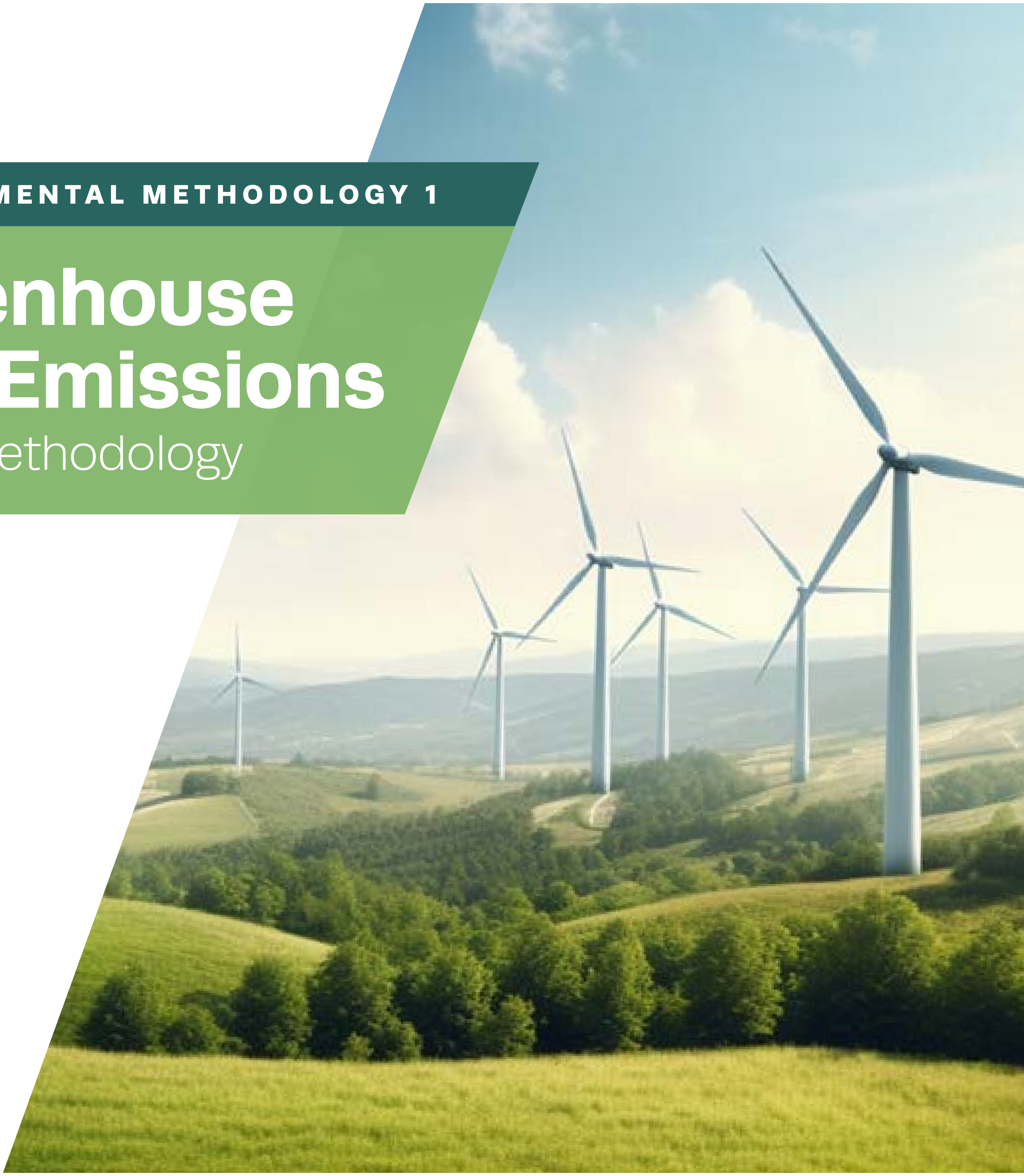
INTERNATIONAL FOUNDATION FOR VALUING IMPACTS

value balancing alliance

ENVIRONMENTAL METHODOLOGY 1

Greenhouse Gas Emissions

Topic Methodology



This publication has been produced by the International Foundation for Valuing Impacts (IFVI) in partnership with the Value Balancing Alliance (VBA) as part of the impact accounting system (the Methodology).

The Methodology is a globally applicable and comprehensive methodology for the public good for valuing organizational social and environmental impact that is designed for incorporation into financial analysis and organizational planning and decision-making. The Methodology is governed by the Valuation Technical & Practitioner Committee (VTPC), an independent committee comprising 18 members, established by IFVI and authorized by its Terms of Reference to direct, validate, and approve impact accounting research and methodology produced by the cooperation of the IFVI and VBA.

VTPC members are global leaders in the fields of impact, sustainability, accounting, business, and finance. Members provide advice in their individual capacities as experts, with composition and procedures designed to ensure independence, balance, and the avoidance of conflicts of interest. Please refer to the full Terms of Reference for information regarding membership, voting, and approval processes.

Methodology development aims to follow a rigorous and credible due process balanced with the urgent and dynamic needs of stakeholders in the face of great social and environmental challenges. The development process is outlined in the Due Process Protocol and designed to be impact-focused, stakeholder-informed, collaborative, and transparent. As detailed in the Due Process Protocol, formal methodology statements undergo public exposure prior to final approval by the VTPC.

The IFVI Board of Directors provides oversight to the Due Process Protocol through its Due Process Oversight Committee. More information about the VTPC and Due Process Protocol are available in the VTPC Terms of Reference and Due Process Protocol.

Questions or comments about IFVI governance or methodology can be submitted to the VTPC at VTPCLeadership@ifvi.org, the Chair of the DPOC

at DueProcessOversight@ifvi.org, or directly to technical staff at research@ifvi.org.

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Executive Summary

- This Greenhouse Gas (GHG) Emissions Topic Methodology can be used by preparers of impact accounts to measure and value the impact of GHG emissions on people and the natural environment. This Topic Methodology can also be applied by users of impact information to manage the sustainability-related risks, opportunities, and impacts of an entity and inform decision-making regarding an entity's contribution to sustainability.
- To use this Topic Methodology in its entirety, preparers should:
  - develop a full accounting of GHG emissions including *Scope 1, Scope 2, Scope 3 Upstream*, and *Scope 3 Downstream*;
  - utilize the impact pathway and value factor developed in this Topic Methodology to convert GHG emissions into impact accounts;
  - present any related impact information with supplemental notes and qualitative commentary necessary to meet the qualitative characteristics of impact information as outlined in General Methodology[1]: Conceptual Framework for Impact Accounting.
- **Section 1** introduces the purpose of the document, outlines key concepts and definitions, and defines the scope for the Topic Methodology. This includes defining greenhouse gasses as any gas that absorbs infrared radiation in the atmosphere, in alignment with the GHG Protocol.
- **Section 2** develops the impact pathway of GHG Emissions, consisting of inputs, activities, outputs, outcomes, and impacts. An entity's activities that use energy or resources serve as inputs to the impact pathway, leading to the output of greenhouse gas emissions. This leads to outcomes related to natural capital and environmental quality, resulting in impacts on human well-being. These impacts include:
  - reduced human health;
  - losses in labor availability;
  - increased energy demand;
  - elevated water requirements;
  - damage to the built environment;
  - reduced production from the environment; and
  - decreased ecosystem services.
- **Section 3** establishes the data required from the entity to implement the Topic Methodology, including:
  - Scope 1 Emissions;
  - Scope 2 Emissions;
  - Scope 3 Upstream Emissions; and
  - Scope 3 Downstream Emissions.
- The data requirements are fully aligned with disclosure requirements established by relevant standard setters including the International Financial Reporting Standards (IFRS) S2: Climate-related Disclosures, Global Reporting Initiative (GRI) 305: Emissions 2016, and European Sustainability Reporting Standards (ESRS) E1: Climate Change for GHG Emissions.

[1] See General Methodology 1: Conceptual Framework for Impact Accounting.

Executive Summary

- **Section 4** outlines the approach of the Topic Methodology for measuring and valuing the impacts of GHG emissions, leading to a value factor that uses the social cost of carbon (SCC).
    - Two SCC models are used to create the value factor: The Greenhouse Gas Impact Value Estimator (GIVE) and The Data-Driven Spatial Climate Impact Model (DSCIM) by Resources for the Future and the Climate Impact Lab, respectively.
    - The Topic Methodology adopts a dynamic discount rate that meets a near-term social discount rate of 2%.
- This approach leads to a globally applicable social cost of carbon of $236 per metric tons of CO_2e for 2023.
    - This number will be adjusted over time based on adjustments for inflation, expanded damage functions, updated estimates of future damages, or conceptual advances that align with the General Methodology.
- To determine the societal cost of an entity's GHG emissions, preparers then multiply the value factor by the GHG emissions with each scope category considered separately.
- **Section 5** articulates opportunities for further development of the Topic Methodology, including potential areas of improvement in social cost of carbon models and improvements in the ability to measure and track all scopes of emissions for entities.
- This Topic Methodology builds on frameworks and protocols published by leading organizations in the impact management ecosystem and sustainability-related disclosures required by governing jurisdictions and international standard setters, including:
    - Climate Impact Lab;
    - European Sustainability Reporting Standards (ESRS);
    - GHG Protocol;
    - Global Reporting Initiative (GRI);
    - Intergovernmental Panel on Climate Change (IPCC);
    - International Financial Reporting Standards (IFRS);
    - Resources for the Future; and
    - The Transparent Project.

1. Introduction

1. Introduction

1.1 DOCUMENT PURPOSE

1. The purpose of this document is to outline the Topic Methodology for Greenhouse Gas emissions (henceforth, GHG Methodology) as part of the *impact accounting* methodology being developed by the International Foundation for Valuing Impacts and the Value Balance Alliance.

2. The impact accounting methodology measures and values the *impacts* of corporate entities (entities or an entity) in monetary terms for the purposes of preparing impact accounts and generating impact information. The GHG Methodology can be used to inform internal decision-making, investment decisions, and understand the significance of GHG emissions impacts of an entity.

3. Preparers of impact accounts should adhere to the entirety of the Methodology to the fullest extent possible and should disclose any deviations from it when shared with users of impact information.

1.2 TOPIC DESCRIPTION

4. For the purposes of the GHG Methodology, GHGs are components of the atmosphere that absorb and emit infrared radiation effectively trapping and emitting heat towards the surface of Earth.[2]

5. Due to human-related activities, including activities from corporate entities, the concentration of CO_2 (a significant GHG) has risen to over 420 ppm, or 140 ppm above pre-industrial levels. Most of the GHG emissions have come directly from burning fossil fuels for energy or transportation as well as physical and chemical processing.[3] The increased concentration of GHGs in the atmosphere alters the *physical environment* by increasing temperatures, altering precipitation patterns, raising sea level, acidifying oceans, and intensifying the severity and frequency of extreme climate events (e.g., droughts, wildfires, hurricanes, floods).[4]

6. Each of these changes to the environment directly affects society by increasing human mortality and displacement, exacerbating outbreaks of infectious diseases, deteriorating food supplies, flooding coastal areas, and damaging infrastructure, to name a few.

7. The negative impacts on *stakeholders* from GHG emissions has impelled a significant global response to limit warming to under 1.5°C requiring global GHG emissions to reach net-zero by 2050.[5] Achieving this target will limit and reduce catastrophic and irreversible additional impacts from GHG emissions.

8. The GHG Methodology takes a societal perspective and not that of a discrete affected stakeholder group. This is done by considering the impacts on all of society from each ton of GHG emitted.

9. The GHG Methodology, as presented, covers an entity's own operations as well as its upstream and downstream value chain. The extent to which all value chain levels should be included in impact accounts is dependent upon the relevance of the impacts at each value chain level from an impact materiality perspective.

