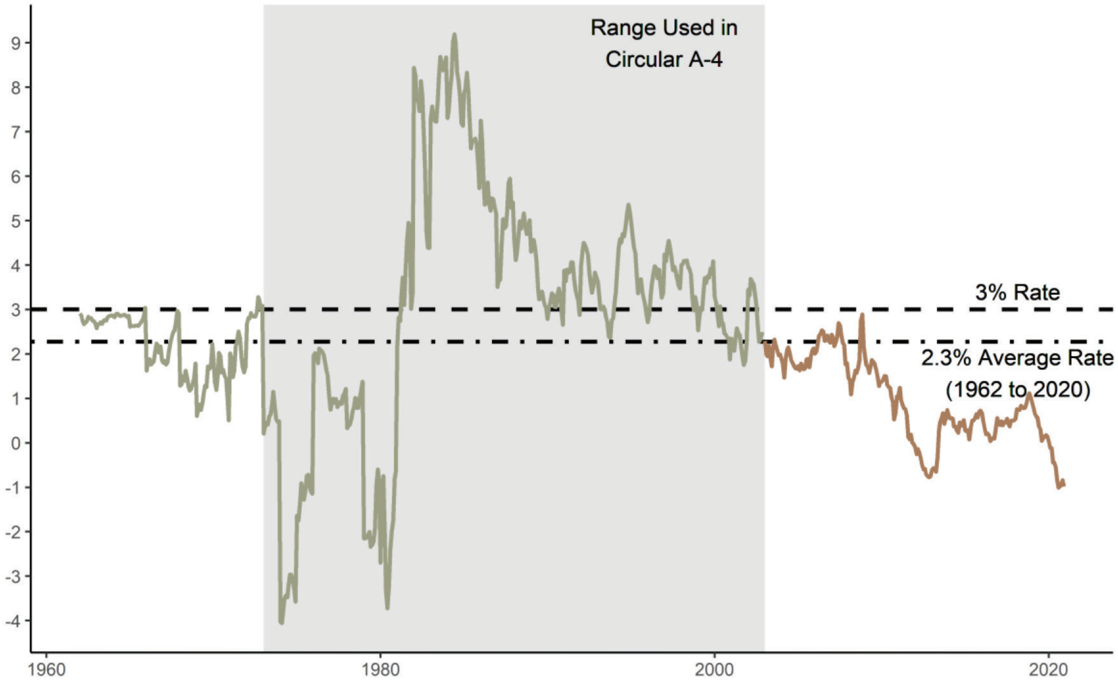
Inappropriately high discount rates. The Working Group recommends against using a 7% discount, which reflects the opportunity cost of capital,[68] to estimate the value of the SC-GHG.[69] It identifies several reasons for this recommendation, which are consistent with findings and recommendations of 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]

