STANDARDIZED NATURAL CAPITAL MANAGEMENT ACCOUNTING

A methodology promoting the integration of nature in business decision making

June 2023

About this document

This document was developed through the EU LIFE program by the Transparent Project. Detailed feedback from a number of experts helped to steer its development. Input from a consultation as well as a piloting process contributed to the presented standardized approach and this documentation.

Disclaimer

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FOREWORD

The accelerating deterioration of natural ecosystems, the loss of biodiversity, and a rapidly changing climate are fundamentally changing the traditional context for business decision making. Once a fringe discussion, the role that natural systems play is now accepted in the mainstream as essential to the functioning of our economic and financial systems.

Governments, business leaders, and investors across the world are increasingly recognizing their dependence on the health of natural capital, and the ways in which their impacts on nature may undermine their continued success. The urgent need for action is reflected in significant momentum globally towards better understanding, measuring, and managing the role of non-financials in enterprise value. The realms of academia, finance, business, and policy are all contributing to the further development and harmonization of approaches.

In Europe, the urgency of the environmental crisis has been recognized by policymakers in the Green Deal. Through a comprehensive set of policy measures, such as the Sustainable Finance Disclosure Regulation (SFDR), the Corporate Sustainability Reporting Directive (CSRD), the Taxonomy Regulation, or the work of the Joint Research Centre (JRC) around Organization Environmental Footprints (OEF) and Product Environmental Footprints (PEF), the European Commission has demonstrated its commitment that a shift is required in the way that both the public and private sectors understand and account for their relationships with nature.

Both at the EU and international level, the Transparent project, G7 and others (such as the International Foundation for Valuing Impacts) support the harmonization of impact measurement and valuation methods.

There are now many examples of how business has applied a multi-capitals approach to inform decisions. But even with internationally recognized harmonized frameworks such as the Natural Capital Protocol [1], practice to measure and steer business is not yet standardized through the application of concepts in a consistent manner.

To achieve the ambition of the Green Deal and the globally agreed UN Sustainable Development Goals, requires a robust approach to accounting for natural capital that is generally accepted and commonly used by all businesses. To support effective and informed business decision making, this approach needs to address conceptual matters and also the practical challenges of implementing natural capital accounting.

With generous funding from the EU Commission through the EU LIFE program, the Transparent Project has brought together the Value Balancing Alliance (VBA), the Capitals Coalition, and the World Business Council for Sustainable Development (WBCSD) in a public-private partnership to deliver the necessary standardization.

Through a business-led approach and building on the wealth of experience that has evolved, the consortium has developed this document outlining a standardized methodology for natural capital management accounting in business.

The focus of this document is on management accounting principles, noting that good accounting information may support external reporting to stakeholders for satisfying the requirements of the CSRD, the EU's Taxonomy Regulation, or other international standards.

The Transparent Project marks a major contribution to the European Commission's commitment "to support businesses and other stakeholders in developing standardized natural capital accounting practices within the Union and internationally, with the aim of ensuring appropriate transaction costs" (Green Deal 2019, CSRD 2021 recital 38 [2]).

Together with its sister project, Align, which will provide integrated guidance focused on the challenging natural capital aspect of biodiversity, we believe that the guidance provided through the Transparent methodology will support a more sustainable financial and economic system that delivers value for nature and people alongside business and the economy.

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ABOUT

The Value Balancing Alliance is a non-profit alliance of more than 25 multinational companies who share a common goal: to develop a standardized methodology of impact measurement and valuation for monetizing and disclosing positive and negative impacts of corporate activity. The objective of such a methodology is to provide guidance on how impacts can be integrated into business decision making to support greater sustainability and transparency in business. Member companies pilot the methodology to ensure feasibility, robustness, and relevance. The Alliance is supported by the four largest professional service networks – Deloitte, EY, KPMG, and PwC – and works in close collaboration with the International Foundation for Valuing Impacts (IFVI).

The Capitals Coalition is a global collaboration redefining value to transform decision making. It sits at the heart of an extensive global network which has united to advance the capitals approach to decision-making. The ambition of the Coalition is that by 2030 the majority of businesses, financial institutions and governments will include the value of natural capital, social capital and human capital in their decision making and that this will deliver a fairer, just and more sustainable world.

The World Business Council for Sustainable Development is the premier global, CEO-led community of over 200 of the world's leading sustainable businesses working collectively to accelerate the system transformations needed for a net-zero, nature-positive, and more equitable future. Since 1995, WBCSD has been uniquely positioned to work with member companies along and across value chains to deliver impactful business solutions to the most challenging sustainability issues.