10. While the GHG Methodology measures the impacts of the entity on stakeholders, understanding and managing GHG impacts may also help an entity manage production needs, operational costs, supply chain disruptions, or resource allocation. GHG impact accounts can also provide guidance to manage and mitigate transition and physical risks.[6,7]

[2] The definition aligns with the GHG Protocol and IPCC. See definition from the United Nations Framework Convention on Climate Change (UNFCCC) in the Glossary.

[3] See GHG Protocol. (2004): Corporate Accounting and Reporting Standard, Chapter 4.

[4] See further detail of climate change effects in IPCC. (2023): Climate Change 2023 Synthesis Report.

[5] See the Paris Agreement (2015) to the United Nations Framework Convention on Climate Change.

[6] Transition risks include policy and legal, technology, market, and reputation risks while physical risks include acute and chronic risks as defined in TCFD. (2017): Recommendations of the Task Force on Climate-related Financial Disclosures.

[7] Opportunities exist to map the work presented in the GHG Emissions Topic Methodology to global frameworks such as the UN Sustainable Development Goals (SDG), System of Environmental Economic Accounting (SEEA), the Global Biodiversity Framework, or others.

1. Introduction

1.3 KEY CONCEPTS AND DEFINITIONS

11. For the purposes of applying the GHG Methodology, the following terms are defined:

a) **Greenhouse Gases:** Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorinated compounds (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).[8]

b) **Scope 1, 2, and 3 Emissions:** Categorizations of emissions, both direct and indirect, from a particular entity. See Appendix A for individual definitions of Scope 1, 2 and 3.[9]

c) **CO_2 equivalents:** A metric used to compare the emissions of different greenhouse gases by converting them to a standardized unit based upon their *global warming potential* (GWP).[10]

d) **Social Cost of Carbon (SCC):** The net present value of aggregate climate damages from one more metric ton of carbon in the form of carbon dioxide (CO_2), conditional on a global emissions trajectory over time.[11] The SCC is used to develop the value factor.

e) **Discounting/social discount rate:** A mathematical operation that aims to make monetary (or other) amounts received or expended at different times (years) comparable across time. The social discount rate is the value used to discount future monetary amounts. If the social discount rate is positive, future values are given less weight than those today. [12]

12. A complete set of defined terms is included in the Glossary.

1.4 SCOPE AND ASSUMPTIONS

13. The GHG Methodology includes the impacts of all GHGs as defined by the GHG Protocol and the Intergovernmental Panel on Climate Change (IPCC).[13] The accurate quantification of carbon dioxide and methane are particularly important as they represent 79% and 12% of the global GHG emissions, respectively.[14]

14. Full value chain emissions fall within the scope of the GHG Methodology. This includes upstream (cradle-to-gate), *direct operations (gate-to-gate)*, and downstream (gate-to-grave) as defined in General Methodology 1.[15] An entities' own operations should be the same scope used for financial statements to ensure comparability. GHG emissions may be based on model predictions and not directly measured due to the challenges of measuring upstream and downstream emissions.[16]

15. The GHG Methodology recognizes full responsibility of an entity for its upstream and downstream emissions in alignment with the GHG Protocol. GHG emissions are attributed to an entity through physical or economic relationships by partitioning the inputs or outputs related to the emissions and determining the portion that is linked to the entity.[17] The inclusion of value chain GHG emissions means that double counting across entities in the same value chain will occur. However, this will not lead to double counting within an entity's impact statement.

16. An entity can take a location-based or market-based approach when quantifying Scope 2 emissions. If using the market-based approach, *renewable energy certificates* (RECs) can be considered within the scope of the GHG Methodology.

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[8] Definition of greenhouse gases aligns with the GHG Protocol.

[9] See further details of Scope emission definitions in the GHG Protocol (2004): Corporate Accounting and Reporting Standard.

[10] See definition provided by UNFCCC in the Glossary.

[11] See definition from the International Panel on Climate Change (IPCC) in the Glossary.

[12] Ibid.

[13] See GHG Protocol. (2004): Corporate Accounting and Reporting Standard and IPCC (2022): Climate Change 2022: Impacts, Adaptations, and Vulnerability.

[14] See definition in Section 1.3 for comprehensive list of GHGs; and United States EPA (2023): Overview of Greenhouse Gases.

[15] This scope is the same as the ESRS, IFRS, and GRI. In these documents, GHG emissions are categorized into Scope 1, 2, and 3 emissions as defined by the GHG Protocol.

[16] See Section 3.3.

[17] See Greenhouse Gas Protocol. (2011): Corporate Value Chain (Scope 3) Accounting and Reporting Standard, Supplement to the GHG Protocol Corporate Accounting and Reporting Standard. Note that in the GHG Protocol, the process of attribution is referred to as allocation.

1. Introduction

17. Carbon offset projects do not fall within the scope of the GHG Methodology. This includes any offset projects developed within the value chain or purchased through carbon credits.

18. Avoided emissions do not fall within the scope of the GHG Methodology. Avoided emissions (also sometimes referred to as *Scope 4 emissions*) are the difference between GHG emissions that occur or will occur and GHG emissions that would have occurred without the solution.[18] While not exclusively, these most often are considered as a result of the use of a product and often occur outside the value chain or traditional inventories of GHGs.[19]

19. Because GHG emissions quickly mix in the atmosphere and societal impacts are global, the spatial boundary of the impacts includes the entire planet. Therefore, there are no special geographical considerations to use the GHG Methodology leading to one global value factor. Similarly, the reliance on GHGs for energy and transport is universal to nearly all business contexts.

[18] See World Business Council for Sustainable Development. (2021). Guidance on avoided emissions: Helping businesses drive innovations and scale solutions toward net zero.

[19] See World Resources Institute. (2019): Estimating and Reporting the Comparative Emissions Impacts of Products.

2. Impact Pathway

2. Impact Pathway

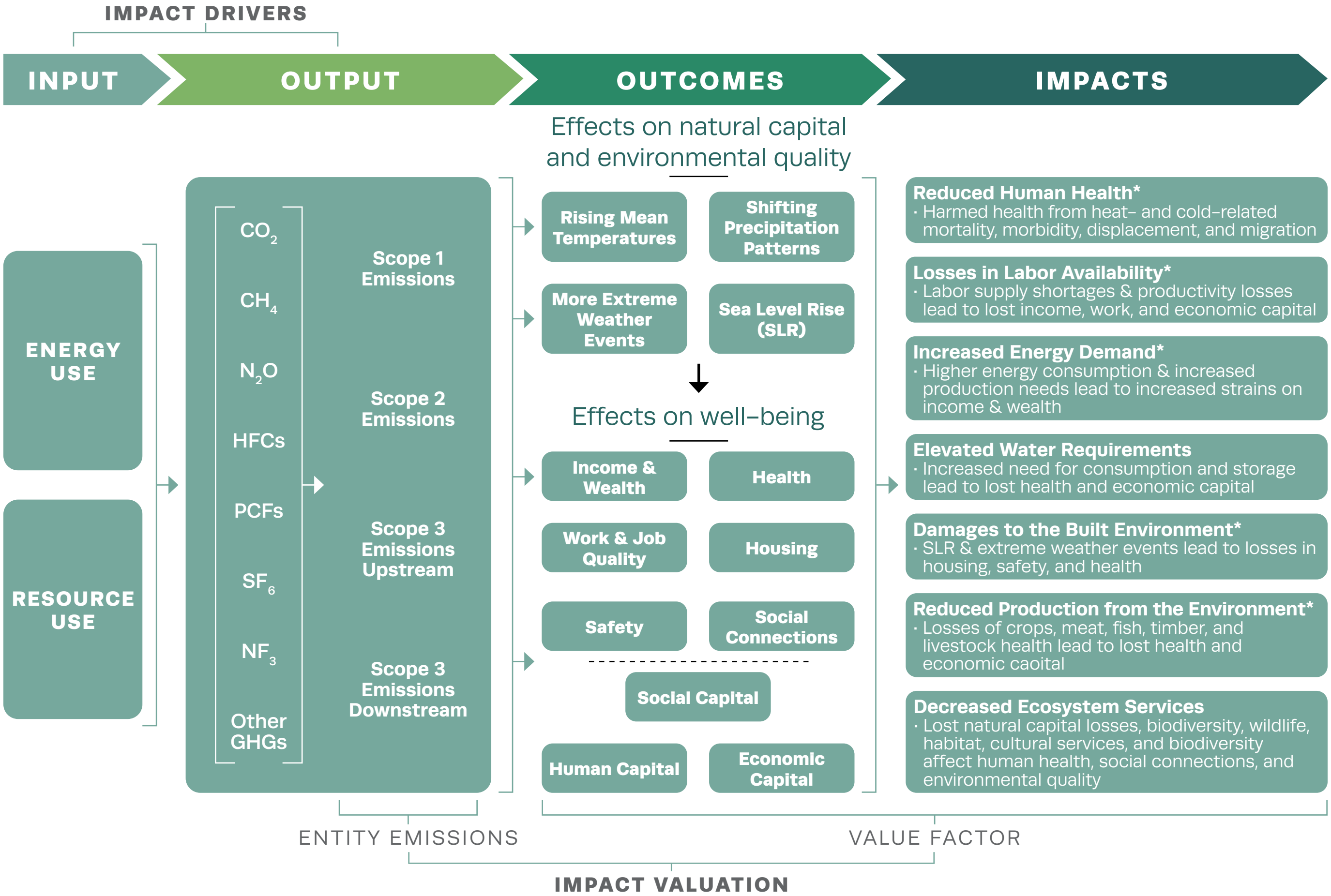
2.1 SUMMARY

20. The impact pathway is the series of consecutive, causal relationships, starting at an input for an entity's activities and linking its actions with related changes in people's well-being. It serves as the foundation of the impact accounting methodology.

21. Outcomes and impacts are defined by various dimensions of people's well-being and aspects that describe the condition of the natural environment, presented in alignment with the OECD Framework for Measuring Well-being.[20]

22. Detailed components of the impact pathway are outlined in subsequent sections, leading to the measurement and valuation of an entity's GHG emissions in *Section 4: Outcomes, Impacts, and Valuation.*

23. The impact pathway for GHG emissions is as follows:



*Starred impacts are those included in the models used to determine the value factor

Figure 2: GHG emissions impact pathway

2.2 DESCRIPTION AND NOTES

24. The primary inputs for the GHG emissions impact pathway are energy use and resource use. Because using fossil fuels to drive these activities are universal to numerous business activities, every entity likely has processes that lead to GHG emissions.

25. The outputs from the entity are GHG emissions. The main categories of emission sources include *stationary combustion*, *mobile combustion*, *process emissions*, and *fugitive emissions.*[21] The GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorinated compounds (PFCs), sulfur hexafluoride (SF_6), nitrogen trifluoride (NF_3), and other, less common GHGs.

26. The outcomes from the accumulation of GHGs in the atmosphere alter the environmental quality and natural capital dimensions of well-being.[22]

[20] OECD. (2020). How's Life? 2020: Measuring Well-being.

[21] See GHG Protocol. (2004): Corporate Accounting and Reporting Standard, Chapter 6: Identifying and Calculating GHG Emissions for further guidance.

[22] Changes to the environment are evaluated relative to environmental conditions had each metric ton of GHG not been emitted.

2. Impact Pathway

Nature has a systemic relevance for society and thus these effects drive the subsequent outcomes.[23] These include rising mean temperatures, shifting precipitation patterns, sea level rise, and more extreme weather events.[24] The physical changes are also becoming more unpredictable in their frequency and magnitude adding further risks to entities, investors, and stakeholders. Every inhabited region of the planet and, therefore, every entity are affected by these outcomes.

