NEW YORK STATE | Department of Environmental Conservation

Establishing a Value of Carbon

GUIDELINES FOR USE BY STATE AGENCIES

Kathy Hochul, Governor | Amanda Lefton, Acting Commissioner

Record of Revision

Revision Date	Description of Changes
June 2021	For consistency with IWG interim estimates released in February 2021, estimates of the values for carbon dioxide, methane, and nitrous oxide are revised to reflect the usage of the annual GDP Implicit Price Deflator values in the U.S. Bureau of Economic Analysis' (BEA) NIPA Table 1.1.9.
June 2021	For consistency with the IWG approach, the values for methane and nitrous oxide have been rounded to two significant figures and a recalculation of estimates using the PAGE model to exclude a small number of model runs in which a climate discontinuity is triggered in the marginal run but not the baseline run, leading to spuriously high values.
October 2021	Correction of a typo in the Executive Summary stating the central value for the value of nitrous oxide was $142,000 per ton was changed to $42,000 per ton.
May 2022	Added values for hydrofluorocarbons (HFCs), updated text to describe these values, and provide an example. Updated the description of federal policy regarding global versus domestic SCC.
August 2023	Added values for an additional HFC (HFC-236fa) and sulfur hexafluoride (SF6), updated text to describe these values, and provided both formats used by the federal government (Tables 1-11 in this document and Tables A1-A11 in the Appendix.
April 2025	Revised values for all gases to reflect the average values of new models adopted by the EPA: DSCIM, GIVE, and a damage function based on a meta-analysis by Howard and Sterner (2017). A Ramsey discounting scheme has been applied to future damages, with initial discount rates starting at 2.5%, 2.0%, and 1.5%. Tables of values were moved to the Appendix.

Contents

Executive Summary

The Climate Leadership and Community Protection Act directed the Department of Environmental Conservation (the Department or DEC) to establish a value of carbon for use by State agencies. This guidance document provides a recommended procedure for using a damages-based value of carbon along with a general review of the marginal abatement cost approach. This guidance provides damages-based values as a tool to aid state agencies in the consideration of greenhouse gas emissions and climate change in their decision-making. In some decision-making contexts, particularly those that have a history of valuing carbon such as the New York electric industry, alternative approaches may be more appropriate for both resource valuation and benefit-cost analyses.

This guidance document is designed to provide accessible and practical assistance to State agencies and authorities for applying a damages-based value of carbon where it is useful and appropriate. It is not the intention of the Department that this guidance be interpreted as establishing a requirement on any public or private entity.

Where appropriate, the Department is recommending the use of the 2023 U.S. Environmental Protection Agency (2023 EPA) damages-based value of carbon[1], also referred to as the social cost of greenhouse gases (GHGs), for carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons (HFCs). These values are in 2020 dollars per metric ton of emissions (adjusted for inflation) at three near-term discount rates (2.5%, 2.0%, and 1.5%) that are then allowed to vary within the model as a function of the growth rate of per capita consumption (a Ramsey discount method). EPA, in collaboration with Resources for the Future (RFF) and the Climate Impact Lab (CIL), developed social cost estimates for 8 HFCs (HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-227ea, HFC-236fa, and HFC-245fa). Estimates for sulfur hexafluoride (SF_6) were made by the CIL and the Department using the 2023 EPA methodology and are provided in 2020 dollars per metric ton of emissions (adjusted for inflation). Recommendations are also provided for assessing other greenhouse gases and public health impacts.

[1] U.S. Environmental Protection Agency, *Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review" EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances* (2023) EPA-HQ-OAR-2021-0317.

EPA announced that it would reconsider its Social Cost of Carbon approach and inclusion of the social cost of carbon within its regulatory decision making factors. The Department will continue to utilize the approach outlined in this Value of Carbon Guidance and incorporate the most up to date science in its framework regardless of federal rollbacks.

For social cost estimates for emissions that will occur between the present and the year 2050, the Department specifically recommends that State entities provide an assessment using the approach to discounting in 2023 EPA, with a central value that is estimated using the 2.0 percent near-term discount rate as the primary value for decision-making, while also reporting estimates at 1.5 and 2.5 percent to provide a comprehensive analysis. State agencies should consider this range of discount rates to be consistent with the federal government's guidance on using a damages-based value of carbon. This range translates into a 2020 value of carbon dioxide of $117 - 337 per ton, with a central value of $193 per ton; a 2020 value of methane of $1,257 - 2,305 per ton, with a central value of $1,648 per ton; a value of nitrous oxide of $35,232 - 87,284 per ton, with a central value of $54,139 per ton. The Appendix to this document contains tables of the annual values estimated for these gases, several HFCs, and sulfur hexafluoride for the years 2020 through 2050. For the social cost of emissions that happen after the year 2050, please contact the Department for additional guidance on how to apply discount rates to estimate their net present value.

Various jurisdictions have used the damages-based value of carbon as part of cost benefit analyses, rulemaking processes, environmental assessment, and for demonstrating the benefits of climate change policies. These and other applications are reviewed along with simplified examples in this document. State agencies and authorities may apply this guidance in those contexts or identify additional applications for the Value of Carbon and develop additional guidance. DEC and NYSERDA staff are available to assist in addressing any technical or implementation questions related to this guidance or the Value of Carbon. Please contact the DEC Office of Climate Change at 518-402-8448 or climatechange@dec.ny.gov.

I. Purpose of this Guidance

The Climate Leadership and Community Protection Act, Chapter 106 of the Laws of 2019 (CLCPA) provides direction to all State entities regarding actions to address climate change. This guidance is intended to address the following directive, as added to the Environmental Conservation Law:

> *§ 75-0113. VALUE OF CARBON.*
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> *1. No later than one year after the effective date of this article, the Department, in consultation with the New York State Energy Research and Development Authority, shall establish a social cost of carbon for use by State agencies, expressed in terms of dollars per ton of carbon dioxide equivalent.*
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> *2. The social cost of carbon shall serve as a monetary estimate of the value of not emitting a ton of greenhouse gas emissions. As determined by the Department, the social cost of carbon may be based on marginal greenhouse gas abatement costs or on the global economic, environmental, and social impacts of emitting a marginal ton of greenhouse gas emissions into the atmosphere, utilizing a range of appropriate discount rates, including a rate of zero.*
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> *3. In developing the social cost of carbon, the Department shall consider prior or existing estimates of the social cost of carbon issued or adopted by the federal government, appropriate international bodies, or other appropriate and reputable scientific organizations.*

This guidance establishes a value of carbon based on an estimate of net damages incurred as a result of climate change, which also formed the basis of the U.S. federal government's "social cost of carbon."[2] This guidance also considers the types of State activities for which this approach may be best suited and discusses some key considerations.

State agencies may find the damages-based value of carbon provided in this guidance useful for describing the global value of policies, programs, or projects or for estimating global damages in an assessment of benefits and costs. However, other values of carbon may be established by the Department or other State entities for other purposes. In particular, the

[2] Interagency Working Group on Social Cost of Greenhouse Gases, U.S. Government, *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (2016).

marginal abatement cost has been used in some instances, including by New York State in the electric power sector, to aid in planning to meet discrete greenhouse gas reduction goals.

The guidance is broken down into seven parts, including this Part that describes the purpose. Part II lists definitions for terms used throughout this guidance. Part III describes the "value of carbon" concept in a broad sense and explains the differences between the two approaches referred to in the CLCPA: (i) the damages approach used to establish the federal social cost of carbon and the primary focus of this guidance; and (ii) the marginal abatement cost approach. Part IV provides additional details on the damages approach, how it was calculated by the federal government, and how it may be updated. Part V explains when a damages-based value of carbon could be used by State entities and reviews the key considerations that would need to be addressed. Part VI describes how the damages approach may be applied to all greenhouse gases that are subject to the CLCPA. Part VII provides example scenarios in which the greenhouse gas emissions associated with a project and a policy are evaluated using the damages-based value of carbon. A separate appendix to this document provides the estimates of the values of carbon dioxide, methane, nitrous oxide, several HFCs, and sulfur hexafluoride for the years 2020 through 2050 at 2.5%, 2.0%, and 1.5% near-term discount rates.