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

LIST OF ACRONYMS

AWARE – Available Water Remaining

CE – choice experiment

CSRD – Corporate Sustainability Reporting Directive

CV – contingent valuation

DALY – Disability-adjusted life year

EEIO – Environmentally extended input-output model

EFRAG – European Financial Reporting Advisory Group

EoL – End of life

EP&L – Environmental Profit and Loss Account

GDP – gross domestic product

GHG – greenhouse gas

GTP – Global Temperature change Potential

GWP – Global Warming Potential

IMF – International Monetary Fund

IO – input-output model

IPBES - Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPCC – Intergovernmental Panel on Climate Change

ISO – International Organization for Standardization

IUCN – International Union for Conservation of Nature

JRC – Joint Research Centre

LCA – life cycle assessment

LCI – life cycle inventory

LCIA – life cycle impact assessment

MRIO – multiregional input-output

NCMA – natural capital management accounting

NOx – nitrogen oxides

OEF – Organization Environmental Footprint

PEF – Product Environmental Footprint

PPP – purchasing power parity

R&D – research and development

SCC – social cost of carbon

SEEA – System of Environmental Accounting

SFDR – Sustainable Finance Disclosure Regulation

TCFD – Task Force on Climate-Related Financial Disclosures

TNFD – Taskforce on Nature-related Financial Disclosures

UNEP – United Nations Environment Programme

VBA – Value Balancing Alliance

VOC – volatile organic compounds

VSL – value of a statistical life

VSLY – value of a statistical life year

WASH – water access, sanitation, and hygiene

WBCSD – World Business Council for Sustainable Development

WFN – Water Footprint Network

WRI – World Resources Institute

WSI – Water Scarcity Index

YLD – years lost due to disability

YLL – years of life lost

1. BACKGROUND

1.1. About Transparent

In line with the ambition of the European Green Deal, Transparent is a public-private partnership to develop standardized natural capital accounting and valuation principles as a means of mobilizing the private sector in support of the green transition. In particular, the Transparent Project supports the call by the European Commission to support businesses and their stakeholders in their efforts to standardize natural capital accounting in the EU and globally.

The partners of the Transparent Project include the Value Balancing Alliance (VBA), the Capitals Coalition (CC), and the World Business Council for Sustainable Development (WBCSD).

Transparent partners successfully tendered for the EC grant for preparatory policy actions funded through the EU LIFE program. To promote the uptake of corporate natural capital accounting (and the insights such accounting brings to decision makers at the executive level), the tender called for the development of a standardized natural capital management accounting methodology that would result in the successful development of Environmental Profit and Loss Accounts. The expectation was that the methodology should cover both impacts and dependencies and should be suitable for integration in corporate strategic decision-making processes rather than focused on external reporting covered by other EU and global initiatives.[1]

As part of the Transparent Project, in addition to this document outlining a standardized methodology for natural capital management accounting (NCMA), separate documents providing general and sector-specific guidance have been developed to support implementation of the methodology. The NCMA general guidance document provides an overview of and additional resources in support of the steps needed for the application of natural capital management accounting, including a "management blueprint". NCMA sector-specific guidance documents are available for the chemicals, apparel, and agri-food sectors. The sector-specific guidance addresses practical matters in more detail, including considerations for first-time users of natural capital accounting and recommendations for integrating natural capital accounting into business systems and processes.

1.2. About natural capital management accounting

Natural capital is the stock of renewable and non-renewable natural resources, both biotic and abiotic (e.g., plants, animals, air, water, soils, minerals), that combine to yield a flow of benefits to people. This corresponds to "environmental assets" in the System of Environmental-Economic Accounting (SEEA) framework, which takes a (macro)economic perspective based on national accounts [3]. Changes to natural capital may affect the extent and condition of natural resources as well as the ecosystem services[2] that natural capital provides. For the purposes of understanding, measuring, and valuing the impact of business activities on nature, the NCMA methodology and system of accounting does not attempt to estimate the overall state of natural capital. The focus is on the change in the flow of ecosystem services from one period to the next that affects society. It is only at a national accounts level and in assessing performance against the Sustainable Development Goals that it becomes meaningful and appropriate to consider the macro or total impact of human activities on nature.

[1] Currently, there is no regulatory requirement to disclose natural capital accounting results. If results are to be externally disclosed, careful consideration is needed to ensure compliance with regulatory requirements.

[2] Ecosystem services are the "contributions of ecosystems to the benefits that are used in economic and other human activity" [46] (paragraph 2.14) which can be classified into provisioning, regulating, cultural, and supporting services.

Natural capital accounting is the compilation of consistent and comparable data on natural capital and the flow of services generated, using an accounting approach to show the contribution of the environment to the economy or business and the impact of the economy or business on the environment [4].