27. Outcomes that affect natural capital and environmental quality can be linked to outcomes that affect the well-being of people and society in general. Income and wealth, health, work and job quality, housing, safety, social connections, human capital, social capital, and economic capital are all affected due to the systemic and fundamental reliance on temperature, rainfall, and safety from extreme weather. See Figure 2 for more detail on these linkages.

28. The outcomes described that result in changes to the physical environment drive numerous impacts. These include reduced human health and well-being, losses in labor availability, increased energy demand, elevated water requirements, damage to the built environment, reduced production from the natural environment (e.g., food and timber), and decreased *ecosystem services*.[25] This list is extensive and covers many known impacts but is likely not exhaustive.

29. Present research has not yet captured all impacts on society in rigorous models. Therefore, impact accounts derived using the value factor described in section 4.2 result in an understatement of negative impacts. New research will continue to develop techniques to capture additional impacts, leading to increases in the value factor. The impacts currently included in the value factor models in section 4.2 are starred in Figure 1.[26] A discussion of model limitations can be found in Appendix B.

[23] See NGFS. (2023). The Green Scorpion: the Macro-Criticality of Nature for Finance. which expands on this systemic relevance.

[24] For further detail see IPCC (2023): Climate Change 2023 Synthesis Report.

[25] See IPCC. (2022): Climate Change 2022: Impacts, Adaptation and Vulnerability and Figure SPM.2 from IPCC (2022): Summary for Policymakers Figure SPM.2 for further detail on impacts.

[26] Also see Appendix B: Methodological Details for further information about the incorporation of impacts into models that develop value factors.

3. Impact Driver Measurements

3. Impact Driver Measurements

30. *Impact drivers* consider inputs and outputs and reflect the data needs expected of a preparer to provide an impact account for GHG emissions. The section below outlines the specific data needed along with how these data align with various respective reporting standards.

3.1 DATA REQUIREMENTS

31. To utilize the GHG Methodology, the total GHG emissions of an entity should be measured, including Scope 1, 2, and 3. All three scopes as measured according to the GHG Protocol are fully attributable to the entity as the GHG Protocol allocates emissions to entities in a manner consistent with the requirements in the General Methodology.

32. To normalize the potential impacts of different GHGs, all GHGs should be converted to CO_2 *equivalents* (CO_2e) using Global Warming Potential (GWP). GWP values reflect the warming period over a 100-year time horizon and should come from the most recent assessment from the IPCC.[27]

33. All GHG emissions data should be in units of metric tons of CO_2e.

34. To provide sufficient detail for impact accounts, emissions data should be considered in 4 distinct categories: Scope 1, Scope 2, Scope 3 Upstream, and Scope 3 Downstream.[28]

35. The GHG Protocol[29] is the recommended source to guide preparers through calculating GHG emissions.

36. Supplemental notes or qualitative commentary should be included in GHG emissions impact accounts as noted in General Methodology 1. For GHG emissions this may include but is not limited to approaches to handling emissions data gaps, key assumptions, progress towards rigorous targets (e.g., Science-based Targets), and adherence to planetary boundaries and thresholds.

37. The data requirements of the GHG Methodology are fully aligned with disclosure requirements established by relevant standard setters including the European Sustainability Reporting Standards *E1: Climate Change,* the International Financial Reporting Standards *S2: Climate-related Disclosures*, and the Global Reporting Initiative *305: Emissions 2016*. Additional alignment may exist with other regional or topic specific reporting standards as well. Further details are presented in Table 1 and Appendix D.

Metric	ESRS E1: Climate Change	IFRS S2: Climate Related Disclosures	GRI 305: Emissions 2016
Scope 1 Emissions	Fully aligned E1-6 Paragraph 41(a)	Fully aligned Climate-related metrics paragraph 29(a)(i)(1)	Fully aligned Disclosure 305-1
Scope 2 Emissions	Fully aligned E1-6 Paragraph 41(b)	Fully aligned Climate-related metrics paragraph 29(a)(i)(2)	Fully aligned Disclosure 305-2
Scope 3 Emissions	Fully aligned E1-6 Paragraph 41(c)	Fully aligned Climate-related metrics paragraph 29(a)(i)(3)	Fully aligned Disclosure 305-3

Table 1. Alignment with reporting standards[30]

[27] As of publication, the most recent GWP values are in the Sixth Assessment Report (AR6). IPCC. (2023): Climate Change 2023: Synthesis Report.

[28] Upstream Scope 3 includes categories 1-8 and Downstream Scope 3 includes categories 9-15 from the GHG Protocol. (2004): Corporate Accounting and Reporting Standard.

[29] This includes all resources through the GHG Protocol but of particular relevance here includes the GHG Protocol Corporate Accounting and Reporting Standard (2004), the Corporate Value Chain (Scope 3) Standard (2011), Scope 2 Guidance, and Scope 3 Calculation Guidance

[30] Categories of alignment include (1) fully aligned: data from reporting can be used as is for preparation of impact accounts; (2) expands upon: data from reporting conceptually aligns with the impact accounting methodology, but additional detail, context, or presentation is necessary for an accurate accounting of impact; or (3) independent: Data needed for the preparation of impact accounts are not covered by the reporting standards and would require separate data collection and analysis.

3. Impact Driver Measurements

3.2 DATA SOURCES, GAPS, AND UNCERTAINTY

38. Preparers should strive to measure GHG emissions in a manner that is complete, neutral, and free from error. This includes faithfully representing the emissions from all value chain operations.

39. In practice, barriers such as cost or availability of data may limit preparers from measuring, in their entirety, Scope 1, 2, and 3 emissions. Alternative approaches that utilize estimates or proxies to calculate GHG emissions can be used when necessary to represent the full scope of GHG emissions.[31]

40.In alignment with the GHG Protocol, preparers should prioritize approaches that:[32,33]

a) directly measure GHG emissions over those that estimate GHG emissions based on calculations from activity data (e.g., liters of fuel),

b) utilize primary data from specific activities within a company value chain over secondary data, and

c) consider sources of data that are of the highest quality possible.

41. In alignment with the GHG Protocol, high quality data sources should consider:[34]

a) technological representativeness. The extent to which the data matches the technology used.

b) temporal representativeness. The extent to which the data matches the time or age of the activity.

c) geographical representativeness. The extent to which the data matches the location of the activity.

d) completeness. The extent to which the data is statistically representative of the activity.

e) reliability. The extent to which the data sets and sources are dependable.

42. When estimates require secondary data both Environmentally-extended input output (EEIO) models and process-based models can be used.

43. Uncertainty will arise when quantifying GHG emissions. Preparers should report qualitative uncertainty and, when possible, quantitative uncertainty. These may include but are not limited to propagated measured uncertainty, pedigree matrices, sensitivity analyses, or probability distributions.[35]

[31] The GHG Protocol maintains a list of third-party databases that can assist preparers in collecting necessary data for Scope 3 GHG emissions. https://ghgprotocol.org/life-cycle-databases

[32] Adapted from Greenhouse Gas Protocol (2011): Corporate Value Chain (Scope 3) Accounting and Reporting Standard.

[33] The Partnership for Carbon Accounting Financials (PCAF) also has resources to evaluate data quality based on the GHG Protocol. Specifically see PCAF. (2022): The Global GHG Accounting and Reporting Standard Part A: Financed Emissions; Chapter 10 Annex.

[34] Adapted from Table 7.6 from GHG Protocol. (2011): Corporate Value Chain (Scope 3) Accounting and Reporting Standard.

[35] The GHG Protocol provides approaches and calculation tools for estimating uncertainty of GHG emissions on the "Calculation Tools" section of their website. https://ghgprotocol.org/calculation-tools-and-guidance

4. Outcomes, Impacts, and Valuation

4. Outcomes, Impacts, and Valuation

44. The impacts that result from the GHG emissions of an entity affect environmental quality and natural capital and are linked to the well-being of people through their effects on income and wealth, health, work and job quality, housing, safety, social connections, human capital, social capital, and economic capital.

45. The two most common approaches for valuing GHG emissions are (1) a damage-based approach that determines the outcomes and impacts on society of each additional ton of GHG emitted (e.g. the *social cost of carbon* – SCC) and (2) an abatement-based approach that determines the cost to avoid additional emissions or remove GHGs from the atmosphere (e.g. *carbon dioxide removal* cost or marginal abatement cost).

46. In the GHG Emissions Topic Methodology, the *social cost of carbon* (SCC) approach is used to determine GHG value factor. The SCC is calculated using *Integrated Assessment Models* (IAMs) that link projections of future GDP, human population, and GHG emissions to changes in outcomes and impacts.[36] The SCC collapses the impact measurement and valuation stages of the impact pathway into a summary value that is directly multiplied by GHG emissions.

47. Two SCC models are used to determine outcomes, impacts, and valuation: The Greenhouse Gas Impact Value Estimator (GIVE)[37] and the Data-driven Spatial Climate Impact Model (DSCIM).[38] Both models produce independent representations of the social cost of carbon using bottom-up damage modules. Therefore, the value factors developed from each model are given equal weight using an average to produce a single value factor for use in impact accounts. This approach maximizes the distinctive and complementary strengths of each model. For additional information about both models, Appendix B has extensive detail about the methodological approaches.

48. The GIVE and DSCIM models are significantly advanced over other models because they:

a) are built on extensive input data from a large representative sample of countries over longer time periods;

b) model impacts on society to the year 2300;[39]

c) analyze impacts at either national or sub-national scales allowing for greater precision of analysis;

d) predict future impacts by also incorporating human adaptation in response to climate events;

e) can estimate uncertainty through all components of the model; and

f) are actively updated allowing the GHG Methodology to incorporate the latest advances in GHG emissions valuation.

4.1 HOW TO CALCULATE IMPACTS

49. To determine the societal cost of an entity's GHG emissions (GHG $\text{Value}_{\text{Total}}$), preparers should use the following equation:

$$\sum(Em_{scope} * V_f) \text{ from Scope 1–3} = \textbf{GHG Value}_{\textbf{Total}} \quad \text{(Eq. 1)}$$

where Em_{scope} represents GHG emissions from each scope category and V_f represents the value factor. The scopes considered in the sum include Scope 1, Scope 2, Scope 3 Upstream, and Scope 3 Downstream.

Equation (1) can be broken out into four individual equations:

$$Em_{scope1} * V_f = \textbf{GHG Value}_{scope1} \quad \text{(Eq. 2)}$$

$$Em_{scope2} * V_f = \textbf{GHG Value}_{scope2} \quad \text{(Eq. 3)}$$

$$Em_{scope3up} * V_f = \textbf{GHG Value}_{scope3upstream} \quad \text{(Eq. 4)}$$

$$Em_{scope3down} * V_f = \textbf{GHG Value}_{scope3downstream} \quad \text{(Eq. 5)}$$

50. To calculate the GHG impact (GHG Value), the value factor (V_f) is multiplied by the emissions of that scope (e.g. Em_{scope1}) using equations 2 – 5. The GHG Value from each of these equations provides detail about how GHG impacts are driven by emissions from each scope. The total GHG impact is determined by summing the GHG impact from each scope using equation 1.

51. The value factor (V_f) is the same in all equations above and defined in section 4.3. The data needed for each Em_{scope} are provided by the preparer and guided by section 3.1. The definitions of each scope are the same used by the GHG Protocol.

[36] See Appendix B: Methodological Details for further information about SCC models.

[37] See Rennert et al. (2022): Comprehensive evidence implies a higher social cost of CO_2.

[38] See The Climate Impact Lab. (2022): Data-driven Spatial Climate Impact Model User Manual.

[39] See Appendix B, paragraph B8 for an explanation of why the impacts are projected through 2300.