This guidance establishes a value of carbon that can be used by State entities to aid decision-making and used as a tool for the State to demonstrate the global societal value of actions to reduce greenhouse gas emissions. The Department recommends that a value of carbon be used as part of a full and transparent assessment of environmental, economic, and social impacts, wherever appropriate. This guidance does not impose a compliance obligation or fee on any entity; the imposition of any such new compliance obligation or fee on any entity would require separate State action.

II. Definitions

Discount Rate – a reduction (or "discount") in value each year as a future cost or benefit is adjusted for comparison with a current cost or benefit[3]; a higher rate places a higher value on the present. Previous iterations of the federal social cost of carbon used static discount rates whereas the 2023 EPA methods use dynamic or Ramsey discounting, which allows the starting, near-term discount rates to then vary with projected economic growth.

[3] National Academies of Sciences, Engineering, and Medicine, *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide* (National Academies Press, 2017) doi: 10.17226/24651.

Greenhouse Gas – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and any other substance emitted into the air that may be reasonably anticipated to cause or contribute to anthropogenic climate change.[4]

Marginal Greenhouse Gas Abatement Cost – a monetary estimate of the cost, usually in dollars per ton of carbon dioxide, associated with the last unit (the marginal cost) of emission abatement for varying amounts of greenhouse gas emissions reduction.[5]

Social Cost (of Carbon) – an estimate, in dollars, of the present discounted value of the future damage caused by a metric ton increase in emissions of a specific greenhouse gas into the atmosphere in that year or, equivalently, the benefits of reducing emissions of that gas by the same amount in that year. It is intended to provide a comprehensive measure of the net damages—that is, the monetized value of the net impacts—from global climate change that result from an additional ton of emissions.[6]

Value of Carbon – any representation of monetary cost applied to a unit of greenhouse gas emissions, expressed in terms of the net cost of societal damages (i.e., social cost of carbon), marginal greenhouse gas abatement cost, or using another approach.

III. What is a Value of Carbon?

A value of carbon is a monetary representation of the impact of a marginal change in greenhouse gas emissions. This value is usually expressed in terms of dollars per ton of a specific gas, such as carbon dioxide. Placing a value on greenhouse emissions can be a useful tool for policymaking and for decisions regarding proposed projects, as it allows the costs associated with emissions, and the benefits of avoided emissions, to be compared to other monetary values.

The CLCPA directed the Department to consider two approaches for establishing a value of carbon.[7] The first approach is based on the monetary cost of damages that would result from an

[4] Environmental Conservation Law § 75-0101(7).
[5] e.g., F. Kesicki and N. Strachan, "Marginal abatement cost (MAC) curves: confronting theory and practice," *Environmental Science and Policy* 14 (2011): 1195-1204, https://doi.org/10.1016/j.envsci.2011.08.004.
[6] National Academies, 2017, op. cit.
[7] There are additional ways to establish a monetary value for a ton of greenhouse gas emissions. For example, the Regional Greenhouse Gas Initiative, 6 NYCRR Part 242, establishes a market-based compliance cost on carbon dioxide emitted from certain power plants and the Public Service Commission

incremental increase in emissions as a result of climate change, commonly referred to as the social cost of carbon. The second approach, the marginal abatement cost, establishes a value of carbon with reference to a specific emissions reduction goal. In other words, what would be the cost to reduce, or *abate*, the last metric ton of emissions by the amount needed to meet a particular emissions target at least cost.

The Damages Approach and the Social Cost of Carbon

The damages approach provides a monetary estimate of the impacts on society from activities that are a source of greenhouse gas emissions. Greenhouse gas emissions are often described as a negative externality in the economy and as a market failure, as there are costs to society from such emissions that are not accounted for in market prices. A market may in turn allow greenhouse gas emissions to exceed socially optimal levels. A damages-based value of carbon puts the effects of climate change into economic terms to help decisionmakers understand the economic impacts of decisions that would increase or decrease emissions.

A damages-based value of carbon can be used on its own, such as an informational item, or compared to other monetary values in a cost-benefit analysis. The most common damage valuation in use in the U.S. is the federal government's "social cost of carbon" metric,[8, 9] which was first established in 2007 as an estimate of the global, net damages from an additional ton of carbon dioxide added to the atmosphere. The federal Interagency Working Group on the Social Cost of Greenhouse Gases (or "federal IWG") established this metric specifically for use in the cost-benefit analyses that are required as part of regulatory actions by the federal government. The federal government later established social cost values for methane, nitrous oxide, and certain HFCs for the same purposes. The Department has strongly supported the use of these metrics by federal agencies to more fully account for the benefits of reducing greenhouse gas emissions, particularly when measured as global damages.[10] The U.S. Government Accountability Office reviewed the history and status of the federal IWG metrics and the

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Clean Energy Standard, Case 15-E-0302, sets Tier 1 compliance costs based on the results of competitive solicitations for renewable energy generation projects. These costs could also be incorporated into the development of a marginal abatement cost.

[8] IWG, 2016, op. cit.

[9] U.S. EPA, 2017, op. cit.

[10] See e.g., Comments of the New York State Department of Environmental Conservation, 10-26-2018, *National Highway Traffic Safety Administration (NHTSA) Proposed Rule: The Safer Affordable Fuel-Efficient Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks*, NHTSA-2018-0067-11905.

prospects for future improvements.[11] Federal administrations have also appropriately suggested that these metrics could be used to inform environmental reviews.[12] This could be federal environmental reviews conducted under the National Environmental Policy Act, or state reviews conducted under state law analogs, such as the New York State Environmental Quality Review Act. U.S. States have also used the federal social cost of carbon as an informational item to accompany climate change planning documents.[13]

There is a large volume of literature describing the limitations of the federal social cost of carbon, which include the uncertainty inherent in predicting long-term economic, demographic, and climatic changes. Such limitations also include many of the issues that are common to environmental cost-benefit analyses, such as the difficulty in putting a monetary cost on non-monetary values, such as human health, and in selecting a discount rate. Approaches for addressing these issues are described later in this guidance.

The Marginal Abatement Cost Approach

An alternative approach to valuing carbon included in the CLCPA reflects the cost of a marginal reduction in emissions. Marginal abatement cost typically is derived from a “marginal abatement cost curve,” which can be generated either by plotting abatement measures along an increasing scale of cost per emission reduction or by using economic or energy models to evaluate the level of emissions reductions across an economy or a sector resulting from the imposition of a carbon price. The marginal abatement cost is the highest cost required to meet the emission reduction goal.

Whereas the damages approach is intended to establish a value of carbon for all sectors, marginal abatement costs are typically estimated for sector-specific technologies, markets, and emission reduction goals. That is, the marginal abatement approach requires an analysis of the relevant economic sector or sectors and policy options of interest for the relevant timeframe, which could result in multiple values of carbon that differ between economic sectors or policies.

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[11] Government Accountability Office, *Identifying a Federal Entity to Address the National Academies’ Recommendations Could Strengthen Regulatory Analysis* (2020) GAO-20-254.

[12] For example, in 2023 the Council on Environmental Quality issued interim guidance to assist federal agencies in their consideration of the effects of greenhouse gas emissions and climate change when evaluating proposed major federal actions, *National Environmental Policy Act Guidance on Consideration of Greenhouse Gas Emissions and Climate Change*, 88 Fed. Reg. 1196 (Jan. 9, 2023). See also *Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews*, 81 Fed. Reg. 51866 (Aug. 5, 2016).