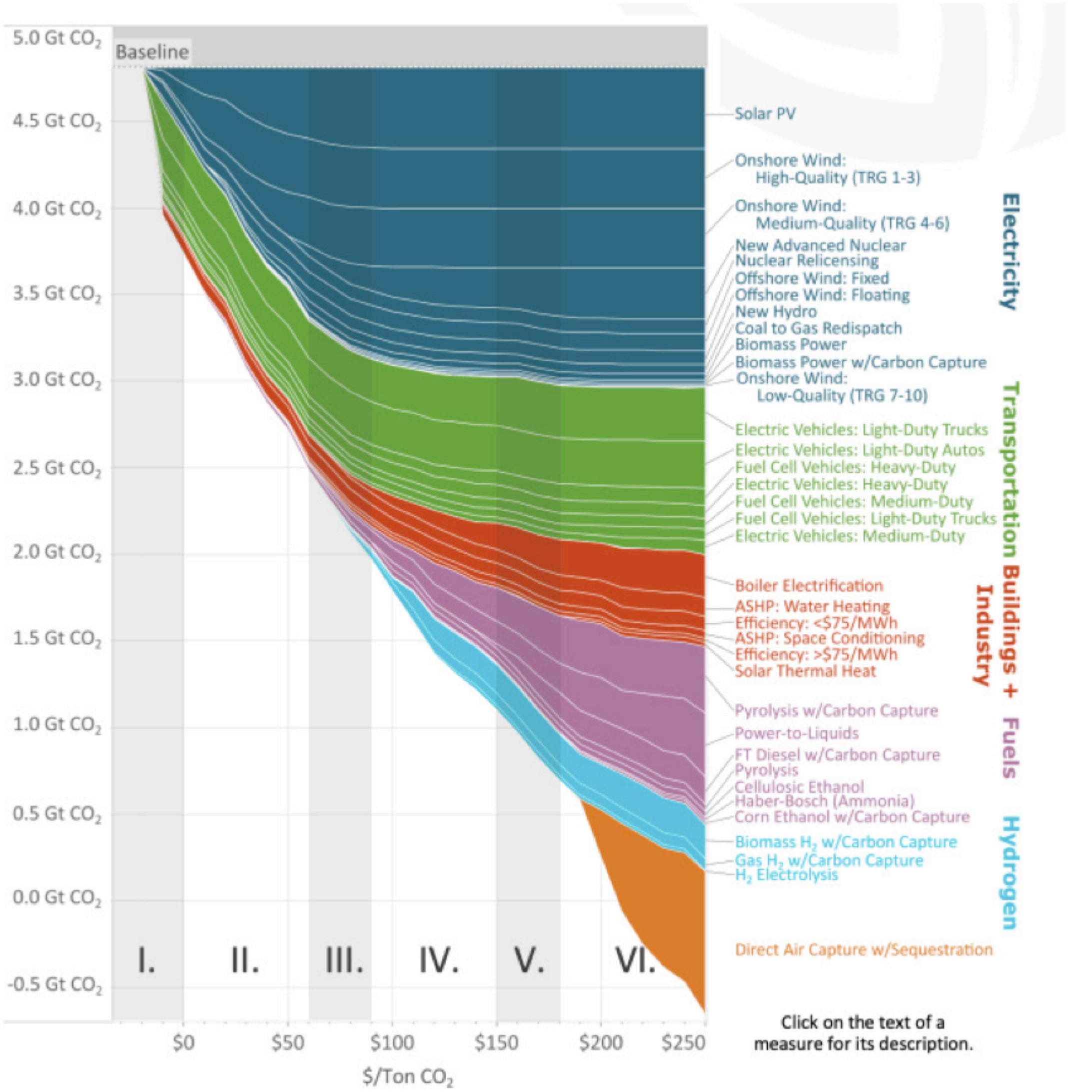
2.2.1. Marginal Abatement Cost Curves

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]