Natural capital management accounting refers to an internal management information system that combines data in support of corporate decision making. Unlike in statutory accounts, the form and content of management accounts are not determined by regulations and/or related to generally accepted accounting principles that are concerned with properly informing external stakeholders about the (financial) position and performance of an entity. Instead, the quality of natural capital management accounting is ensured by applying best practice developed by the business community, and guided by academia and professional organizations such as IFAC, ICOS, and others.

Environmental profit & loss (EP&L) accounting The concept of a "profit and loss" (P&L) is a common business formulation to assess performance. In accounting terms, it is the difference between revenue generated by a business and the related costs incurred. It represents the change in the stock of financial capital for a business resulting from its operations. The calculation of P&L is based on transactions between market actors such as customers and suppliers. It ignores unpriced "transactions" with the environment which include impacts on natural capital. The EP&L is a means of extending the profit calculation to include both monetary value and the price of environmental impacts of business activities. An EP&L can be presented in different ways to help management understand and respond to the total impact of business activities. Some entities now publish such impact statements in various formats to help their stakeholders understand how the business's activities impact nature or lead to other externalities. In profit and loss calculation, caution needs to be taken when offsetting or netting amounts with different characteristics, to address concerns around additivity. For this reason, it is important to display gross amounts and not merely compute a net amount of externalities and other impacts. Annex I provides a sample template of an EP&L.

Impacts and dependencies, for the purposes of this methodology, refer to relationships a business and its activities have with natural capital. An impact includes externalities or other unpriced effects of business activities on natural capital that result in the consumption or restoration of services provided by natural capital. Impacts are referred to as affecting the "value to society" that results from business activities. Looked at through this lens, business activities have brought about significant improvements in human well-being but often to the detriment of nature and both elements are relevant to understanding the overall performance of a business.

Dependencies refer to the set of relationships that describe the ways a business relies on nature and natural resources to create value. In market economies this "value to business" should be reflected in a business's overall market value (or enterprise value). The concepts of "value to society" and "value to business" are inextricably linked as one cannot exist without the other. Business models employed by business rely on natural, human, and social capital to generate wealth. Beyond market transactions and regulation of economic activity, these dependencies to extract value from the services provided by nature have largely been unaccounted for taken for granted. It has been assumed that the problem of scarcity can be overcome through globalization and through shifting to new or different locations and methods to extract value from nature. The collapse of biodiversity requires a radical rethinking of the way in which the services provided by nature can continue to generate "value for business" while also safeguarding the possibility of a sustainable future.

2. INTRODUCTION

2.1. About the NCMA methodology

This document aims to provide a standardized methodology for developing a basic set of natural capital management accounts at entity level that can support decision makers in orientating their business towards medium- and long-term environmental sustainability and thus reduce pressures on socio-economic systems. The intention is for this methodology to serve as a means of accounting for pressures or impact drivers on nature and the corresponding positive and negative effects these have on society. By focusing on impact drivers as the fundamental accounting concept of this methodology, we are approximating complex cause-effect phenomena and the interaction of systems that collectively contribute to the state and condition of the biosphere and ultimately human society.

This approach is consistent with established scientific best practice as outlined by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) or the International Union for Conservation of Nature (IUCN), for example, as well as corporate biodiversity reporting and disclosure best practice such as the Taskforce on Nature-related Financial Disclosures (TNFD), ESRS E4, or GRI 304 standards. The basic hypothesis is that by recognizing, measuring, and reducing the impact driver profile of business activities, positive changes to the environment – whether limiting further degradation or regenerating natural systems – will follow along the line of established impact pathways. It is acknowledged that the concepts of "impact drivers" and "impact pathways" are a means of modeling cause and effect based on science which shows that reducing impact drivers ultimately results in limiting the overall negative impacts industrialization and other human activities have on nature and ultimately society.

The IPBES summarize the present situation and challenge in their latest report [5], p.14:

> *Nature embodies different concepts for different people, including biodiversity, ecosystems, Mother Earth, systems of life and other analogous concepts. Nature's contributions to people embody different concepts, such as ecosystem goods and services and nature's gifts. Both nature and nature's contributions to people are vital for human existence and good quality of life (human well-being, living in harmony with nature, living well in balance and harmony with Mother Earth, and other analogous concepts). While more food, energy and materials than ever before are now being supplied to people in most places, this is increasingly at the expense of nature's ability to provide such contributions in the future, and frequently undermines nature's many other contributions, which range from water quality regulation to sense of place. The biosphere, upon which humanity as a whole depends, is being altered to an unparalleled degree across all spatial scales. Biodiversity – the diversity within species, between species and of ecosystems – is declining faster than at any time in human history.*

It is against this backdrop that the NCMA methodology has been developed. Natural capital management accounting is an evolving field and the methodology set out in this document will continue to be refined and improve as practice matures and business leaders become familiar with natural capital information in evaluating and making decisions about business activities. Like any methodology that attempts to model cause and effect relationships, the simplifications made here are to facilitate measurement and valuation, recognizing that nature cannot be unbundled into its component parts but that a means of analysis is needed if business activities are to be significantly adapted to transition to a sustainable future. Important qualitative considerations need to be taken into account with regard to how results from use of this methodology are employed in decision-making and in adapting business activities.