[13] See e.g., California Air Resources Board, ”Appendix E Economic Analysis,” *2017 Climate Scoping Plan* (2017).

In New York State today, the electric power sector is best positioned to apply marginal abatement approaches, due to available cost information and its longer history of effective emissions reductions policies. In its review of the federal IWG social cost of carbon, the U.S. Government Accountability Office referred to the marginal abatement cost as a type of “target-consistent approach” to valuing emissions, which reflects the fact that this approach establishes a value that depends in part on the relevant emission reduction target.[14]

Many public and private entities have used marginal abatement cost curves to aid decision making. The federal government, for example, has used marginal abatement curves to describe policy options for reducing non-CO_2 gases.[15] Most notably, the marginal abatement cost approach has been used by some jurisdictions to guide climate change planning at the national level.[16] As in the case of the damages approach, the underlying assumptions can be highly uncertain. For example, marginal abatement costs are sensitive to rates of technological improvements and the costs of and potential for abatement, changes that may not be easily predicted. However, policymakers may regularly update and refine their estimate of marginal abatement costs to address these changes. In this way, the marginal abatement approach can be used along with other metrics in an adaptive planning process and adjusted as needed on a regular basis, for example as new and lower-cost technologies are made available.

General Recommendations for Establishing a Value of Carbon

For the purposes of this guidance, the Department is establishing a value of carbon for state agencies based on the damages approach. The rationale for utilizing a damages approach is three-fold. First, the damages approach provides a set of values that can be used by any State entity in a wide variety of contexts to describe the value of any emission reduction, without additional analysis. Secondly, the damages approach is already in use by the State’s counterparts in the federal government for similar types of decisions, such as in the development of regulations and the assessment of environmental impacts. Finally, the Department is not seeking to establish an economic cost, compliance cost, or fee on any entity through this guidance, which would require specific, targeted analyses of the relevant sectors. Instead, the purpose of this guidance is to provide information that can be readily applied by State entities when estimating the greenhouse gas reduction value of their actions.

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[14] GAO, op. cit.
[15] U.S. Environmental Protection Agency, *Global Non-CO_2 Greenhouse Gas Emission Projections and Mitigation Potential: 2015-2050* (2019).
[16] See examples for France and the United Kingdom described in GAO, op. cit.

With regard to the use of other approaches to the value of carbon, including the marginal abatement cost approach, the Department may provide additional guidance at a later date. In the interim, the Department provides the following general recommendations for applying any value of carbon:

- In applying a value of carbon, the Department recommends that the full scope of the emission sources that are subject to the CLCPA be considered whenever possible. For example, the CLCPA includes emissions outside of the state associated with imported fossil fuels and electricity.[17]
- Although the value of carbon is most frequently applied only to carbon dioxide, all relevant greenhouse gases should be assessed. No policy intended to reduce one greenhouse gas should unintentionally increase emissions of other greenhouse gases or result in the "leakage" of emission sources into other jurisdictions, if avoidable.
- The value of carbon should be considered as part of a full assessment of the impacts described within the CLCPA, including to disadvantaged communities, as well as to public health and the environment, per the State Environmental Quality Review Act.[18]
- Careful consideration should be applied when combining different values of carbon and applying the net total to the same marginal ton of emissions as they may represent contradictory or redundant valuations, such as a global damages estimate versus a market-based allowance price. If multiple approaches are used within a decision or planning context, the results should be treated as distinct pieces of information.

IV. Establishing a Damages-Based Value of Carbon

The values derived from the damages approach can be used to help understand the economic impacts of policies or projects that would result in a change in emissions. Policies or projects that would result in increased emissions would have economic costs, while policies or projects that reduce emissions result in economic benefits. When compared against other costs, such as the capital costs associated with a project, the damages-based value of carbon can help determine if a project or policy provides a net benefit or a net cost to the State.

There is extensive literature available that describes the damages-based approach, its uses, and key considerations. Informative documents include the 2023 EPA technical report[19], which

[17] ECL § 75-00101(13).
[18] See ECL Article 8, 6 NYCRR Part 617.
[19] U.S. EPA, 2023, op. cit.

contains an explanation of the methodology adopted in this guidance, as well as the following, which provide information on the precursor federal methodology: federal IWG technical support documents,[20, 21] the National Academies of Sciences 2016[22] and 2017[23] reviews and recommendations for future improvements, the 2020 review provided by the U.S. Government Accountability Office,[24] and the 2021 Regulatory Impact Analysis for phasing down HFCs by the U.S. Environmental Protection Agency.[25] In addition, work is ongoing from organizations such as Resources for the Future, the Climate Impact Lab, and New York University's Institute for Policy Integrity, among others.

The 2023 EPA approach[26] uses probabilistic socioeconomic and emissions projections developed by RFF,[27] an updated climate model,[28, 29] and a sea level model,[30] to translate a marginal increase in emissions into economic impacts. It includes both market and non-market (e.g., mortality) damages. Considerations when applying the damages approach include selection of the geographic scope, timeframe, and the value of the discount rate used to translate future costs to common present values.

At this time, the Department recommends that State entities apply the methods that the 2023 EPA used to establish the social costs of greenhouse gases.[31] Further guidance is provided

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[20] IWG, 2016, op. cit.
[21] Interagency Working Group on Social Cost of Greenhouse Gases, U.S. Government, *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990* (2021).
[22] National Academies of Sciences, Engineering, and Medicine, *Assessment of Approaches to Updating the Social Cost of Carbon: Phase 1 Report on a Near Term Update* (National Academies Press, 2016) doi:10.17226/21898.
[23] National Academies, 2017, op. cit.
[24] GAO, op. cit.
[25] U.S. Environmental Protection Agency, *Regulatory Impact Analysis for Phasing Down Production and Consumption of Hydrofluorocarbons (HFCs). Establishing the Allowance Allocation and Trading Program under the American Innovation and Manufacturing Act* (2021) EPA-HQ-OAR-2021-0044-0227.
[26] U.S. EPA, 2023, op. cit.
[27] Kevin Rennert et al., "Comprehensive evidence implies a higher social cost of CO_2," *Nature* 610 (2022): 687-692, https://doi.org/10.1038/s41586-022-05224-9.
[28] Richard Millar et al., "A modified impulse-response representation of the global near-surface air temperature and atmospheric concentration response to carbon dioxide emissions," *Atmospheric Chem. Phys.* 17 (2017): 7213-7228, https://doi.org/10.5194/acp-17-7213-2017.
[29] P.T. Forster et al., "The Earth's energy budget, climate feedbacks, and climate sensitivity," 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* Ch. 7 (2021) doi: 10.1017/9781009157896.009.
[30] T.E. Wong et al., "BRICK v0.2, a simple, accessible, and transparent model framework for climate and regional sea-level projections," *Geosci. Model Dev.* 10 (2017): 2741-2760, https://doi.org/10.5194/gmd-10-2741-2017.
[31] U.S. EPA, 2023, op. cit.

later in this document as to how State entities may approach these considerations in their own processes and how a comparable metric may be established for the other greenhouse gases that are listed in the CLCPA.

The Federal Social Cost of Carbon

The previous federal IWG[32] method applied the damages approach in order to establish social cost of carbon values that would be used by federal agencies in cost-benefit analyses. The 2023 EPA methods adopt the 2017 National Academies of Sciences, Engineering and Medicine recommendations for improving the IWG methods. Four key considerations are described below: model selection, geographic scope, timeframe, and discount rate.

Model Selection: The 2023 EPA values average the output of three different models: the Global Impact Value Estimator (GIVE),[33] the Data-driven Spatial Climate Impact Model (DSCIM),[34] and a meta-analysis of global climate damage estimates.[35] The models consider changes in net agricultural productivity, property damage from increased flooding, human health, energy systems costs, and other aspects of the economy, in order to provide a comprehensive estimate of impacts from climate change.