4. Outcomes, Impacts, and Valuation

52. Each scope of GHG emissions should be considered separately to increase transparency, comparability, and decision-usefulness. There are likely cases where additional levels of detail may aid decision making. This may include considering each Scope 3 category individually or categorizing Scope 1 and 2 into additional categories.

53. Because GHG Emissions cause negative impacts to stakeholders via the impact pathway, the GHG $Value_{Total}$ is a negative value.

4.2 OUTCOMES AND IMPACTS

54.Outcomes and impacts are determined through the socioeconomics and emissions, climate, and damage modules of GIVE and DSCIM. The approaches used for each module are described below. Additional methodological details are in Appendix B.

a) *Socioeconomic and Emissions Module:* To determine GHG emission trajectories, the Resources for the Future Social Cost of Carbon Initiative emissions pathways (called RFF-SPs) are used. While developed distinctly, these are analogous to the IPCC framework that combines shared socioeconomic pathways (SSPs) with relative concentration pathways (RCPs). The value factor takes a median trajectory from the RFF-SPs that most closely mirrors the SSP2-4.5.[40]

b) *Climate Module:* The climate module determines the environmental outcomes, specifically CO_2 concentration, temperature changes, and sea-level rise.

- To project CO_2 concentrations and temperature changes, both GIVE and DSCIM use the Finite Amplitude Impulse Response (FaIR) model.[41] FaIR is a reduced-complexity climate model that projects various components of the Earth system.
- GIVE and DSCIM utilize two different models to project sea-level rise. GIVE uses the Building blocks for Relevant Ice and Climate Knowledge (BRICK) model.[42] BRICK estimates sea-level rise by incorporating data from glacier, ice cap, and ice sheet melting, oceanic thermal expansion, and land water storage. DSCIM projects sea-level rise by using the Semi-Empirical Sea Level (SESL) to predict global mean sea levels and temperatures with and without an emissions pulse.[43] This information is used to determine global mean sea level changes over time.

c) *Damage Module:* The damage module converts environmental outcomes into well-being outcomes and impacts using the methods described in Table 2 and Appendix B.

[40] See Appendix B: Methodological Details for more information about emissions pathways.

[41] The Finite Amplitude Impulse Response (FaIR) model can be accessed via: https://docs.fairmodel.net/en/latest/

[42] See Wong et al. (2017): BRICK v0.2, a simple, accessible, and transparent model framework for climate and regional sea-level projections.

[43] See Climate Impact Lab. (2022): Data-driven Spatial Climate Impact Model User Manual, Version 092022- EPA.

Impact	GIVE	DSCIM
Reduced human health via heat- and cold-related mortality	Uses a comprehensive meta-analysis[44] which estimated the effects of incremental temperature increases of 1°C on categorical mortality risks.	Derives age-specific relationships between temperature and mortality using subnational data from 40 countries.
Increased energy demand	Links temperature effects of climate change to country-level increases in electricity expenditures through 2100 using the Global Change Analysis Model.[45]	Links temperature effects of climate to electricity and other fuel usage from 146 countries between 1971–2010.[46 47]
Reduced production from the environment via agriculture	Uses a meta-analysis of yield responses of maize, rice, wheat, and soybeans to rising temperatures.[48]	Analyzes the impacts of rising temperature on maize, wheat, rice, soy, sorghum and cassava.[49]
Damages to the built environment and human health via sea-level rise	Assesses the costs associated with various flooding damage adaptation strategies as well as impacts to regional coastlines due to sea-level rise using the Coastal Impacts and Adaptation Model (CIAM).[50]	Assess the costs related to inundation, infrastructure/ population retreat, construction/ maintenance, wetlands, mortality, and physical capital losses from sea-level rise using the Framework for Assessing Changes to Sea-level Model (FACTS).[51]
Losses in labor availability	NA	Increases in daily temperatures are linked to hour reductions for workers in industries where outdoor work is required, such as in construction, agriculture, transportation, and more.[52]

Table 2. Synthesis of approaches for determining well-being outcomes and impacts from GIVE and DSCIM.

[44] See Cromar et al. (2022): Global health impacts for economic models of climate change: A systematic review and meta-analysis.

[45] See Clarke et al. (2018): Effects of long-term climate change on global building energy expenditures.

[46] See Rode et al. (2021): Estimating a social cost of carbon for global energy consumption, Nature.

[47] Dataset can be accessed via IEA: https://www.iea.org/data-and-statistics/data-product/world-energy-balances#data-sets

[48] See Moore et al. (2017): New science of climate change impacts on agriculture implies higher social cost of carbon.

[49] See Hultgren et al. (2022): Estimating global impacts to agriculture from climate change accounting for adaptation.

[50] See Diaz. (2016): Estimating global damages from sea level rise with the Coastal Impact and Adaption Model (CIAM).

[51] See Kopp et al. (2023): The framework for assessing changes to sea-level (FACTS) v1.0-rc: A platform for characterizing parametric and structural uncertainty in future global, relative, and extreme sea-level change.

[52] See Rode et al. (2021): Estimating a social cost of carbon for global energy consumption, Nature.

4. Outcomes, Impacts, and Valuation

4.3 MONETARY VALUATION

55. Monetary valuation uses value factors to estimate the relative importance, worth, or usefulness of changes in well-being indicators in monetary terms. The monetary valuation approach and value factors are developed individually for each impact in the GHG Methodology and then added to obtain a single value factor. Each approach is described briefly below. Additional methodological details are provided in Appendix B.

a) *Reduced human health via heat- and cold-related mortality*: The valuation technique used to determine mortality impacts in GIVE and DSCIM is the *value of statistical life (VSL)*. To align with the studies that produced mortality estimates, the VSL uses the EPA's 1990 Guidance value of $4.8 million, adjusted for inflation to the relevant year (e.g. $10.05 million in 2020 USD).[53]

b) *Increased energy demand:* Changes to energy expenditures are valued using market prices paid to utilities. GIVE estimates energy prices by solving the Global Change Analysis Model calibrated to estimates of energy prices allowing for future predictions to be modulated by energy demand and income. DSCIM uses country-level energy prices from the IEA's World Energy Outlook 2017,[54] and other fuel costs from the International Institute for Applied Systems Analysis (IIASA) Scenario Explorer database.[55] Prices are assumed to grow at rate of -0.27% for electricity and 0.82% for other fuels.

c) *Reduced production from the environment via agriculture:* Both GIVE and DSCIM use market prices of each crop as the basis for valuation. GIVE does this through the Global Trade Analysis Project (GTAP) general equilibrium model, which equilibrates prices based on changes in production while also considering consumption and global bilateral trade flows. DSCIM utilizes country-specific average prices per calorie lost that can respond to changes in production to meet demand.[56]

d) *Damages to the built environment and human health via sea-level rise:* Because impacts from sea-level rise can be valued based on inundation, infrastructure/population retreat, construction/maintenance, wetlands, mortality, and physical capital losses, a variety of valuation techniques are used. Techniques in GIVE and DSCIM include land purchase values for land lost, costs for relocation, construction and maintenance costs of building protection, the value of built capital lost, and the VSL for sea-level associated mortality.[57]

e) *Losses in labor availability:* In DSCIM, changes to labor productivity are valued with the compensating wage increase required to counteract the labor disutility from increased temperatures.

56. *Discounting Module:* Because most impacts from GHGs will materialize in the future, they are converted into present value using a social discount rate. The value factor uses a dynamic (stochastic) social discount rate (Ramsey formula) calibrated to meet a near-term social discount rate of 2%. A 2% social discount rate is reinforced by several recent publications,[58,59] matches real, risk-free interest rates observed over the last 30 years,[60] and follows a more equitable approach to valuing impacts on future generations. Further, a dynamic social discount rate is preferred because a static social discount rate is not appropriate when uncertainty in economic growth is considered in modeling approaches, as is the case in the GIVE and DSCIM models.[61] Additional information about the dynamic social discount rate, including a

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[53] See discussion in Chapter 7, page 8 of U.S. Environmental Protection Agency (2010): Guidelines for Preparing Economic Analyses.

[54] DSCIM documentation notes that "Costs are specified for the following geographies: Japan, European Union, Korea, Brazil, Australia, Mexico, Southeast Asia, Middle East, India, Africa, United States, China, Canada, Russia. When a cost is not available specific to a particular geography, we extend these costs based on UN world region classifications: Oceania receives the Australia cost, N., S., and W. Europe receive the EU cost, E. Europe receives the Russia cost, Central America/Caribbean receive the Mexico cost, S. America receives the Brazil cost, N. Africa receives the Middle East cost, and S. Asia receives the India cost." See footnote 55 in Climate Impact Lab (2022): Documentation for Data-driven Spatial Climate Impact Model (DSCIM).

[55] Scenario explorer database can be accessed via IIASA (2022): https://data.ece.iiasa.ac.at/ar6/#/login?redirect=%2Fworkspaces

[56] See The Climate Impact Lab (2022): Data-driven Spatial Climate Impact Model User Manual.

[57] See documentation for each model for more detail on sea-level valuation.

[58] See Nesje et al. (2023): Philosophers and economists agree on climate policy paths but for different reasons.

[59] See EPA. (2023): Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Science Advances.

[60] See Carleton & Greenstone. (2022): A guide to updating the US government's social cost of carbon.

[61] For more detailed information, refer to section V. Illustrative Calculations of the Social Cost of Carbon and Figure 11 in Rennert et al. (2022), The Social Cost of Carbon: Advances in Long-Term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates.

4. Outcomes, Impacts, and Valuation

justification of the 2% rate selection, determination of the growth rate of consumption and elasticity of marginal utility of consumption, and application of the social discount rate can be found in *Discounting Module* section of Appendix B.[62]

57. Utilizing the considerations above, the value factor for GHG emissions that occur in the year 2023 and 2024 are $236 and $239 per metric tons of CO_2e, respectively (Box 1).[63] Both values are adjusted for inflation to 2023 currency.[64] The value factor increases in the future because emissions in each subsequent year lead to greater impacts because of stressed physical and economic systems and income growth. Future year value factors are in Appendix C.

58. The value factor will be reviewed yearly with updates considered as outlined in Box 2. These updates will likely lead to increases in the value factor each year and will be made to the value factor only without revision to the methodology itself.

Box 1. Value Factor	Box 2. Updating GHG Value Factors
$236 per metric ton of CO_2e for 2023 GHG emissions **$239** per metric ton of CO_2e for 2024 GHG emissions	The SCC used to determine the value factor will be updated regularly to take into consideration: **1.** adjustments for inflation, **2.** updated damage functions that more fully represent the impacts of GHG emissions, **3.** updated estimation of future damages as they are closer to present day, and **4.** advancements to the approved models that align with principles and concepts laid out in the General Methodology

[62] For more detailed information on how near-term dynamic social discount rate can affect SCC, see Extended Data Fig.1 of Rennert et al. (2022), Comprehensive evidence implies a higher social cost of CO_2. To see how changes to the Ramsey formula affect the near-term dynamic social discount rate or the distribution of the dynamic social discount rate behaves over time, see Table 2.4.2 and Figure 2.4.1 of EPA (2023): Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Science Advances.

[63] Social cost estimates specific to methane, nitrous oxide, and hydrofluorocarbons have recently been developed. The GHG Methodology guides users to convert all gasses to CO_2e to simplify data requirements, reinforce comparability of impact accounts, and align with reporting standards. If an entity has separate emissions data for each gas, social costs specific to each gas could be considered. See EPA (2023): Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Science Advances and Tan, T. et al. (2024): The social costs of hydrofluorocarbons and the benefits from their expedited phase-down for more detail.

[64] To increase comparability of impact accounts with other financial information, the value factor in future years will be adjusted for inflation. Two common approaches are to use the Consumer Price Index or the Gross Domestic Product Price Deflator.