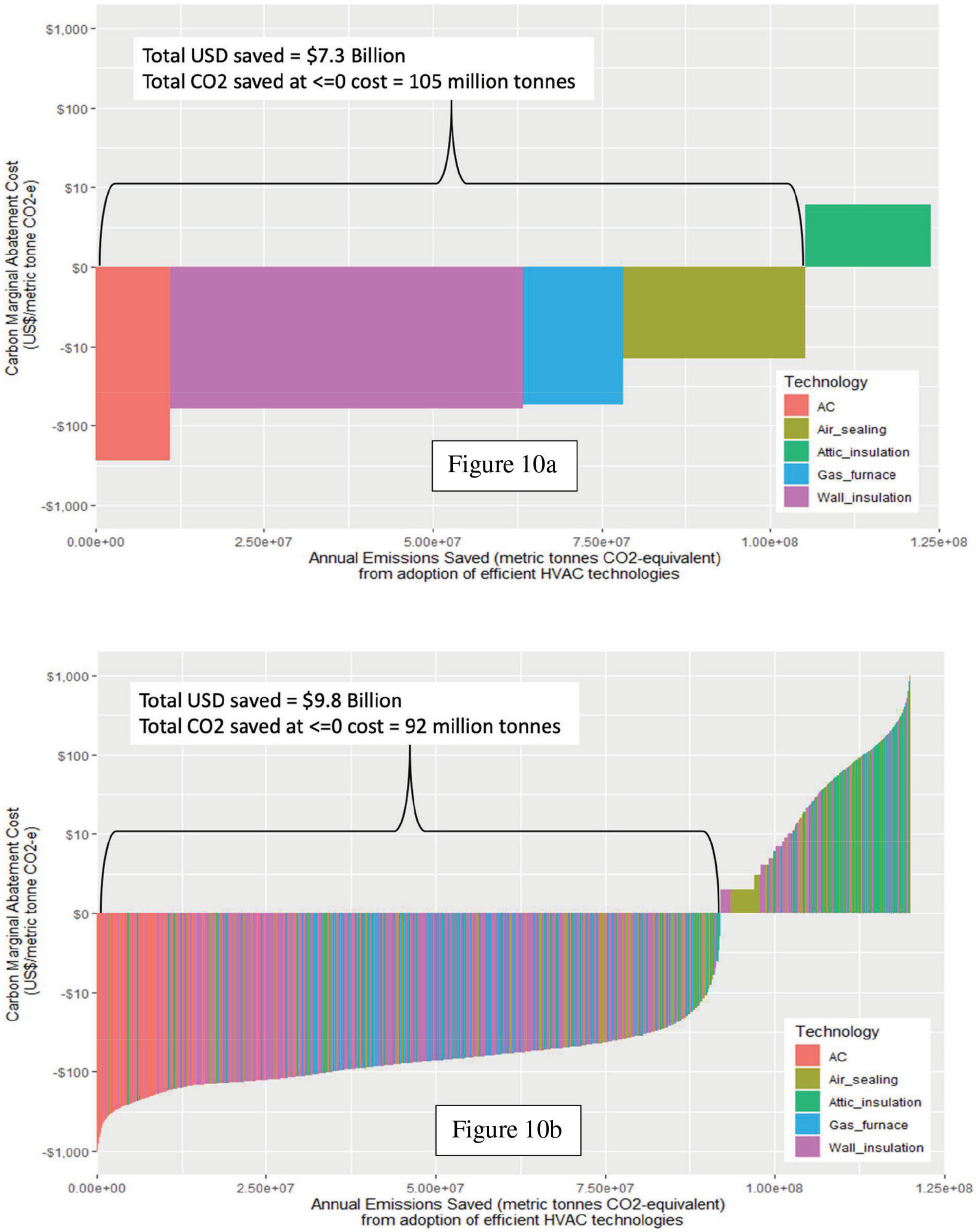
2.2.2. Using MAC Curves: An Example and a Caveat

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]

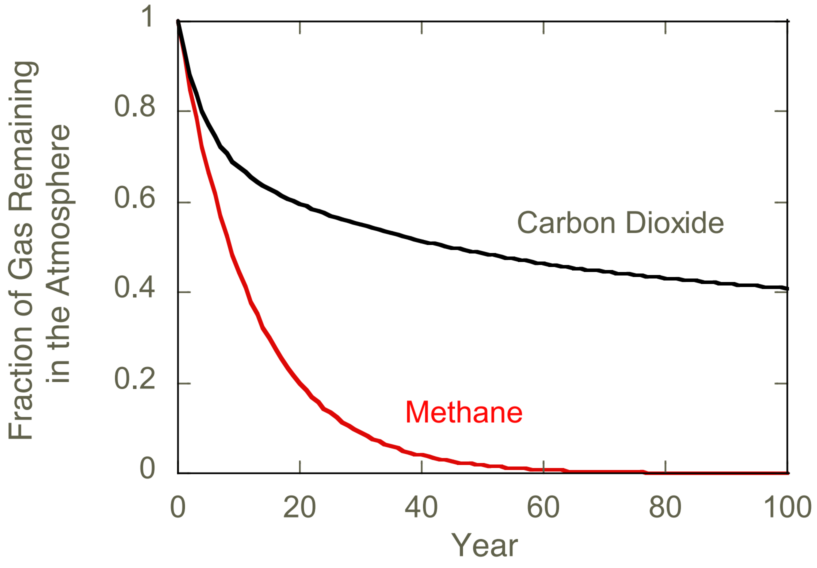
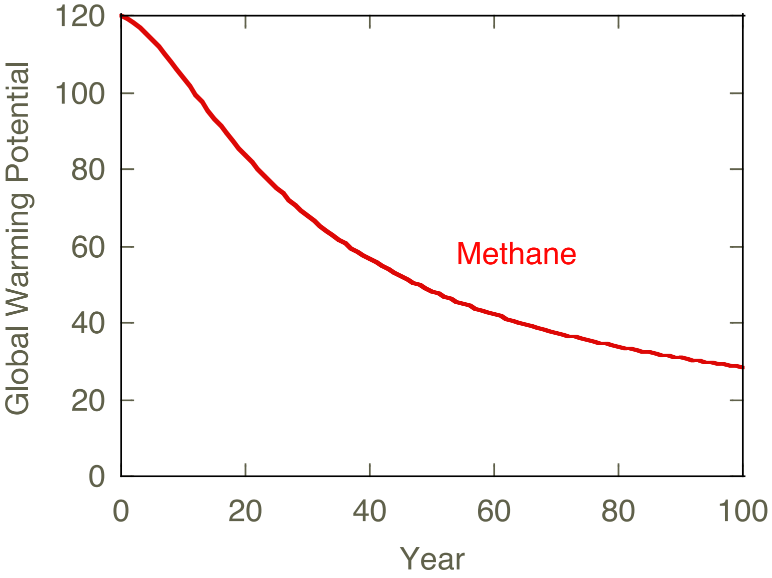