Geographic Scope: Under the CLCPA, New York State is required to consider global damages rather than only domestic or state-based damages.[36] Furthermore, the global cost is the most appropriate value to use due to the global nature of climate change and the economy. Greenhouse gas emissions have an effect on climatic changes worldwide, regardless of where the source of emissions is located. Emissions in New York State will cause damages outside the State and emissions from other jurisdictions will contribute to the damages experienced in New York State.

Timeframe: The 2023 EPA social costs of GHGs estimate damages through 2300 to represent long-term damages, but there is substantial uncertainty when forecasting future damages. For example, some portion of carbon dioxide emissions will persist in the atmosphere for more than a century. As such, the resulting damages must be modeled over that entire period. However,

[32] Initially the Interagency Working Group on the Social Cost of Carbon, later renamed the Interagency Working Group on the Social Cost of Greenhouse Gases.
[33] Rennert et al., op. cit.
[34] Ashwin Rode et al., "Estimating a social cost of carbon for global energy consumption," *Nature* 598 (2021): 308-314, https://doi.org/10.1038/s41586-021-03883-8.
[35] P. Howard and T. Sterner, "Few and not so far between: a meta-analysis of climate damage estimates," *Environ. Resource Econ.* 68 (2017): 197-225, https://doi.org/10.1007/s10640-017-0166-z.
[36] ECL § 75-0113(2).

climate change affects every aspect of the environment, and the uncertainty in predicting those effects will increase as projections extend further into the future. Furthermore, each greenhouse gas has a different atmospheric lifetime, and some are much shorter or much longer in duration than carbon dioxide. Methane, due to its role as an ozone precursor, is also associated with both climate impacts and impacts to public health that may occur over different timeframes.

Discount Rate: Discounting is a common and useful aspect of economic analyses that allows for the balancing of present versus future value, and it has been widely discussed in the literature, particularly in its application to the federal social cost of carbon. Selecting a particular fixed discount rate has a large effect on the estimate of the value of carbon, and there is no consensus or uniform scientific basis for the selection of a discount rate. In its consideration of fixed discount rates, the federal IWG compared a descriptive approach to establishing public preferences, based on observations of consumer behavior, to a normative approach, based on a consideration of the social or ethical implications of discounting damages to future generations.[37] The federal IWG's approach to discounting was primarily based on observations of consumer behavior, as measured through market rates of return. It applied a social discount rate, which reflects the rate at which society as a whole is willing to trade off a value received at one point in time (e.g., today) with a value received at another point in time (e.g., the future). Replacing fixed discount rates with dynamic or Ramsey discounting was one of the main recommendations made by the National Academies of Sciences, Engineering and Medicine in 2017 and adopted in the 2023 EPA methods. The Ramsey discount rates used by EPA and in this guidance start at a near-term value (e.g., 1.5%, 2.0%, or 2.5%) and then vary through time in the model depending on how modeled per capita consumption evolves. These dynamic discount rates are tied to economic growth such that future damages will be discounted less when the modeled consumption growth rate is lower.

Value of Carbon Estimates

The Appendix to this document provides tables with the Social Cost of Greenhouse Gas values for carbon dioxide, methane, nitrous oxide, several HFCs, and sulfur hexafluoride for the years 2020 through 2050 based on the 2023 EPA methodology. The output of individual models for each gas will also be made available online through Open Data NY (data.ny.gov).

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[37] As reviewed in the National Academies reports, op. cit., and IWG "Discount Rate," *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866* (2010) page 18.

V. Guidelines for Applying a Damages-Based Value of Carbon

When Do These Guidelines Apply?

The purpose of this guidance is to aid State entities in decision making by establishing a monetary value of greenhouse gas emission reductions or increases that reflects global societal impacts. This guidance does not itself establish a price or fee for emissions, and the value of carbon presented here is not the only value that may be used by the State. Alternative methods for establishing a value of carbon may be used by State entities, including the Department, as needed to achieve the goals and requirements of the CLCPA as well as other State goals, such as to protect public safety, welfare, and the environment.

The damages approach to establishing a value of carbon may be best suited to the following types of actions:

- Cost-Benefit Analysis, such as may be used to evaluate alternatives as a part of rulemakings or environmental assessments
- Describing the societal benefits of strategic plans, programs, or policies that will reduce greenhouse gas emissions
- Evaluating other types of decisions, such as those regarding State procurements, contracts, grants, or permitting

Recommended Procedure

The Department recommends that State entities apply the 2023 EPA methods when utilizing a damages-based approach to valuing greenhouse gas emissions, along with the recommended steps below.

1. Estimate the emissions for all relevant greenhouse gases.

Carbon dioxide is the greenhouse gas that has had the greatest impact on global climate change. However, it is important to address all greenhouse gases to mitigate climate change. The scope of the CLCPA encompasses carbon dioxide and other major greenhouse gases,[38] other substances that affect climate change, the co-pollutants that are typically associated with greenhouse gas emission sources, as well as the “leakage” of greenhouse gases into other jurisdictions. This guidance is intended to aid in the use of a value of carbon using the damages

[38] See definition of greenhouse gas in ECL 75-0101, which includes additional substances.

approach. State entities may require additional assessments when evaluating actions to meet the requirements of the CLCPA.

A first step in determining the impacts of a given decision will be to determine which of the major greenhouse gases are likely to be associated with or affected by the project, policy, or program in question and then to estimate the emissions of those gases for each year (Table 1). This may already be determined as part of other requirements, e.g., for permits or environmental assessments, or may be informed by other available guidance.[39] A review of all available data and methods for estimating greenhouse gas emissions would be beyond the scope of this document. However, State entities can consult with the Department and NYSERDA to locate additional resources, as needed.

Table 1: Examples of Greenhouse Gas Emission Sources

Greenhouse gas	Examples of primary sources
Carbon dioxide	Fossil fuels, Land management
Methane	Fossil fuels, Land management, Waste, Livestock
Nitrous oxide	Fossil fuels, Soil management, Wastewater
Hydrofluorocarbons (HFCs) and Hydrofluoroolefins (HFOs)	Substitutes for Ozone-Depleting Substances; Refrigeration, Heating and Cooling, Manufacturing
Perfluorocarbons (PFCs)	Manufacturing
Sulfur hexafluoride	Electricity transmission and distribution, Manufacturing
Nitrogen trifluoride	Manufacturing, Research

2. Consider the fullest geographic scope of damages.

The CLCPA directs the Department to establish a value of carbon that considers global damages, which would best protect the public and the environment. As such, the Department recommends that the State use the global estimation of damages included in the 2023 EPA methods.

3. Apply the most up-to-date, peer-reviewed information available.

The 2023 USEPA social cost of carbon was established using the best available models and information available at the time, but regular updates will be needed to improve the estimation of global damages and to integrate up-to-date information on atmospheric greenhouse gas concentrations along with economic, demographic and other parameters. The 2023 EPA methods address recommendations of the National Academies of Sciences, Engineering and

[39] New York State Department of Environmental Conservation. 2009. DEC Policy: Assessing Energy Use and Greenhouse Gas Emissions in Environmental Impact Statements. https://dec.ny.gov/regulations.

Medicine for updating and improving the federal IWG's values[40] and multiple research teams are actively working to address these recommendations and to make additional improvements to the relevant science. The Department recommends that State entities stay apprised of new updates and apply the most up-to-date values available. To support this objective, the Department will synthesize and provide updated values as appropriate, including through updates to the Appendix document.