5. Future Development

5. Future Development

59. The impact pathway and valuation methods presented in the GHG Methodology represent the current state of knowledge built upon decades of rigorous scientific work. But some limitations still exist including the ability of entities to have a complete accounting of Scope 1, 2, and 3 emissions and acknowledgement that the current cost of carbon is still underestimating impact.

60. There are opportunities to further advance impact accounting by exploring new pathways that overcome limitations and reduce uncertainty. Some of these include:

a) new methods and tools that allow for a more complete and accurate accounting of Scope 1, 2, and 3 emissions including separation of each greenhouse gas and Scope 3 category;

b) advancement of social cost of carbon models that incorporate additional damages, greater equity, and gas-specific social costs;

c) incorporation of GHG offsets and carbon credits into impact accounting based on further development of credible frameworks for measuring and verifying their quality and impact; and

d) further incorporation of planetary thresholds and ambitious net-zero targets[65] into models for determining the cost of carbon itself.

61. Significant updates on any of the above, among other developments in the landscape will be used inform future updates to the GHG Methodology, which will be considered periodically.

[65] Such as those set by the Science-based Targets Initiative.

Appendix A: Glossary

Appendix A: Glossary

TERM	DEFINITION	SOURCE[66]
Avoided Emissions (Scope 4 emissions)	Avoided emissions (also sometimes referred to as *Scope 4 emissions*) are the difference between GHG emissions that occur or will occur and GHG emissions that would have occurred without the solution. Examples of products (goods and services) that avoided emissions include low-temperature detergents, fuel-saving tires, energy-efficient ball-bearings, and teleconferencing services. Other terms used to describe avoided emissions include climate positive, net-positive accounting, and scope 4.	World Business Council for Sustainable Development (WBCSD)
Carbon Credit	One carbon credit is equivalent to one metric ton of carbon dioxide, or the equivalent amount of a different GHG reduced, sequestered or avoided.	UNDP
Carbon Dioxide Equivalent (CO_2e)	A metric used to compare the emissions of the different greenhouse gases based upon their global warming potential (GWP). Global warming potentials are used to convert greenhouse gases to carbon dioxide equivalents.	UNFCCC
Carbon Offset Project	A specific project or activity designed to achieve GHG emission reductions, storage of carbon, or enhancement of GHG removals from the atmosphere. GHG projects may be stand-alone projects, or specific activities or elements within a larger non-GHG related project.	GHG Protocol
Carbon Offsets	A discrete GHG reduction used to compensate for (i.e., offset) GHG emissions elsewhere, for example to meet a voluntary or mandatory GHG target or cap. Offsets are calculated relative to a baseline that represents a hypothetical scenario for what emissions would have been in the absence of the mitigation project that generates the offsets. To avoid double counting, the reduction giving rise to the offset must occur at sources or sinks not included in the target or cap for which it is used.	GHG Protocol
Carbon Dioxide Removal (CDR)	Refers to technologies, practices, and approaches that remove and durably store carbon dioxide (CO_2) from the atmosphere.	IPCC
Direct Operations/ Operational Processes (Gate-to-Gate)	Covers activities over which the business has direct operational control, including majority owned subsidiaries.	Natural Capital Protocol

[66] Some definitions are adapted from the original source.

Appendix A: Glossary

TERM	DEFINITION	SOURCE
Discounting/ Social Discount Rate	A mathematical operation that aims to make monetary (or other) amounts received or expended at different times (years) comparable across time. If the social discount rate is positive, future values are given less weight than those today.	IPCC
Downstream Processes (gate-to-grave)	Covers activities linked to the purchase, use, re-use, recovery, recycling, and final disposal of the business' products and services.	Natural Capital Protocol
Ecosystem Services	The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth. The concept "ecosystem goods and services" is synonymous with ecosystem services.	The Millennium Ecosystem Assessment
Fugitive Emissions	Emissions that are not physically controlled but result from the intentional or unintentional releases of GHGs. They commonly arise from the production, processing transmission storage and use of fuels and other chemicals, often through joints, seals, packing, gaskets, etc.	GHG Protocol
Global Warming Potential (GWP)	The index used to translate the level of emissions of various gases into a common measure in order to compare the relative radiative forcing of different gases without directly calculating the changes in atmospheric concentrations. GWPs are calculated as the ratio of the radiative forcing that would result from the emissions of one kilogram of a greenhouse gas to that from the emission of one kilogram of carbon dioxide over a period of time (usually 100 years).	UNFCCC
Greenhouse Gas (GHG)	Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).	UNFCCC
Impact	A change in one or more dimensions of people's well-being directly or through a change in the condition of the natural environment.	N/A (GM1)

Appendix A: Glossary

TERM	DEFINITION	SOURCE
Impact Accounting	The system for measuring and valuing the impacts of corporate entities and generating impact information to inform decisions related to sustainability performance.	N/A (GM1)
Impact Drivers	Refers to the sequence of an entity's inputs and outputs that may have positive and/or negative impacts on people's well-being.	Impact Management Platform (GM1)
Impact Pathway	The series of consecutive, causal relationships, ultimately starting at an input for an entity's activities and linking its actions with related changes in people's well-being.	ISO (GM1)
Input	The resources and business relationships that the entity draws upon for its activities.	Impact Management Platform (GM1)
Integrated Assessment Models (IAMs)	Computational models of global climate change that include representation of the global economy and greenhouse gas emissions, the response of the climate system to human intervention, and impacts of climate change on the human system.	The National Academies of Science, Engineering, and Medicine
Mobile Combustion	Burning of fuels by transportation devices such as cars, trucks, trains, airplanes, ships, etc.	GHG Protocol
Outcome	The level of well-being experienced by people or condition of the natural environment that results from the actions of the entity, as well as from external factors. Outcomes are used to describe the one or more dimensions of people's well-being that are affected by an input, activity, and/or output.	Impact Management Platform (GM1)
Output	The direct result of an entity's activities, including an entity's products, services, and any by-products.	Impact Management Platform (GM1)
Physical Environment	Refers to abiotic, or non-living, components of Earth (e.g., atmosphere, climate, and weather attributes, etc.)	N/A
Process Emissions	Emissions generated from manufacturing processes, such as CO_2 that arise from the breakdown of calcium carbonate ($CaCO_3$) during cement manufacture.	GHG Protocol

Appendix A: Glossary

TERM	DEFINITION	SOURCE
Renewable Energy Certificate (REC)	A type of energy attribute certificate defined as representing the property rights to the generation, environmental, social, and other non-power attributes of renewable electricity generation.	GHG Protocol
Scope 1 Emissions	Emissions from operations that are owned or controlled by the reporting company.	GHG Protocol
Scope 2 Emissions	Emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting company.	GHG Protocol
Scope 3 Emissions	All indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions.	GHG Protocol
Social Cost of carbon (SCC)	The net present value of aggregate climate damages from one more metric ton of carbon in the form of carbon dioxide (CO_2), conditional on a global emissions trajectory over time.	IPCC
Stakeholders	Stakeholders are defined as those who can affect or be affected by the entity.	European Sustainability Reporting Standards (GM1)
Stationary Combustion	Burning of fuels to generate electricity, steam, heat, or power in stationary equipment such as boilers, furnaces, etc.	GHG Protocol
Value of a Statistical Life	The amount individuals would be willing to pay or to accept to experience small changes in mortality risk, aggregated to estimate the monetary value of a reduction in mortality risk of 100%.	US EPA
Upstream Processes (Cradle-to-gate)	Covers the activities of suppliers, including purchased energy.	Natural Capital Protocol

Appendix B: Methodological Details

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INTRODUCTION

B1. Analyses that assess the *impacts in monetary terms* of climate change date back to the early 1990s.[67] These analyses, commonly termed the social cost of carbon (SCC), took a wide variety of approaches in early years to link GHG emissions with societal impacts. Dozens of models have been developed in the ensuing decades leading to ever-evolving approaches and significant advances in quantification of GHG emission impacts. Today numerous countries, entities, and municipalities utilize the SCC approach to measure the impacts of GHG emissions.

B2. Of the various models used to value SCC, two have emerged as significantly advanced over their predecessors and alternatives: the Greenhouse Gas Impact Value Estimator (GIVE) produced by Resources for the Future and the University of California Berkeley [68] and the Data-driven Spatial Climate Impact Model (DSCIM) produced by the Climate Impact Lab.[69] While there are some differences in the approaches of each model, they are notable improvements due to higher resolution input data from more countries and over longer time periods, the ability to produce outputs at a finer spatial resolution, damage models that build in human adaptation in response to climate events, prediction of damages through the year 2300, and the ability to estimate uncertainty through all modules.

B3. Each model excels in distinct areas. DSCIM predicts impacts at a sub-national spatial resolution meaning that predictions are more precisely tied to local factors. DSCIM also has an advanced adaptation model which predicts how society and markets will evolve in response to climate damages. GIVE runs at the country scale and can represent decisions at national scales. The more advanced socioeconomic projections come from the GIVE research group as well, providing ideal complementary information. Finally, a recent synthesis of the SCC literature conducted by the United States EPA concluded that these two models represent the most advanced approaches to calculating an SCC and used it for their updated guidance for cost-benefit analysis for the United States federal government.[70] A third model developed from Howard and Sterner (2017)[71] was considered in the EPA report but not included the GHG Emissions Topic Methodology as it utilized a top-down, meta-analysis-based damage function that did not align with an impact pathway-based approach.

BACKGROUND

B4. Estimating the SCC requires linkages across fields that span earth science, climate science, economics, sociology, and biology. Estimates of the SCC typically use integrated Assessment Models (IAMs) and each model can vary significantly in approach, underlying data resolutions, and feedback mechanisms. However, these IAMs typically have a similar structure including four modules: (1) socioeconomics and emissions, (2) climate, (3) damages, and (4) discounting (Figure B1).

B5. Within the IAM structure, each module produces information that is used by the next module. The socioeconomics and emissions module projects future GDP and human population, allowing future projections of anthropogenic GHG emissions to be created. Projections of GHG emissions become the inputs of the climate module. The climate module translates these GHG emissions into future CO_2 concentrations, temperatures, and sea level rise. The damage module uses the changes to the physical environment along with socioeconomic variables to produce societal economic damages. At this point in the process, the entire model is run twice. In the first iteration, the model is run as is with no additions (e.g., the 'baseline' iteration). In the second iteration, the model is run with an additional pulse of GHG emissions at a particular year of interest. This results in SCC estimates over an expected timescale in which the additional pulse of GHG emissions is expected to cause monetary impact. Finally, the discounting module translates multi-year, economic damages into present-day monetary values (i.e., the year at which the unit of emissions was released).

[67] See Nordhaus. 1991: Economic approaches to greenhouse warming and Frankhauser 1996: Climate change costs: recent advancements in the economic assessment.

[68] See Rennert et al. (2022): Comprehensive evidence implies a higher social cost of CO_2.

[69] See Climate Impact Lab. (2022): Data-driven Spatial Climate Impact Model User Manual, Version 092022- EPA.

[70] See EPA. (2023): Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Science Advances.

[71] Howard, P. H., & Sterner, T. (2017). Few and Not So Far Between: A Meta-analysis of Climate Damage Estimates.