Figure 2-8. Global Warming Potential for Methane over Time; $GWP_{20yrs} = 84$, $GWP_{100yrs} = 28$.[122]



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_{13} + CC_{14}.

[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.
	Electric Utility IRPs	Colorado Pub. Utilities Comm'n	Inform electricity resource planning
	Gas Distribution System	New York Pub. Service Comm'n	Utilities' have developed Gas BCA Handbooks based on BCA Framework
	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)
	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 **Proposed Scenario SC-CH_4** **Proposed Scenario (Total)[b]**	2.2–9.7 0.49–1.3 2.7–11.0	2.0–7.9 0.85–2.0 2.8–9.9

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

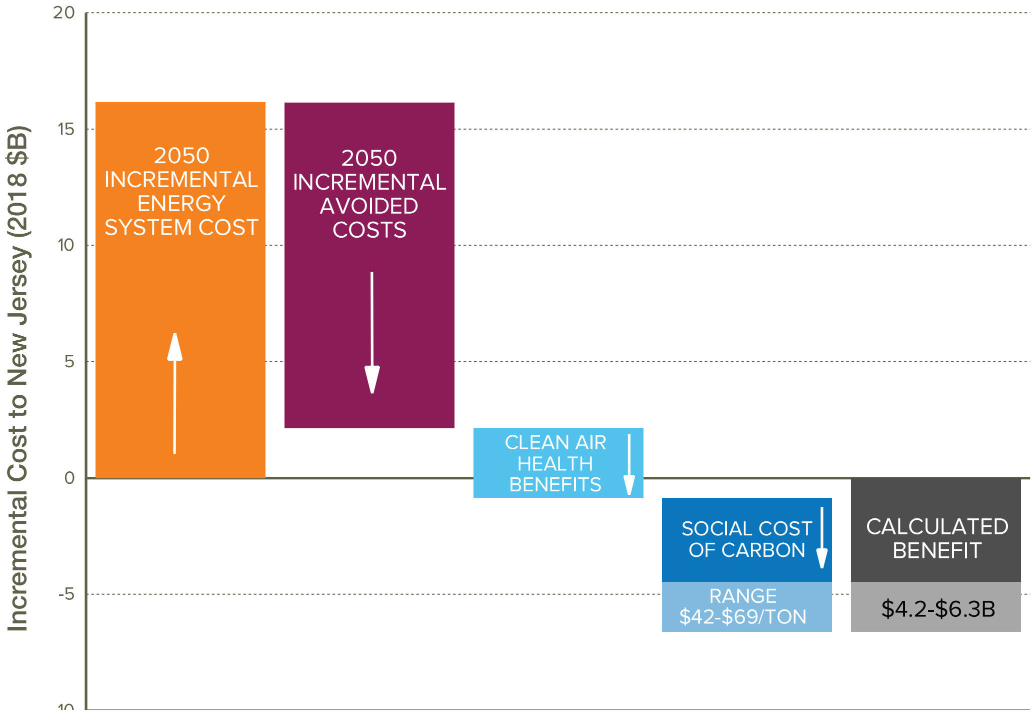
Table 4-6. Estimated Social Cost (Avoided Economic Damages) of Measures Considered in the Proposed Scenario (Natural and Working Lands)[47]

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.

[11] EPA, Guidelines for Preparing Economic Analysis, *supra* note 6, at 6-1, 6-11 to 6-17.

[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).