4. Apply an appropriate discount rate.

Importantly, because the damages-based value of carbon described here is not intended to levy an actual cost or fee on any entity, the selection of the near-term discount rate should not be interpreted as having an actual, direct cost to the public. Since the damages-based value of carbon is used primarily for societal decision making, the correct discount rate reflects the rate(s) at which society as a whole is willing to trade off a value received today with a value received at any point in the future. As has been the case with the use of the social cost of carbon by federal agencies, the range of values produced by the different near-term discount rates can be used to describe the potential impacts of global climate change and to compare this alongside other economic and environmental costs and benefits.

The CLCPA requires the Department to consider "a range of appropriate discount rates, including a rate of zero" when establishing a value of carbon.[41] The Department issued the initial Value of Carbon Guidance based on the best available approaches at the time. Based on the initial and recent assessment of the literature and consultation with State partners and stakeholders, the Department recommends that State entities present the damages-based value of carbon using the range of estimates produced by the near-term discount rates from 1.5 to 2.5 percent, with a central value that is estimated at the 2.0 percent discount rate, to ensure that State agencies are properly informed in their decision-making.

The Department recommends the use of a central discount rate to establish a central value of the potential impacts from the marginal increase in emissions. This central rate should be used as the primary value for decision-making purposes. Using a near-term discount rate of no more than 2.0 percent to establish a central value is recommended for three reasons.

First, although higher discount rates may be appropriate for guiding the long-term investment of private funds, they are less appropriate for decisions regarding public safety and welfare,

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[40] National Academies, 2017, op. cit.
[41] ECL § 75-0113(2).

particularly when considering the scope and scale of the impacts to the public from global climate change.

Second, multiple lines of research have concluded that the static discount rates originally used by the federal IWG underestimate the value of avoided damages from greenhouse gas emissions. Experts now generally consider a lower range to be more acceptable.[42] In alignment with the 2023 EPA methods, the near-term discount rates presented in Appendix A are 1.5, 2.0, and 2.5 percent, a range that is still centered at 2 percent but includes a narrower range than previous iterations of this guidance, which provided values at static discount rates of 1, 2, and 3 percent. A lower discount rate may help address the underestimation of the potential damages from climate change. Although the updated models attempt to capture the impacts of large-scale singular events or irreversible climatic tipping points, they are difficult to monetize. Using a lower discount rate can accommodate the difficulty in capturing these outcomes.

Finally, the Department is not recommending that a discount rate of zero be applied to the damages-based estimate that is provided here. Consistent with the requirements of the CLCPA a rate of zero is among the range of discount rates considered as part of developing this guidance document. A discount rate of zero treats present value and future value equally and assumes that the public has no preference regarding value over time periods or based on the relative wealth of a society, which may not be valid. As reviewed by the National Academies of Sciences, Engineering and Medicine, Ramsey or dynamic discounting has been adopted in the 2023 EPA methods and by the Department to help address the uncertainty associated with discounting, future economic growth, and climate change damages.[43]

Reporting a range of values may be appropriate, including estimates at a lower near-term discount rate of 1.5 percent, as this recognizes that the public may have differing preferences and acknowledges that there is no one correct value. Federal agencies have reported the social costs using multiple rates.[44] An additional benefit of considering multiple rates is that the impact of the discount rate is made apparent and a wider range of potential benefits may be considered.

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[42] Moritz A. Drupp et al., "Discounting disentangled," *American Economic Journal: Economic Policy* 10, no. 4 (2018): 109-134 and M.D. Bauer and G.D. Rudebusch, "The Rising Cost of Climate Change: Evidence from the Bond Market," *Federal Reserved Bank of San Francisco Working Paper Series* (2020).
[43] National Academies, 2017, op. cit.
[44] See e.g., Greenhouse Gas Emissions and Fuel Efficiency Standards: Medium- and Heavy-Duty Engines and Vehicles; Phase 2, 81 Fed. Reg. 73,478, 73,876 (Oct. 25, 2016).

VI. Guidelines for Assessing Multiple Greenhouse Gases

The CLCPA emission reduction requirements cover seven types of greenhouse gases that are commonly included in international climate policy: carbon dioxide, methane, nitrous oxide, HFCs, PFCs, sulfur hexafluoride, and nitrogen trifluoride.[45] The EPA has estimated the values of carbon dioxide, methane, nitrous oxide, and several HFCs, and provided the means to estimate the value of sulfur hexafluoride. However, all greenhouse gases, including other HFCs, PFCs and synthetic gases of emerging importance like hydrofluoroolefins (HFOs), are relevant to planning and State decision-making under the CLCPA. In some cases, policies and projects that would reduce the emissions of one gas may lead to increases in other emissions. These types of interactions should be anticipated and, where possible, assessed using a comparable level of assessment. The damages-based approach may assist State entities in evaluating conflicts and potential tradeoffs.

Establishing a value of carbon for different greenhouse gases is complicated by two factors: (i) each gas affects climate change differently; and (ii) some gases are associated with additional impacts unrelated to climate change (e.g., local human health impacts). All greenhouse gases included in the CLCPA are well-mixed gases that contribute to atmospheric warming. However, methane and most HFCs have shorter atmospheric lifetimes than carbon dioxide, sulfur hexafluoride, or nitrous oxide. As such, the long-term damages associated with the climate impacts of these different greenhouse gases should be expected to vary. Besides impacts caused by climate change, carbon dioxide and methane emissions may also be associated with other impacts, such as changes in agricultural productivity or local impacts on air quality and human health.

Recommended Approach

Following the 2023 EPA methods, the updated models have been used to develop social cost estimates for carbon dioxide, methane, nitrous oxide, several HFCs, and sulfur hexafluoride. These values are available in the social cost tables in the Appendix to this guidance. The same methods can be applied to other well-mixed GHGs including the synthetic greenhouse gases. This guidance may be updated as evaluations of the social costs of these and other greenhouse gases are completed. Work is also underway to understand the social costs of the hydrofluoroolefins (HFOs) that are potential replacements for HFCs in some applications.

[45] 6 NYCRR Part 496 per ECL § 75-0101(7).

Establish a value for each greenhouse gas using best available information.

The Department recommends that, where appropriate, State entities use the 2023 EPA social cost estimates for each GHG following the guidelines provided in Part VI. Each of these estimates represents a gas-specific, but comparable, assessment of the value of a marginal ton of these greenhouse gases in terms of global damages related to climate change.

In September 2021, the EPA released the “Regulatory Impact Analysis for Phasing Down Production and Consumption of Hydrofluorocarbons (HFCs)” that includes estimates of the social costs of different HFCs.[46] Estimates for these gases were then updated by the EPA by incorporating them into the GIVE, DSCIM, and meta-analysis models[47] and are provided in the updated Appendix of this guidance document.

Certain gases such as sulfur hexafluoride and HFC-236fa are very long-lived compared to the year 2300 cut-off in the time horizon addressed by the models. HFC-236fa has an atmospheric lifetime of 213 years and sulfur hexafluoride’s is 1,000 years. Since the models do not capture the impact of the marginal damages that occur after the year 2300, only a portion of the damages caused by these long-lived pollutants can be estimated using this approach. For example, a pulse emission of sulfur hexafluoride that occurred in 2020 will maintain a tail of elevated concentration that extends far into the future such that 75% of the emission pulse (in ppb-years) will occur after the year 2300 and only 25% can be captured during the period that is assessed by the models (2020-2300).

For the greenhouse gases not included in this guidance, the Department considers the peer-reviewed scientific literature to be the best source of information. In some cases, there may be an estimation of damages for specific gases that may be useful even if the underlying methods are not identical to the federal methods. For example, Shindell et al. (2015[48]) provided an estimation of damages from multiple pollutants based on one of the federal IWG damage models. This includes values for pollutants that were not named in the CLCPA that may be of interest, such as black carbon. When work on these additional gases is comparable to the 2023 EPA methods, the Department may supplement this guidance with additional information that will help State entities apply new research.