Appendix B: Methodological Details

MODULES FOR THE INTEGRATED ASSESSMENT MODEL (IAM)

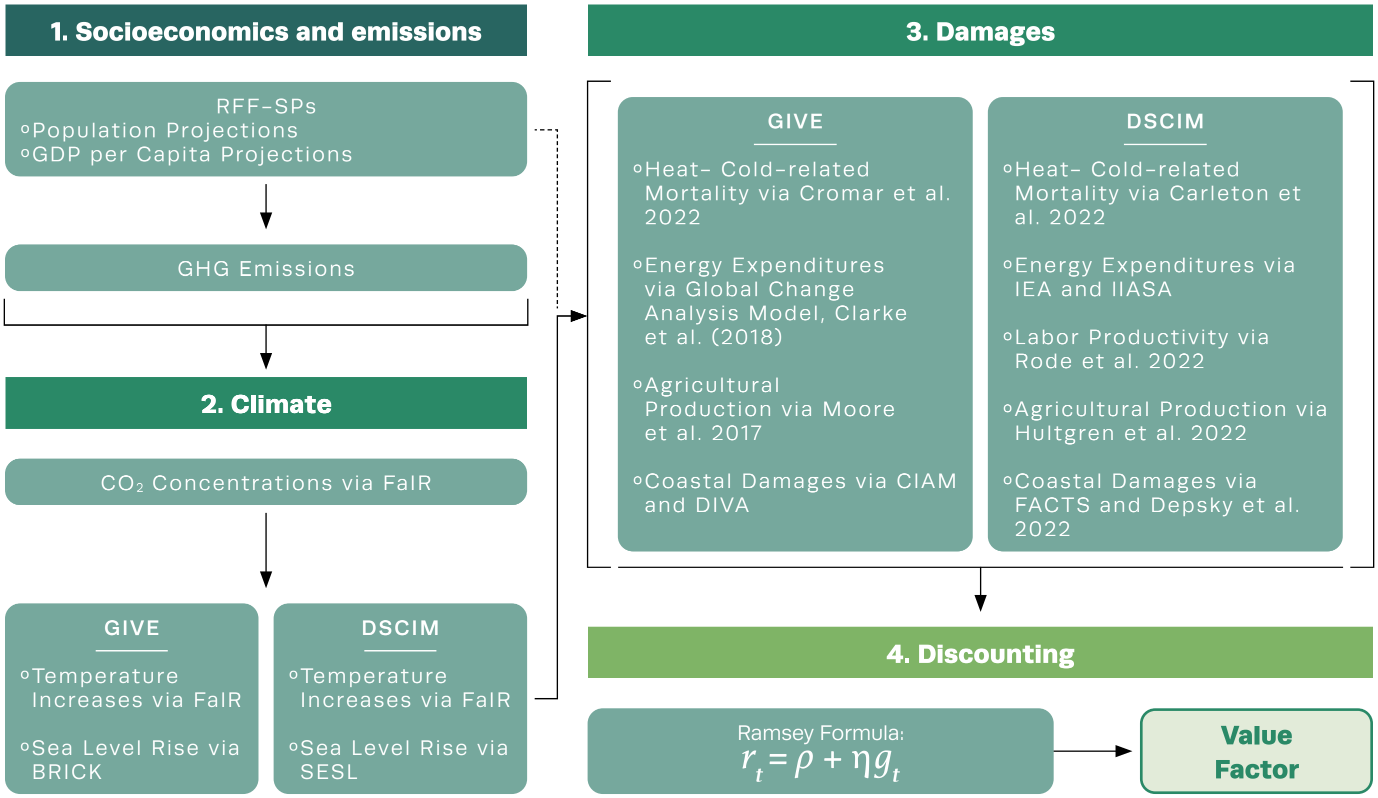

Figure B1. Diagram of the four modules that are used to develop a value factor via integrated assessment models including approaches used by GIVE and DSCIM.

SOCIOECONOMIC AND EMISSIONS MODULE

B6. The Socioeconomic and Emissions Module represents the first step in the SCC process. Information within this module serves two purposes: (1) to model future GHG emissions, which serves as the input for the Climate Module, and (2) provide projections of GDP and human population, which serve as inputs or the damage and discounting modules. Socioeconomic trajectories are significant predictors of climate damages because population and income levels together increase GHG emissions and lead to more willingness for climate change avoidance.[72] A pulse of GHGs emitted today will have long-lasting effects on the planet. As a result, it is crucial that parameters used in the SCC valuation process (1) are projected far into the future, (2) account for future regulatory policies and technological advancements, (3) incorporate the complex uncertainties associated with each estimate and (4) are disclosed in a transparent fashion.

B7. Both GIVE and DSCIM utilize models developed under the Resources for the Future Social Cost of Carbon Initiative (called RFF-SPs), which are designed to produce socioeconomic projections through the lens of SCC estimates.[73] Similar to the IPCC-sponsored Relative Concentration Pathways (RCP) scenarios, RFF-SPs establish future emissions projections by a range of possible radiative forcing values reached by 2100 (e.g., SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5). Scenarios were developed using a classical model of structured expert judgment. Experts provided quantiles of uncertainty for fossil fuel and process-related emissions (incorporating emission sensitivity to five GDP per capita trajectories), changes in natural CO_2 stocks and carbon abatement technologies, CH_4 concentrations, and N_2O concentrations for years 2050, 2100,

[72] Ibid.

[73] See Rennert et al. (2022). The Social Cost of Carbon: Advances in Long-Term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates.

2150, 2200, and 2300.[74] The GHG Emissions Topic Methodology applies RFF-SP scenario SSP2-4.5, which most closely mirrors the median scenario developed by the expert panel.

B8. The RFF-SPs build probabilistic projections of human population and GDP to the year 2300. The year 2300 was chosen to satisfy recommendations from the United States National Academies, which suggest modeling the time horizon "far enough in the future to provide inputs for estimation of the vast majority of discounted climate damages."[75] In the case of the GIVE and DSCIM models, marginal damages and social discount rates peak by 2100 and continue to steadily decline through 2300, capturing the majority of damages associated with CO_2, CH_4, and N_2O emissions.

B9. For human population estimates, the mean RFF-SP population trajectory shows a gradual increase in human population until a peak of ~11 billion around the year 2100, followed by a gradual decline beyond the year 2300, at which the population is under 10 billion. Projected mean RFF-SP GDP per capita growth rates remain relatively consistent at 1.6% until 2100. Values decline gradually between 2100-2200, leveling off to 1.1% in the year ~2200. The mean RFF-SP projection predicts CO_2 emissions will peak before 2050, followed by a gradual decline towards net-zero emissions through 2300.

CLIMATE MODULE

B10. The climate module uses emissions projections to model future physical climate variables – namely, CO_2 concentrations, temperature, and sea level rise (SLR). This process starts by modelling the impact GHG emissions projections have on energy imbalance imposed on the climate system (i.e., radiative forcing), accounting for heat uptake by the world's oceans. This process allows for the projection of important climate variables (e.g., sea level rise) which serve as inputs to the damage module. The final input relayed to the damage module is estimated by creating a modelled baseline scenario (represented by the RFF-SPs themselves, a scenario without a given pulse of emissions) and comparing the results to a scenario in which a pulse of GHG emissions is produced in the year of interest.

B11. Both GIVE and DSCIM determine climate responses (in terms of the global climate system and carbon dynamics) by utilizing version 1.6.2 of the Finite Amplitude Impulse Response (FaIR) model.[76,77] FaIR has been used extensively in peer-reviewed literature and includes methodological transparency, model simplicity, accuracy, and disclosure of uncertainty.[78]

B12. GIVE and DSCIM use different models to project sea level rise (SLR). GIVE uses the Building blocks for Relevant Ice and Climate Knowledge (BRICK) model.[79] BRICK estimates SLR by incorporating data from glacier, ice cap, and ice sheet melting, oceanic thermal expansion, and land water storage. BRICK also models tipping point events, such as rapid ice sheet melting when threshold temperatures are crossed. DSCIM projects SLR by using the Semi-Empirical Sea Level (SESL) to predict global mean sea levels and temperatures with and without an emissions pulse.[80] This information is used to determine global mean sea level changes over time. Estimate uncertainty is incorporated using the Framework for Assessing Changes to Sea-level (FACTS). FACTS creates SLR alternative probability distributions of global SLR, regional SLR, and extreme levels of SLR that are aligned with results presented in the IPCC's AR6.[81]

DAMAGE MODULE

B13. The damage module converts changes to the physical environment to damages in monetary terms

[74] See Figure 7 of Rennert, K. et al. (2022). The Social Cost of Carbon: Advances in Long-Term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates.

[75] National Academies Press. (2017). Valuing Climate Damages: Updating estimation of the social cost of carbon dioxide.

[76] See the 'Climate models' subsection of the Methods in Rennert et al. 2022. Comprehensive evidence implies a higher social cost of CO_2; See Section 3.2 in Climate Impact Lab. (2022). Documentation for Data-driven Spatial Climate Impact Model (DSCIM).

[77] The Finite Amplitude Impulse Response (FaIR) model can be accessed via: https://docs.fairmodel.net/en/latest/

[78] See Climate Impact Lab. (2022): Data-driven Spatial Climate Impact Model User Manual, Version 092022- EPA.

[79] See Wong et al. (2017). BRICK v0.2, a simple, accessible, and transparent model framework for climate and regional sea-level projections.

[80] See Climate Impact Lab. (2022). Data-driven Spatial Climate Impact Model User Manual, Version 092022- EPA.

[81] See Kopp et al. (2023). The framework for assessing changes to sea-level (FACTS) v1.0-rc: A platform for characterizing parametric and structural uncertainty in future global, relative, and extreme sea-level change.

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(impacts). The outputs of the damage module can be generally divided into market damages (e.g., changes to agricultural productivity) and non-market damages (e.g. mortality rates).[82] GIVE and DSCIM differ markedly in their approach to the damage module, which is discussed below.

B14. The GIVE model has, thus far, incorporated four damages: heat- and cold-related mortality, energy expenditures, agricultural productivity, and coastal effects including land/capital loss and mortality.

a. GIVE incorporates heat- and cold- related mortality estimates using results from a comprehensive meta-analysis[83] which estimated the effects of incremental temperature increases of 1°C on categorical mortality risks (e.g., cardiovascular, respiratory, gastrointestinal, etc.). Excess mortality estimates are valued by using the EPA's 1990 Guidance value for a statistical life (VSL) of $4.8 million, adjusted to $10.05 million in 2020 dollars.[84]

b. Energy expenditures are modeled by linking temperature effects of climate change to country-level increases in electricity expenditures through 2100 using the Global Change Analysis Model.[85,86] Country-level energy expenditures are valued by multiplying excess energy expenditure by prices of those utility services and scaling globally by comparing country-level GDP.

c. Agricultural productivity damages are determined using research provided by Moore et al. 2017,[87] which determined the effects of rising temperatures on agricultural yield shocks. This was done by (1) creating a meta-analysis of 1010 published estimates of yield responses of maize, rice, wheat, and soybeans to climate change and (2) monetizing these impacts via the Global Trade Analysis Project (GTAP) general equilibrium model, which comprehensively tracks global bilateral trade flows and models the production and consumption of commodities for all national economies.[88]

d. Finally, GIVE incorporates coastal damages via the Coastal Impacts and Adaptation Model (CIAM), which assesses the costs associated with various flooding damage adaptation strategies as well as impacts to regional coastlines due to SLR.[89] Coastal impacts are valued via the Dynamic Interactive Vulnerability Assessment (DIVA) database, selecting the least-cost strategy for region-specific coastlines.[90]

B15. DSCIM incorporates five damage categories: Heat- and cold- related mortality, energy expenditures, labor productivity, and agricultural damages.

a. DSCIM estimates heat- and cold- related mortality by deriving age-specific relationships between temperature and mortality using subnational data from 40 countries (1990-2020).[91] Similar to GIVE, heat- and cold-related mortality is valued using the EPA's VSL adjusted to 2019 dollars.[92]

b. Electricity expenditures are incorporated using information provided by an estimate of climate change on global energy consumption.[93] This research utilizes electricity and other fuel usage from 146 countries between 1971-2010 from the International Energy Agencies' (IEA) World Energy Balances dataset.[94] These impacts are valued using two data sources – present-day electricity costs are provided by region via the IEA's World

[82] See Section 2.3: Damage Module of EPA. (2023). Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Science Advances.