[13] *See, e.g.*, Antonio Colmenar-Santos, David Borge-Díez & Enrique Rosales-Asensio, Reconciliation of Social Discount Rate and Private Finance Initiative: Application to District Heating Networks in the EU-28, in District Heating and Cooling Networks in the European Union (2017) (describing programs that encounter the problem of different perspectives on discounting and must somehow specify subsidy levels on an internally consistent basis).

[14] Howard & Schwartz, *supra* note 7.

[15] *See* Energy Conservation Program: Energy Conservation Standards for Manufactured Housing, 86 Fed. Reg., 47,744 (Aug. 26, 2021).

[16] Dept't of Energy, Technical Support Document: Supplemental Notice of Proposed Rulemaking Proposing Energy Conservation Standards for Manufactured Housing, 13A-1 (2021), https://www.regulations.gov/document/EERE-2009-BT-BC-0021-0590.

[17] 86 Fed. Reg. 47,751 tbl. I.10

[18] *Id.* at iii.

[19] *Id.*

[20] 86 Fed. Reg., 47,751 tbl. I.10.

[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.

[22] *Id.*

[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).

[40] *E.g.*, Order Instituting Rulemaking, Cal. Pub. Utils. Comm'n R2001007 (Jan. 16, 2020); Order Initiating Investigation Into Retail Natural Gas for GHG Emissions, Colo. PUC Case No. 20M-0439G (Oct. 29, 2020); Vote and Order Opening Investigation, Mass. Dep't Pub. Utils. Case 20-80 (Oct. 29,. 2020); Order Instituting Proceeding, N.Y. Pub. Serv. Comm'n Case 20-G-0131 (Mar. 19, 2020).

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

[42] *See, e.g.*, ConEdison, Benefit Cost Analysis Handbook 1 (2018) (listing "categories of utility expenditure" to which the BCA Framework must be applied).

[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.").

[44] Cal. Air Res. Board., Draft 2022 Scoping Plan Update (May 10, 2022), https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf.

[45] *Id.* at 121-122 .

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

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

[48] *See generally id.*

[49] N.J. Bd. Pub. Utils. et al., New Jersey Energy Master Plan: Pathway to 2050, at 12–15 (2019).

[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).

[53] *See* Max Sarinsky et al., Inst. for Pol'y Integrity, Broadening the Use of the Social Cost of Greenhouse Gases in Federal Policy 26 (2021); Richard Revesz & Max Sarinksy, *The Social Cost of Greenhouse Gases: Legal, Economic, and Institutional Perspective* 25–26 Yale J. Regul. (forthcoming 2022), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3903498.

[54] Md. Code Ann. § 14-410(3).

[55] Cal. Pub. Cont. Code § 3500(1)(f).

[56] *Id.* § 10326.2(a)(4).

[57] Sarinsky et al., *supra* note 53, at 26; Revesz & Sarinsky, *supra* note 53, at 25–26.

[58] 48 C.F.R. § 2.101.

[59] Federal Acquisition Regulation: Minimizing the Risk of Climate Change in Federal Acquisitions, 87 Fed. Reg. 57,404 (Oct. 15, 2021).

[60] N.Y. Gen. Mun. Law § 104-b(1).

[61] N.Y. Exec. Order No. 4 § C (Apr. 24, 2008).

[62] Atlas Pub. Pol'y, Fleet Procurement Analysis Tool User Guide 3 (2021), https://atlaspolicy.com/wp-content/uploads/2021/04/Fleet-Procurement-Analysis-Tool-User-Guide.pdf.

[63] *Id.* at 3, 10.

[64] *Id.* at 10. The tool applies, by default, the SC-GHG based on a 3% discount rate, *id.* at 15, but that default setting can be adjusted to reflect a different discount rate for emissions. Atlas Pub. Pol'y, *Fleet Procurement Analysis Tool: Excel Tool with U.S. Market Defaults* (last visited Apr. 5, 2022), https://atlaspolicy.com/wp-content/uploads/2021/11/Fleet-Procurement-Analysis-Tool_v1.24.xlsm.

[65] *Id.*

[66] Charles Satterfield et al., Atlas Pub. Pol'y, Electrification Assessment of Public Vehicles in Washington 19 (2020), https://leg.wa.gov/JTC/Documents/Studies/Electrification/FinalReport_ElectrificationStudy_Nov2020.pdf.