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[46] HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, HFC-236fa, HFC-245fa, and HFC-43-10mee. U.S. EPA, 2021, op. cit.

[47] U.S. Environmental Protection Agency, ”The Social Cost of Hydrofluorocarbons,“ accessed 01-27-2025, https://github.com/USEPA/schfc.

[48] Drew T. Shindell, ”The social cost of atmospheric release,” *Climatic Change* 130 (2015): 313-326, https://doi.org/10.1007/s10584-015-1343-0.

The method that has been widely discussed in the literature is to adjust the federal social cost of carbon values using carbon dioxide-equivalence, as determined by the Intergovernmental Panel on Climate Change (IPCC)'s Global Warming Potential metric (or GWP; Table 2). The GWP expresses how much more energy is trapped by a unit emission of a particular gas relative to a unit emission of carbon dioxide over a specified time frame.[49] The GWP metric is a useful heuristic for policymakers as it provides a simplified framework for emissions accounting. However, as the IPCC has discussed, the GWP is not a full representation of the physical properties of each gas or its potential impacts, and it is a relative value that is heavily influenced by the IPCC's current estimation of the radiative forcing caused by carbon dioxide.[50] The 2023 EPA social cost methods use a simple physical climate model known as the Finite Amplitude Impulse Response (FAIR) [51] to capture the climate response to emissions in such a way that modeled warming influences the carbon cycle and the uptake of carbon into lands and oceans. In its sixth assessment report,[52] the IPCC used this same model to help translate the radiative forcing caused by a unit emission of a greenhouse gas to an increase in global surface temperature. This is one of a number of additional steps necessary to translate an increment of radiative forcing as represented by GWP into future economic damages.[53] Contributing to the complexity are possible temporal offsets between changes in radiative forcing caused by emissions and the damages that they cause, the much longer time horizon (2300) used in the social cost models than either the 20-year or 100-year GWP, and variation of the discount rate through time as the social cost models reflect projected economic growth, among others. Thus, it is not necessarily appropriate to multiply the federal social cost of CO_2 values by the relative GWP of a given greenhouse gas in order to determine the social cost of that gas.

Although there is broad consensus that using the GWP is not appropriate for this purpose, using the approach is still recommended by some authors as an alternative to omitting an assessment of these gases altogether, or essentially treating these gases as if they have no impact or a value of zero.[54] The Department recommends that every effort be made to assess the damages

[49] Commonly 100-years, but the CLCPA defines carbon dioxide-equivalence in terms of 20-years. ECL § 75-0101(2). As the IPCC has stated, the choice of time horizon is subjective. Like the discount rate, the difference reflects a preference for weighing near-term versus long-term impacts.
[50] As discussed by Working Groups 1 and 3 in the Fifth Assessment Report.
[51] Christopher J. Smith et al., "FAIR v1.3: a simple emissions-based impulse response and carbon cycle model." *Geosci. Model Dev.* 11, no. 6 (2018): 2273– 2297, https://doi.org.10.5194/gmd-11-2273-2018.
[52] Forster et al., op. cit.
[53] Alex L. Marten et al., "Incremental CH_4 and N_2O mitigation benefits consistent with the U.S. government's SC-CO_2 estimates." *Climate Policy* 15, no. 2 (2014): 272-298, https://doi.org/10.1080/14693062.2014.912981.
[54] e.g., Marten et al., and National Academies, 2017, op. cit.

of each gas and that peer-reviewed research on damages be applied whenever possible (see above). State entities and partners should also undertake additional analyses of any additional gases that may be associated with policies of interest to ensure that actions to reduce one gas do not inadvertently increase other gases with the unintended outcome of undermining the ability of the policy to achieve the requirements of the CLCPA. When including damage estimates for other gases, agencies should indicate how the value was determined, either through application of the GWP metric or by referencing the relevant publication, and consideration should be made as to whether the analysis is likely to have over or under-estimated actual damages.

It is also important to note that two of the types of gases listed in the CLCPA, HFCs and perfluorocarbons (PFCs), represent multiple separate gases that would impose different impacts. Table 2 provides information for some gases, but the most recent IPCC Assessment Report should be consulted with regards to the full suite of greenhouse gases. There are greenhouse gases that may be relevant to State entities that are not named in the CLCPA. For example, HFCs were introduced to replace ozone-depleting substances, which are greenhouse gases[55] that are subject to a separate international phase-down. These gases may continue to be used until the available supply is diminished. State entities may wish to assess the benefits of further, more accelerated reductions and would be able to demonstrate these benefits using the damages approach.

[55] e.g., the 20-year GWP of CFC-12 is 11,400 and HCFC-22 is 5690, which are two commonly used substances.

Table 2. Example Global Warming Potential Values

		IPCC AR5		IPCC AR6	
Greenhouse gas	Lifespan (years)	100-YEAR GWP	20-YEAR GWP	100-YEAR GWP	20-YEAR GWP
Carbon dioxide (CO_2)	~100[56]	1	1	1	1
Methane (CH_4)	11.8	28	84	27.9	81.2
Nitrous oxide (N_2O)	109	265	264	273	273
Hydrofluorocarbons (HFCs)					
HFC-134A	14.0	1300	3710	1530	4140
HFC-125	30	3170	6090	3740	6740
HFC-32	5.4	677	2430	771	2690
HFC-143A	51	4800	6940	5810	7840
Perfluorocarbons (PFCs)					
PFC-14	50,000	6630	4880	7380	5300
PFC-116	10,000	11100	8210	12400	8940
PFC-218	2,600	8900	6640	9290	6770
PFC-318	3,200	9540	7110	10200	7400
Sulfur hexafluoride (SF_6)	3,200	23500	17500	24300	18200

Seek comparable, damages-based values for additional impacts.

Carbon dioxide and methane play other roles on earth besides being greenhouse gases. For example, the positive effect of atmospheric carbon dioxide concentrations on crop yields[57] is incorporated into the GIVE social cost model along with the effects of rainfall and temperature. Alternatively, methane is a precursor to tropospheric ozone that therefore has negative potential human health impacts. It is possible to estimate additional damages from methane so that they can be more easily integrated into cost benefit analyses or in the description of the benefits of emission reduction policies. The Department recommends consideration of such estimates if available in the peer-reviewed literature.[58]

VII. Example Applications

The following hypothetical examples are provided to illustrate how State entities could use a damages-based value of carbon in different decision contexts. These examples are intentionally

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[56] Some portion of emitted CO_2 is taken up by the biosphere and some portion will persist in the atmosphere for the full lifespan of the gas.
[57] Frances C. Moore et al., "New science of climate change impacts on agriculture implies higher social cost of carbon," *Nature Commun* 8, no. 1607 (2017): https://doi.org.10.1038/s41467-017-01792-x.
[58] D.T. Shindell et al., "The social cost of methane: theory and applications," *Faraday Discussions* 200, (2017): 429-451, https://doi.org/10.1039/C7FD00009J.

over-simplified and are intended to illustrate the utility of the value of carbon at a high-level. Real world examples can also be found in the record of federal decisions, such as by searching for the “social cost of carbon” in the Federal Register. The Department also seeks public input on other applications of the value of carbon by state entities.

Each of the examples below uses the 2023 EPA social costs of carbon dioxide, methane, nitrous oxide, and HFCs (see separate Appendix). These are provided in 2020 dollars. Agencies can update these values with inflation as needed. However, these values will remain static until the Department provides an update based on new peer-reviewed models.

Estimating the Emission Reduction Benefits of a Plan or Goal

An agency has developed a strategic plan with the goal of reducing carbon dioxide emissions 50% over ten years from current levels, or 50,000 metric tons over 10 years. In order to determine the benefits to society in terms of avoided damages, the agency will need to determine the annual level of emission reductions (or emissions avoided) compared to a no action scenario. If split evenly across all 10 years, the year-on-year reduction would be 5,000 metric tons per year (see table).