[83] See Cromar et al. (2022). Global health impacts for economic models of climate change: A systematic review and meta-analysis.

[84] See discussion in Chapter 7, page 8 of U.S. Environmental Protection Agency (2010): Guidelines for Preparing Economic Analyses.

[85] See Clarke et al. (2018). Effects of long-term climate change on global building energy expenditures.

[86] See Edmonds et al. (2004). Stabilization of CO_2 in a B2 world: insights on the roles of carbon capture and disposal, hydrogen, and transportation technologies.

[87] See Moore et al. (2017). New science of climate change impacts on agriculture implies higher social cost of carbon.

[88] Ibid.

[89] See Diaz (2016). Estimating global damages from sea level rise with the Coastal Impact and Adaption Model (CIAM).

[90] See Vafeidis et al. (2008). A new global coastal database for impact and vulnerability analysis to sea-level rise.

[91] See Carleton et al. (2022). Valuing the global mortality consequences of climate change accounting for adaptation costs and benefits.

[92] Ibid.

[93] See Rode et al. (2021). Estimating a social cost of carbon for global energy consumption, Nature.

[94] Dataset can be accessed via IEA. https://www.iea.org/data-and-statistics/data-product/world-energy-balances#data-sets

Energy Outlook 2017,[95] and other fuel costs are obtained from the International Institute for Applied Systems Analysis (IIASA) Scenario Explorer database.[96]

c. Labor productivity damages are represented by the relationship between temperature increases and labor losses, measured in terms of labor disutility.[97] Increases in daily temperatures have been connected to hour reductions for workers in industries where outdoor work is required, such as in construction, agriculture, transportation, and more. The compensating wage increase required to counteract the labor disutility is used to value the impact.

d. Agricultural production damages are determined by analyzing the impacts on six staple crops which represent ~two-thirds of global crop caloric production – maize, wheat, rice, soy, sorghum and cassava.[98] Agricultural damages are valued by incorporating the economics surrounding agricultural adaptations, including costs, benefits and adaptation adoption rates, while also accounting for the beneficial effects of CO_2 fertilization.[99]

e. Finally, coastal damages are accounted for by determining the effects of SLR on coastal inundation. As discussed in the climate section, DSCIM utilizes the FACTS model to provide global SLR projections. Coastal damages are valued via the DSCIM-Coastal v1.0 modelling platform[100] which incorporates costs related to inundation, infrastructure/population retreat, construction/maintenance, wetlands, mortality, and physical capital losses from SLR.

B16. Both GIVE and DSCIM include transparent modelling techniques that incorporate uncertainty parameters for each damage function.[101,102]

B17. Both GIVE and DSCIM are iterative and modular that will continue to be updated as state-of-the-art modeling techniques and further information becomes available. Active research is exploring biodiversity, ecosystem services, labor productivity, wildfire, ocean impacts, conflict, and migration damages. As more categories of damages are added to these IAMs, estimates of SCC are likely to increase. Thus, current SCCs determined by IAMs are likely underestimates of the total impact of GHGs.

DISCOUNTING MODULE

B18. Damages from carbon emitted today cause long-lasting impacts on stakeholders including future generations. In the discounting module, future marginal damages determined by the damages module are discounted to present day values.

B19. The prevailing approach to discounting climate-related impacts is to use the Ramsey formula[103] to create a dynamic social discount rate. Generally, the Ramsey formula is denoted as: $r_t = \rho + \eta g_t$

Where r_t represents the social discount rate at time, g_t represents the rate of pure time preference, represents the mean consumption growth rate to year t, and η represents the elasticity of marginal utility of consumption. By utilizing this formula, a dynamic social discount rate is created that responds to changes in the consumption growth rate.

[95] DSCIM documentation notes that "Costs are specified for the following geographies: Japan, European Union, Korea, Brazil, Australia, Mexico, Southeast Asia, Middle East, India, Africa, United States, China, Canada, Russia. When a cost is not available specific to a particular geography, we extend these costs based on UN world region classifications: Oceania receives the Australia cost, N., S., and W. Europe receive the EU cost, E. Europe receives the Russia cost, Central America/Caribbean receive the Mexico cost, S. America receives the Brazil cost, N. Africa receives the Middle East cost, and S. Asia receives the India cost." See footnote 55 in Climate Impact Lab. (2022). Documentation for Data-driven Spatial Climate Impact Model (DSCIM).

[96] Scenario explorer database can be accessed via IIASA (2022). https://data.ece.iiasa.ac.at/ar6/#/login?redirect=%2Fworkspaces

[97] See Rode et al. (2021). Estimating a social cost of carbon for global energy consumption, Nature.

[98] See Hultgren et al. (2022). Estimating global impacts to agriculture from climate change accounting for adaptation.

[99] See Moore et al. (2017). New science of climate change impacts on agriculture implies higher social cost of carbon.

[100] See Depsky et al. (2022). DSCIM-Coastal v1.0: An Open-Source Modeling Platform for Global Impacts of Sea Level Rise.

[101] See Rennert et al. (2022). Comprehensive evidence implies a higher social cost of CO_2.

[102] See section 4: Damages Module in Climate Impact Lab. (2022). Data-driven Spatial Climate Impact Model User Manual, Version 092022- EPA.

[103] See Ramsey, F.P. (1928). A mathematical theory of saving.

Appendix B: Methodological Details

B20. The pure rate of time preference (ρ) considers how much we discount the future simply because it is in the future. There is some convergence among economists and philosophers that the pure rate of time preference should be low or near zero as an ethical stance on intergenerational equity.[104,105] The elasticity of marginal utility of consumption (η) considers the rate at which marginal utility of consumption changes as society grows richer. This parameter is acknowledging that richer societies value one dollar less than poorer societies (Diminishing Marginal Utility of Income). Most current studies propose that this parameter should be driving social discount rates.

B21. However, the DSCIM and GIVE models address probabilistic socio-economic scenarios (as discussed in the *Socioeconomic and Emissions Module* section above). As a result, the average consumption of growth to year t, g_t, must incorporate degrees of uncertainty; otherwise, the average social discount rate to year t, r_t, will also be uncertain.[106] Thus, the classical Ramsey equation denoted above is modified to represent a dynamic (stochastic) social discount factor, where stochastic marginal damages from an incremental pulse of emissions (MD_t) is discounted to a present value (PV) equivalent via:

$$PV(MD_t) = E[\int_{t=0}^{T} e^{-(\rho+\eta g_t)t} MD_t]$$

Where the expression $e^{-(\rho+\eta g_t)t}$ represents a stochastic discount factor due to a stochastic growth rate. The importance of applying dynamic discount factors is being recognized in the literature as an important update in connecting climate and macro-economics.[107,108,109.]

B22. Both GIVE and DSCIM have been implemented with the Ramsey formula using parameters that correspond to a near-term target social discount rate of 2%. This differs from the previous U.S. government estimates for a *static* social discount rate of 3%. It has been argued since then that the choice of a *static* 3% social discount rate effectively treats costs to a very rich hypothetical future generation the same as if an equivalent cost were applied to an impoverished hypothetical future generation, which is incorrect from a welfare perspective and receives little support from economists working in the nexus of climate and macro-economic research.[110] The selection of a 2% near-term target social discount rate – leading to a pure rate of time preference (ρ) of 0.20% and an elasticity of marginal utility of consumption (η) of 1.24[111] – ensures that scenarios in which both marginal damages and consumption growth are high will be discounted at a higher rate.[112] A 2% social discount rate is consistent with real, risk-free interest rates observed over the last 30 years.

104 See Carleton & Greenstone. (2022). A guide to updating the US government's social cost of carbon.

105 See Nesje et al. (2023). Philosophers and economists agree on climate policy paths but for different reasons.

106 See the Stochastic Growth Discounting with Economic Uncertainty section of Rennert et al. (2022), The Social Cost of Carbon: Advances in Long-Term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates.

107 See Barnett et al. (2020). Pricing Uncertainty Induced by Climate Change.

108 See Barnett et al. (2022). Climate Change Uncertainty Spillover in the Macroeconomy.

109 See Cai and Lontzek. (2019). The Social Cost of Carbon with Economic and Climate Risks.

110 See page 35 of Rennert et al. (2022), The Social Cost of Carbon: Advances in Long-Term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates.

111 See Rennert et al. (2022): Comprehensive evidence implies a higher social cost of CO_2.

112 See page 66 of EPA. (2023): Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Science Advances.

Appendix B: Methodological Details

MODEL OUTPUTS AND VALUE FACTORS

B23. Both GIVE and DSCIM produce a social cost of carbon for each individual impact in the damage module. These are summarized in Table B1. Because of the distinct and complimentary approaches used by each model, the estimates of impacts by category often vary. In both models, mortality from heat and cold exposure represent the largest impacts while coastal damages are consistently small for both. There is notable divergence in the estimated impacts on agricultural production with the GIVE model producing a much higher impact. Additional analysis of the differences in GIVE and DSCIM can be found in the 2023 EPA report.

B24. The total social costs of carbon from GIVE and DSCIM are averaged to determine the value factor in a given year. The utilization of both models takes advantage of their complimentary strengths and their consideration as two equally advanced models.

MODEL LIMITATIONS

B25. Both GIVE and DSCIM represent substantial progress in the development of SCC estimates and represent a cutting-edge development in the field. However, both models still do not capture several important categories of climate impacts and associated damages, generally due to data and modeling limitations.[113] Both GIVE and DSCIM are iterative, with plans to include more categories of damages in the future. As a result, reported SCCs most likely represent underestimates of the full impact. A non-exhaustive list of limitations to current modeling efforts are described below.

Impact	GIVE (2023 USD)	DSCIM (2023 USD)
Heat- and Cold-Related Mortality	$111	$180
Energy Expenditures	$12	– $4
Agricultural Production	$108	$6
Coastal Damages	$3	$4
Labor Productivity	NA	$50
Total	**$234**	**$236**

Table B1. Breakdown by category of impact on the social cost of carbon from GIVE and DSCIM for 2023 emissions.

[113] See table 3.2.1 of EPA. (2023): Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Science Advances.

Appendix B: Methodological Details

B26. Human health, well-being, built environment, and food production impacts are only partially incorporated in current modeling efforts. Though projections of average temperatures and sea level rise are currently incorporated into the models, temperature extremes and variability are much more difficult to assess and are not currently incorporated. As a result, impacts regarding mortality and morbidity from extreme weather events, such as storms, wildfires, flooding, and sea level rise, are not incorporated into current modeling efforts. Further climate impacts regarding infectious diseases, displacement and migration, and other morbidity (e.g., malnutrition, allergies) are not currently incorporated. Though labor supply (i.e., hours worked) is fully incorporated into current models, labor productivity (i.e., output per hour worked) is not currently incorporated. Built environment impacts, currently represented by the effects of sea level rise on coastal infrastructure, does not incorporate impacts regarding increased coastal storm frequency and intensity, extreme inland weather, and changes to environmental conditions. Food production impacts, currently represented by agriculture and crop production, does not incorporate impacts regarding livestock productivity or fishery/aquaculture production.

B27. Other impact categories are fully unrepresented in current modeling efforts. These categories include damages related to forestry (timber, pulp, paper production), tourism (i.e., declining visitation to recreational fishing areas, skiing, scuba diving, etc.), ecosystem services (i.e., provisioning and regulating services, biodiversity, natural capital used in marketable goods), crime (property, violent), national security, or impacts in trade and logistics.

B28. Current and future work will actively explore ways to incorporate categories that are not represented, or under-represented, in current model iterations. Areas of active research are exploring how to incorporate damages associated with biodiversity, ecosystem services, labor productivity, wildfire, ocean impacts, conflict, and migration damages.