[67] U.S. Postal Serv., National News: USPS Places Order for 50,000 Next Generation Delivery Vehicles; 10,019 to Be Electric, Mar. 24, 2022, https://bit.ly/3v4Enmz.

[68] U.S. Postal Service, Final Environmental Impact Statement: Next Generation Delivery Vehicle Acquisitions (Dec. 2021) [hereinafter "USPS FEIS"].

[69] The Postal Service also considers a 100% internal combustion engine fleet, but that is omitted for the sake of simplicity. *See id.* at 3-6.

[70] *See* Argonne National Laboratory, *GREET® Model*, https://greet.es.anl.gov/ (last visited Apr. 4, 2022).

[71] *See* U.S. EPA, *Emissions & Generation Resource Integrated Database (eGrid)*, https://www.epa.gov/egrid (last visited Apr. 4, 2022).

[72] *See* U.S. EPA, MOVES and Other Mobile Source Emissions Models, https://www.epa.gov/moves (last visited Apr. 4, 2022).

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

[74] *Id.* at 4-24 to 4-25.

[75] *Id.* at 4-28, 4-31.

[76] *Id.* at 4-23.

[77] *Id.* at 4-31 tbl 4-6.13.

[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).

[79] Colo. Exec. Order D 2022 016 (Apr. 2022)

[80] *Id.* § III(A)(2).

[81] *Id.* (citing Colo. Rev. Stat. § 40-3.2-106(4)).

[82] *See* Comments of the Attorneys General of the States of New York, Colorado, Connecticut, Delaware, Illinois, Maryland, Minnesota, New Jersey, North Carolina, Oregon, Vermont, and Wisconsin, the Commonwealth of Massachusetts, and the California Air Resources Board on the Office of Management and Budget's Notice of Availability and Request for Comment on Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates Under Executive Order 13,990, 86 Fed. Reg. 24,669 (May 7, 2021) at 7 (June 21, 2021); *see also* Cal. Dep't of Transp., Cal-B/C Parameter Guide Version 7.1, at 19–20 (Nov. 2019), https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/transportation-economics/cal-bc/cal-bc_parameter_guide_ada_final- a11y.pdf (citing Interagency Working Group on Social Cost of Carbon, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, May 2013, Revised July 2015).

[83] Cal. Dep't of Transp., *supra* note 82, at 19–20.

[84] U.S. Dep't of Transp., Benefit-Cost Analysis Guidance for Discretionary Grant Program 38 (rev. 2022), https://www.transportation.gov/sites/dot.gov/files/2022-03/Benefit%20Cost%20Analysis%20Guidance%202022%20%28Revised%29.pdf.

[85] *Id.*

[86] U.S. EPA, *Volkswagen Clean Air Act Civil Settlement*, https://www.epa.gov/enforcement/volkswagen-clean-air-act-civil-settlement (last visited Mar. 31, 2022) (linking to key documents and describing facts and process of the case).

[87] Sarinsky et al., *supra* note 53, at 19–20.

[88] 49 U.S.C. § 32912(c)(1)(A)(i).

[89] Sarinsky et al., *supra* note 53, at 21.

[90] *See* U.S. Gov't Accountability Off., Oil, Gas, and Coal Royalties: Raising Federal Rates Could Decrease Production on Federal Lands but Increase Federal Revenue, GAO-17-540, at 9 (2017) (listing royalties charged by each of the six states in which 90% of fossil fuel resource extraction from federal lands occurs).

[91] Cong. Research Serv., Federal Land Ownership: Overview and Data 1 (updated Feb. 21, 2020); see also Bureau of Ocean Energy Mgmt, *About BOEM: Fact Sheet 1–2* (updated Jan. 2021)

[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).

[95] U.S. Dep't of the Interior, Report on the Federal Oil and Gas Program 10 (Nov. 2021).

[96] *See id.* at 8.

[97] Brian C. Prest & James H. Stock, Res. For the Future Working Paper 21-08, *Climate Royalty Surcharges* 3 (rev. Jan 2022), https://media.rff.org/documents/Prest_Stock_2022_-_Climate_Royalty_Surcharges.pdf.

[98] *Id.*

[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).

[101] Sarinksy et al., *supra* note 53, at 22.

[102] Colo. Const. Art. IX, § 10.

[103] Nev. Rev. Stat. § 321.0005.

[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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