Greenhouse gas	Emissions in 2020 (kt)	Reduction 2030	Annual Emission Reductions 2020-2030 (kt)
Carbon dioxide	100	50%	5

The net present value of the plan is equal to the cumulative benefit of the emission reductions that happened each year (adjusted for the discount rate). In other words, the value of carbon is applied to each year, based on the reduction from the no action case, 100,000 tons in this case. The Appendix provides the value of carbon for each year. For example, the social cost of carbon dioxide in 2021 at a 2% discount rate is $197 per metric ton. The value of the reductions in 2021 are equal to $197 times 5,000 metric tons, or $985,000; in 2022, $200 times 10,000 tons, or $2,000,000, etc. This calculation would be carried out for each year and for each discount rate of interest. The results for all three recommended discount rates are provided below.

Based on this assessment, the net present value of the plan by the end of 2030 ranges from $32.2-$93.0 million or $53.4 million using the central discount rate of 2.0%. It may be that actions to reduce carbon dioxide will affect the emissions of other greenhouse gases as well. The net present value of those impacts may be estimated and combined with the net present value of the avoided carbon dioxide.

Annual and Cumulative Value of CO_2 Reductions *(Totals May Not Sum Due to Independent Rounding.)*					
Year	Annual CO_2 Emission Reduction (Kt)	Total CO_2 Emission Reduction (Kt)	Annual Benefits ($K) [Total CO_2 Emission Reduction * Value]		
			2.5%	2.0%	1.5%
2021	5	5	595	985	1,705
2022	5	10	1,220	2,000	3,460
2023	5	15	1,875	3,060	5,265
2024	5	20	2,560	4,160	7,120
2025	5	25	3,250	5,300	9,000
2026	5	30	3,990	6,450	10,950
2027	5	35	4,760	7,665	12,950
2028	5	40	5,560	8,920	15,000
2029	5	45	6,345	10,170	17,100
2030	5	50	7,200	11,500	19,200
10-Year Cumulative Value			37,355	60,210	101,750
Net Present Value			32,173	53,420	93,008

Net Costs and Benefits in an Environmental Assessment or Rulemaking

An agency is tasked with assessing the net costs of a project or policy and a no-action alternative. A separate assessment has determined that the other monetary costs, which may include the costs of compliance with the policy or the capital costs of the project, will be $100,000 per year for 5 years and that the end result will be a reduction of methane of 500 metric tons.

Greenhouse gas	Emission Reduction 2020-2025 (mt)	Reduction per year (mt)	Total Cost ($K)	Cost per year ($K)
Methane	500	100	500	100

As in the example above, the benefits in terms of avoided damages from climate change can be estimated by multiplying the emission reduction in each year by the relevant value (i.e., the federal social cost of methane). As discussed in the guidance, methane emissions are also associated with damages related to public health that are not included in the federal value for methane, but these could be included in the overall net cost. The example table below includes a placeholder for additional health-related damages. If the health-related damages are omitted the net benefit of the action (or benefits minus costs) ranges from $1.8 million to $3.4 million. The net present value ranges from $1.6 million to $3.2 million with a central value of $2.2

million. The net value of the no-action alternative may be considered to be the inverse of the cumulative benefit, or a cumulative *cost* to society of up to $3.8 million.

Cumulative And Net Costs and Benefits from Methane Reductions *(Totals May Not Sum Due to Independent Rounding.)*										
Year	Total CH_4 Emission Reduction (Mt)	Annual Benefits ($K) 2.5%			Annual Benefits ($K) 2.0%			Annual Benefits ($K) 1.5%		
		CLIMATE	HEALTH	TOTAL	CLIMATE	HEALTH	TOTAL	CLIMATE	HEALTH	TOTAL
2021	100	132			172			239		
2022	200	278			360			496		
2023	300	437			562			769		
2024	400	609			780			1,060		
2025	500	795			1,012			1,369		
Cumulative Benefit		2,252			2,887			3,932		
Cumulative Cost		-500			-500			-500		
Cumulative Net Value		1,752			2,387			3,432		
Net Present Value		1,590			2,211			3,243		

Describing the Benefits of a Procurement Plan

An agency plans to replace three fleet vehicles with new, zero-emission electric vehicles and would like to describe the societal benefits of this plan. The agency has estimated that the lifecycle carbon dioxide emissions associated with the new vehicles are up to 80% lower than its current sedans, when powered by the electricity grid in upstate New York.[59] A lifecycle value would be appropriate as the CLCPA directs agencies to reduce emissions associated with imported fossil fuels and electricity.

Greenhouse gas	Annual Emission Reduction Per Vehicle (mt)	Annual Emission Reduction All Vehicles (mt)
Carbon dioxide	2.5	7.5

By applying the value of carbon provided in the Appendix tables, the agency can estimate the total annual benefit of the new vehicles, plus the total value over 5 years or longer. In this example, the full 7.5 tons of reductions are realized in the first year and repeated in each subsequent year. The estimated benefit of the new vehicles in the first five years range from

[59] Example comparing a Chevrolet Bolt with a Chevrolet Cruze from: N. Nigro and A. Walsh, "EV Smart Fleets. Electric Vehicle Procurements for Public Fleets" Atlas Policy (2017) https://atlaspolicy.com.

$1,988 to $15,420. Fossil fuels and electricity generation are also associated with methane and nitrous oxide emissions, the value of which could be estimated as well.

Annual and 5-Year Cumulative Value of CO_2 Reductions
(Totals may not sum due to independent rounding.)

Year	Annual CO_2 Emission Reduction (mt)	Annual Benefits ($) [$CO_2$ Emission Reduction * Value]		
		2.5%	2.0%	1.5%
2020	7.5	878	1,448	2,528
2021	7.5	893	1,478	2,558
2022	7.5	915	1,500	2,595
2023	7.5	938	1,530	2,633
2024	7.5	960	1,560	2,670
5-Year Cumulative Value		4,583	7,515	12,983
Net Present Value		4,359	7,220	12,599

Comparing Alternative Technologies

This example applies the value of carbon for HFCs, which are used as refrigerants in many types of equipment. In this case, there are multiple alternative types of heat pump systems and refrigerants. This example illustrates the different social costs when choosing between alternative refrigerants. This example does not compare heat pumps to other types of appliances that they may replace (i.e., fossil fuel boilers or furnaces, air conditioning). Such a comparison would also consider emissions from the combustion of fossil fuels, refrigerant leakage from air conditioning equipment, and emissions from the electricity used to power a heat pump or air conditioning equipment.

The building manager for a 5-floor multifamily residential building with 40 apartments solicited bids for retrofitting the building with heat pumps. They received 4 bids for systems that each have an average lifetime of 16 years. The building's efficiency manager uses the following information about each system to calculate and compare the social costs of the hydrofluorocarbon (HFC) and hydrofluoroolefin (HFO) refrigerants emitted by each proposed system. These costs represent the economic damages caused by leakage of each of these greenhouse gases into the atmosphere over the heat pump lifetime. The building manager ranks highest the bid that has the lowest net present value of these cumulative costs (see table below). Each bid is described in detail in the text below. Note: The Appendix provides the costs per ton for each HFC, which have been converted to a cost per kg for this example. For the non-

HFC alternative, HFO-1234ze(e), the value of CO_2 is used as a placeholder (see Bid #4). Information on charge size, leak rates, and end-of-life leakage are from NYSERDA (2021).[60]

Comparative Costs of Refrigerant Leakage Value of HFC Emissions at the Central 2% Discount Rate	
	Net Present Value ($)
Bid #1 Multisplits with R-410a	-41,301
Bid #2 VRF with R-410a	-51,798
Bid #3 Multisplits with R-32	-6,927
Bid #4 Multisplits with R-1234ze*	-32

Bid #1 includes 40 individual multisplit heat pumps that contain R-410a refrigerant, with one rooftop condenser and two heads per apartment. Each heat pump contains (2.69 kg) of R-410a refrigerant, which is 50% HFC-32 and 50% HFC-125. The average refrigerant leakage from each heat pump is 6.3% of the initial charge per year (0.17 kg/year) and the end-of-life loss rate is assumed to be 80% of the charge remaining (2.02 kg). The net present value of the damages accrued from HFC leakage during the lifetime of the 40 heat pumps ranges from negative $30,352 at a 2.5% discount rate to negative $58,871 at a 1.5% discount rate, and negative $41,301 at the 2.0% or central discount rate. The social cost of the HFC leakage for each year is presented in the table below.