Appendix C: Future Value Factors and Example Calculations

Appendix C: Future Value Factors and Example Calculations

Table C1 provides value factors for emissions that occur in each year from 2020 to 2035 based on current projections. These values are intended for analysis that is considering forward or backward–looking projections from the present year. For the years 2020 – 2022, the value factors have been adjusted for inflation to the year in reference (e.g. the 2020 Value Factor is in 2020 U.S. Dollars). All values for future years in this table are in 2023 U.S. Dollars.

In this Table, each model predicts damages that will occur each year from the present to the year 2300. The value factor increases in the future because emissions in each subsequent year lead to greater impacts because of stressed physical and economic systems and income growth.

Please note, when referencing Table C1, that these values will vary from the periodic updates of the value factor that are used in the methodology based on the evolving nature of SCC models and the reasons outlined in Box 2.

YEAR OF GHG EMISSIONS	VALUE FACTOR ($/METRIC TON CO_2E)		
	AVERAGE	GIVE	DSCIM
2020	$190	$190	$190
2021	$205	$205	$204
2022	$223	$223	$224
2023	$236	$234	$236
2024	$239	$237	$242
2025	$244	$240	$247
2026	$248	$244	$252
2027	$252	$247	$257
2028	$256	$250	$262
2029	$260	$254	$267
2030	$265	$257	$272
2031	$269	$261	$277
2032	$273	$264	$282
2033	$277	$267	$287
2034	$281	$271	$292
2035	$286	$274	$298

Table C1. Value factors developed from GIVE, DSCIM and Averaged.

Appendix C: Future Value Factors and Example Calculations

EXAMPLE CALCULATION.

Consider a theoretical company with the following GHG emissions profile from the year 2023:

- Scope 1: (*200,000*) metric tons of CO_2e
- Scope 2: (*300,000*) metric tons of CO_2e
- Scope 3 Upstream: (*4 million*) metric tons of CO_2e
- Scope 3 Downstream: (*1 million*) metric tons of CO_2e

To develop impact accounts, preparers can use equations 1 – 5 from section 4.1.
Because the emission occurred in 2023, the value factor of $236 is used.

First, equation 2 can be used to determine Scope 1 Impact:

$Em_{scope1} * Vf = \textbf{GHG Value}_{scope1}$ (Eq. 2)

$200{,}000\ CO_2e * \$236 = \textbf{\$47.2 million}$ (Eq. 2)

Then, equation 3 can be used to determine Scope 2 Impact:

$Em_{scope2} * Vf = \textbf{GHG Value}_{scope2}$ (Eq. 3)

$300{,}000\ CO_2e * \$236 = \textbf{\$70.8 million}$ (Eq. 3)

Then, equation 4 can be used to determine Scope 3 Upstream Impact:

$Em_{scope3up} * Vf = \textbf{GHG Value}_{scope3upstream}$ (Eq. 4)

$4 \text{ million tonnes } CO_2e * \$236 = \textbf{\$944 million}$ (Eq. 4)

Then, equation 5 can be used to determine Scope 3 Downstream Impact:

$Em_{scope3down} * Vf = \textbf{GHG Value}_{scope3downstream}$ (Eq. 5)

$1 \text{ million tonnes } CO_2e * \$236 = \textbf{\$236 millio}$ (Eq. 5)

Then, equation 1 can be used to determine Total Impact:

$\sum(Em_{scope} * Vf) \text{ from Scope } 1-3 = \textbf{GHG Value}_{Total}$ (Eq. 1)

$\$47.2 \text{ million} + \$70.8 \text{ million} + \$944 \text{ million} + \$236 \text{ million} = \textbf{\$1.298 billion}$

Appendix D: Alignment with Reporting Standards

Appendix D: Alignment with Reporting Standards

D1. The data inputs required to prepare impact accounts that measure and value GHG emissions closely align with the disclosure requirements of the European Sustainability Reporting Standards E1: *Climate Change*, the International Financial Reporting Standards S2: *Climate-related Disclosures*, and the Global Reporting Initiative 305: Emissions 2016.

D2. ESRS *E1: Climate Change*:

a) Disclosure Requirement E1-6 paragraph 41 states "The undertaking shall disclose its: (1) gross Scope 1 GHG emissions; (b) gross Scope 2 GHG emissions; (c) gross Scope 3 GHG emissions; and (d) total GHG emissions."

- This statement only considers emissions and requires reporting of Scope 1, 2, and 3. This fully aligns with the total scope of emissions stated in *Section 3.1 Data Requirements* of this Methodology.

b) Paragraphs 45, 46, and 48 state that GHG emissions shall be reported in CO_2e using units of metric tons. This guidance aligns with *Section 3.1 Data Requirements* of this Methodology.

D3. IFRS *S2: Climate-related disclosures*:

a) In the section "Climate-related metrics", paragraph 29 states: "the entity shall disclose its absolute gross greenhouse gas emissions generated during the reporting period expressed as metric tons of CO_2 equivalent, classified as: (1) Scope 1 greenhouse gas emissions; (2) Scope 2 greenhouse gas emissions; and (3) Scope 3 greenhouse gas emissions".

- This statement only considers emissions and requires reporting of Scope 1, 2, and 3. This aligns with the total scope of emissions stated in *Section 3.1 Data Requirements* of this Methodology.

b) Paragraph 29 states that GHG emissions shall be reported in CO_2e using units of metric tons. This guidance aligns with *Section 3.1 Data Requirements* of this Methodology.

D4. GRI *305: Emissions 2016*:

a) Disclosures 305-1 (Scope 1), 305-2 (Scope 2), and 305-3 (Scope 3) require reporting organizations to report the "gross GHG emissions" in each Scope.

- This statement only considers emissions and requires reporting of Scope 1, 2, and 3. This aligns with the total scope of emissions stated in *Section 3.1 Data Requirements* of this Methodology.

b) Disclosures 305-1 (Scope 1), 305-2 (Scope 2), and 305-3 (Scope 3) state that reporting should be "in metric tons of CO_2 equivalent". This guidance aligns with *Section 3.1 Data Requirements* of this Methodology.

Appendix E: Value Commission Transparency Report: Value Factor

Appendix E: Value Commission Transparency Report: Value Factor

This Appendix presents the GHG Emissions Topic Methodology summarized in the form of the Transparency Report proposed by the Value Commission. Minor adaptations have been made to the report structure to align with the impact accounting methodology.

<table>
<tr><th colspan="2">TRANSPARENCY REPORT – VALUE FACTORS</th></tr>
<tr><td colspan="2">Title and version #: GHG Emissions Topic Methodology Value Factor, Version 1
Developed by: International Foundation for Valuing Impacts, in partnership with Value Balancing Alliance
Published and updated date: September 17, 2024</td></tr>
<tr><td colspan="2">Unit: The impact in dollars per metric ton ($/ton) of GHG emissions to calculate the total impact from GHG emissions with the same value used for all geographies.</td></tr>
<tr><td colspan="2">Linkages to other value factors: This value factor is part of the public good, independent, impact accounting methodology being developed by IFVI, in partnership with VBA and can be combined or complemented with value factors from other topic methodologies.</td></tr>
<tr><th colspan="2">SCOPE OF VALUE FACTOR</th></tr>
<tr><td>Impact pathway scope</td><td>• The scope of the value factor includes all GHGs, as defined by the GHG Protocol, along the entire value chain.
• The value factor captures many impacts quantified by leading models while future work will continue to explore the valuation of additional impacts.
• More detail about the impact pathway scope can be found in 'Section 1.4: Scope and Assumptions' and in the GHG Emissions Topic Methodology Basis for Conclusions.
• Application of the methodology by an entity is based on a materiality assessment as outlined by General Methodology 1: Conceptual Framework for Impact Accounting</td></tr>
</table>

Appendix E: Value Commission Transparency Report: Value Factor

	ESTIMATING CHANGES IN WELL-BEING	ESTIMATING MONETARY VALUE
Approach and specificity	• Via the SCC models GIVE and DSCIM, changes in well-being are determined through a combined series of modules that project future population, GDP, GHG emissions, climate, and damages. Each module has a series of sophisticated projections with outputs linking to the next module. • The changes in well-being estimated include reduced human health via heat- and cold-related mortality, increased energy cost, reduced agricultural production from the environment, damages to the built environment and human health via sea-level rise, and losses in labor availability. • Both models have data inputs from many countries and model impacts at the national or sub-national level leading to high-quality representation. • Present research has not yet captured all impacts on society in rigorous models and future work will continue to develop value factors for these impacts. • Additional details about estimating changes in well-being can be found in 'Section 4.2: Outcomes and Impacts' and 'Appendix B: Methodological Details.'	• For each of the changes in well-being societal impacts are modelled through the damage and discounting modules. • The approaches to convert impacts into monetary terms take an array of approaches that can be found in 'Section 4.3: Monetary Valuation'. • Future impacts are discounted to present-day values using a dynamic 2% discount rate. • Because the SCC models have spatially detailed estimations, the approaches are highly specific and consider local considerations in the valuation process. • Additional details about estimating societal impacts can be found in 'Section 4.3: Monetary Valuation' and 'Appendix B: Methodological Details.'
Data inputs	• The data sources to run GIVE and DSCIM are extensive and embedded within the models and associated citations therein. • For data sets, see Table 2, Figure B1, and 'Appendix B: Methodological Details' along with the primary literature sources cited in each.	
VIEWS OF AFFECTED STAKEHOLDERS		
Representation of stakeholders	• The impact accounting methodology is overseen by a Valuation and Technical Practitioner Committee (VTPC) and developed through due process designed to ensure stakeholder inputs and representation. • This process includes independent research, expert engagement, piloting, and a public comment period prior to finalization by the VTPC. [114] • In addition, the development of GIVE and DSCIM both included data inputs and feedback from a globally diverse sample of countries leading to better representation of global stakeholders in each model along with the application of impacts at a more localized level.	

[114] Public comment results can be viewed here: https://ifvi.org/wp-content/uploads/2024/03/IFVI_VBA-GHG-Public-Comment-letters.pdf

Appendix E: Value Commission Transparency Report: Value Factor

ETHICAL DECISIONS IN ESTIMATING SOCIETAL IMPACT	
Equity weightings and income adjustments	• Equity weighting is not incorporated into the value factor. Both GIVE and DSCIM are newer models and have not fully incorporated equity weighting into their frameworks. Exploration of equity weighting incorporation will be considered in future model updates. • Benefit transfer of impacts are done utilizing the relationship between willingness to pay and income and adjusts by applying an income elasticity parameter.
Accounting for future impacts	• The value factor incorporates future impacts from present GHG emissions through the year 2300, further projections than any other models or approaches. • Future impacts are discounted using a 2% dynamic discount rate (Ramsey formula). See 'Appendix B: Methodological Details' for more information about discounting.
Other ethical considerations	• N/A
SENSITIVITY	
Sensitivity to key variables	• Sensitivity analyses have been conducted by model developers of both GIVE and DSCIM as well as the U.S.A. EPA[115]. See these resources and associated citations for added details about sensitivities to various model inputs. • Because the SCC runs and links a series of sophisticated models, many parameters through the linkages can lead to notable changes in the value factor. • Most notably, SCC estimates are highly sensitive to the discount rate with 0.5% changes affecting the value factor by 40 – 70 % depending on other model specifications. The EPA report provides SCC outputs at different discount rates to illustrate this variation. • The value factor is sensitive to the inclusion of some damage functions more than others. Most notably, heat- and cold-related mortality and loss of agricultural production have the most variation within each model and across both models.

[115] For additional insight into sensitivity analyses see: Rennert et al. (2022): Comprehensive evidence implies a higher social cost of CO_2; The Climate Impact Lab. (2022): Data-driven Spatial Climate Impact Model User Manual; EPA (2023): Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Science Advances.

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