[60] New York State Energy Research and Development Authority, "Hydrofluorocarbon Emissions Inventory and Mitigation Potential in New York State, Report Number 21-28, Prepared by Guidehouse, Inc.," https://www.nyserda.ny.gov/publications.

Annual and Cumulative Value of HFC Refrigerant Leakage **Bid #1: Multisplit heat pumps with R-410a**				
Year	Annual R-410a Leakage (kg) for 40 units	Annual Costs ($) for 40 units [Total Cost HFC-32 and HFC-125]		
		2.5%	2.0%	1.5%
2022	6.8	1,002	1,341	1,893
2023	6.8	1,041	1,387	1,947
2024	6.8	1,080	1,433	2,001
2025	6.8	1,119	1,478	2,056
2026	6.8	1,157	1,524	2,110
2027	6.8	1,196	1,570	2,164
2028	6.8	1,235	1,615	2,218
2029	6.8	1,274	1,661	2,273
2030	6.8	1,313	1,707	2,327
2031	6.8	1,356	1,756	2,386
2032	6.8	1,399	1,806	2,444
2033	6.8	1,441	1,856	2,503
2034	6.8	1,484	1,906	2,562
2035	6.8	1,527	1,956	2,621
2036	6.8	1,570	2,006	2,680
2037	87.6	20,781	26,490	35,277
16-Year Cumulative Cost		39,975	51,494	69,462
Net Present Value		-30,352	-41,301	-58,871

Bid #2 includes 5 large VRF (variable refrigerant flow) systems that contain R-410a refrigerant, with one unit installed per floor. Each VRF unit is charged with 27.22 kg of R-410a. The systems have an average annual leakage of 10% of the initial charge per year (2.72 kg/year) and an end-of-life loss of 20% of the remaining charge (4.90 kg). The net present value of the damages accrued from HFC leakage during the heat pumps' lifetime ranges from negative $38,248 at a 2.5% discount rate to negative $73,581 at a 1.5% discount rate, and negative $51,798 at the central 2.0% discount rate. The social cost of the HFC leakage for each year is presented in the table below.

Annual and Cumulative Value of HFC Refrigerant Leakage Bid #2: VRF heat pumps with R-410a				
Year	Annual R-410a Leakage (kg) for 5 units	Annual Costs ($) for 5 units [Total Cost HFC-32 and HFC-125]		
		2.5%	2.0%	1.5%
2022	13.6	2,004	2,683	3,786
2023	13.6	2,082	2,774	3,894
2024	13.6	2,159	2,865	4,003
2025	13.6	2,237	2,957	4,111
2026	13.6	2,315	3,048	4,220
2027	13.6	2,392	3,139	4,328
2028	13.6	2,470	3,231	4,437
2029	13.6	2,548	3,322	4,545
2030	13.6	2,625	3,413	4,654
2031	13.6	2,711	3,513	4,771
2032	13.6	2,797	3,613	4,889
2033	13.6	2,883	3,713	5,006
2034	13.6	2,969	3,813	5,124
2035	13.6	3,055	3,913	5,242
2036	13.6	3,140	4,013	5,359
2037	38.1	9,038	11,521	15,343
16-Year Cumulative Cost		47,426	61,530	83,712
Net Present Value		-38,248	-51,798	-73,581

Bid #3 includes 40 individual multisplit heat pumps that contain R-32, with one rooftop condenser and two heads per apartment. Each heat pump contains (1.91 kg) of R-32 refrigerant (100% HFC-32) and requires less charge than the R-410a multisplit system. The average refrigerant leakage from each heat pump is 3.15% of the initial charge per year (0.06 kg/year) and the end-of-life loss rate is assumed to be 80% of the charge remaining (1.48 kg) (NYSERDA 2021). For this bid, the net present value of the damages accrued from HFC-32 leakage during the heat pumps' lifetime ranges from negative $5,331 at a 2.5% discount rate to negative $9,508 at a 1.5% discount rate, and negative $6,927 at the central 2.0% discount rate. The social cost of the HFC leakage for each year is presented in the table below.

Annual and Cumulative Value of HFC Refrigerant Leakage Bid #3: Multisplit heat pumps with R-32				
Year	Annual R-32 Leakage (kg) for 40 units	Annual Costs ($) for 40 units [Total Cost HFC-32]		
		2.5%	2.0%	1.5%
2022	2.4	106	137	190
2023	2.4	112	143	197
2024	2.4	117	150	204
2025	2.4	123	156	211
2026	2.4	128	162	218
2027	2.4	134	168	225
2028	2.4	140	175	232
2029	2.4	145	181	240
2030	2.4	151	187	247
2031	2.4	158	195	255
2032	2.4	164	202	263
2033	2.4	171	210	272
2034	2.4	178	217	280
2035	2.4	184	225	289
2036	2.4	191	232	297
2037	61.6	5,074	6,145	7,837
16-Year Cumulative Cost		7,276	8,885	11,457
Net Present Value		-5,331	-6,927	-9,508

Bid #4 includes 40 individual multisplit heat pumps that contain R-1234ze, with one rooftop condenser and two heads per apartment. Each heat pump contains (3.23 kg) of R-1234ze refrigerant (HFO-1234ze(E)). The average refrigerant leakage from each heat pump is 3.15% of the initial charge per year (0.10 kg/year) and the end-of-life loss rate is assumed to be 80% of the charge remaining (2.50 kg) (NYSERDA 2021). The social costs of HFO-1234ze(E) have not been assessed yet, so the manager substitutes the social cost of CO_2 for HFO-1234ze(E), knowing that the GWP of HFO-1234ze(E) is similar to that of CO_2. The net present value of the damages accrued from HFO-1234ze(E) leakage ranges from negative $19 at the 2.5% discount rate to negative $55 at the 1.5% discount rate, with a value of negative $32 at the 2.0% central discount rate.

Annual and Cumulative Value of HFC Refrigerant Leakage Bid #4: Multisplit heat pumps with R-1234ze				
Year	Annual R-1234ze Leakage (kg) for 40 units	Annual Costs ($) for 40 units [Total Cost HFO-1234ze(e)*]		
		2.5%	2.0%	1.5%
2022	4	0.49	0.80	1.38
2023	4	0.50	0.82	1.40
2024	4	0.51	0.83	1.42
2025	4	0.52	0.85	1.44
2026	4	0.53	0.86	1.46
2027	4	0.54	0.88	1.48
2028	4	0.56	0.89	1.50
2029	4	0.56	0.90	1.52
2030	4	0.58	0.92	1.54
2031	4	0.59	0.94	1.56
2032	4	0.60	0.95	1.58
2033	4	0.61	0.96	1.59
2034	4	0.62	0.98	1.61
2035	4	0.63	0.99	1.63
2036	4	0.64	1.01	1.65
2037	104.4	17.12	26.73	43.53
16-Year Cumulative Cost		26	40	66
Net Present Value		-19	-32	-55