The focus of this methodology is to measure and value how business activities affect societies through changes in natural capital and ecosystem services, and how businesses can identify their dependencies on natural capital through ecosystem services (incorporating double materiality logic). To this end, the NCMA methodology focuses on the application of natural capital accounting in a business decision-making context, that is, in a management accounting rather than an external reporting capacity.[3] In doing so, it also aims to improve data quality and robustness for business decision making, noting that these improved data can, in turn, be used for external reporting to stakeholders.

This methodology sets out pragmatic steps for establishing corporate natural capital management accounts, based on extensive benchmarking and testing of methodologies [5]. For simplicity, this process of natural capital accounting is referred to as an "environmental profit and loss"[4] (EP&L) as a means of designating the change in natural capital resulting from a business's activities.

In developing this methodology, the Transparent Project adhered to the following guiding objectives:

- Enable decision makers to improve business decisions
- Standardize where possible, provide guidance where needed
- Consider scalability and practical feasibility

Building on the Natural Capital Protocol [1] and specifically Steps 05-07 (Figure 1), the NCMA methodology provides consistency in how businesses should measure and value natural capital impacts and dependencies.[5]

Figure 1. Framework of the Natural Capital Protocol [1]

3 Currently, there is no regulatory requirement to disclose natural capital accounting results. If results are to be externally disclosed, careful consideration is needed to ensure compliance with regulatory requirements.
4 It is important to not confuse the concept of a financial accounting profit and loss statement drawn up for an entity's capital providers and the calculation of an EP&L for management accounting purposes where it is principally information for internal decision-making and not for satisfying accountability obligations to shareholders.
5 To frame, scope and apply your assessment, you should follow the actions set out in all nine Steps of the Natural Capital Protocol [1].

The NCMA methodology can furthermore be embedded in other relevant frameworks such as the Corporate Sustainability Reporting Directive (CSRD) [6], the EU Taxonomy Regulation, TNFD [7], and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [5]. In developing the methodology, particular care has been taken to align with the latest developments of the TNFD, CSRD, and other EU initiatives.

The focus of this methodology is on measuring and valuing impacts on society. While dependencies are acknowledged, these should be seen as components of "value to business" and are to some extent already accounted for in the accounting system of a business and its risk management. This methodology provides insights into how companies can further their thinking about their dependencies on natural capital and how these might be valued (based on the concept by UN SEEA). Additional research is needed to guide companies in how to measure and value their dependencies on nature for the purpose of understanding and evaluating the performance of a business. The work of the Task Force on Climate-Related Financial Disclosures (TCFD) has highlighted the need for capital providers to understand the fragility of certain business models given the advance of climate change. The viability of business models should be carefully considered and evaluated in decision making to safeguard a business's ongoing ability to create value.

2.2. About the intended users

This methodology is primarily intended for those responsible for preparing management information to support internal decision making at the corporate level. Whilst those responsibilities sit with the corporate accounting and control departments, the methodology may be implemented by other corporate functions such as:

- Accounting and controlling
- Operations, departments, and data holders
- Sustainability management
- Finance

These teams typically contain expertise on impact pathways and the links between corporate activities and impacts. Where necessary, those applying the methodology can work with the accounting and controlling function to ensure that the data produced are reliable. The methodology may also serve those using the results of natural capital accounting for business steering and decision-making purposes by providing background on the methodological underpinnings of the results. While the methodology was developed to be applied at the corporate level, it can also be applied at other organizational levels. This allows to define, scale, and integrate business activities for which impact measurement and valuation is needed.

2.3. General management accounting principles

Accounting standards broadly fall within two categories: principle-based and rule-based. Given the variety of possible applications of natural capital accounting, this methodology is grounded in a principle-based approach, building on existing frameworks where possible and following the principles set out by the Natural Capital Protocol [1]:

- **Relevance:** Ensure that you consider the most relevant issues throughout your capitals assessment including the impacts and/or dependencies that are most material for the business and its stakeholders.
- **Rigor:** Use technically robust (from a scientific and economic perspective) information, data, and methods that are also fit for purpose.
- **Replicability:** Ensure that all assumptions, data, caveats, and methods used are transparent, traceable, fully documented, and repeatable. This allows for eventual verification or audit, as required.

- **Consistency:** Ensure the data and methods used for an assessment are compatible with each other and with the scope of analysis, which depends on the overall objective and expected application.

If you plan to disclose accounting results publicly, you should explicitly consider additional principles for financial and sustainability reporting and regulatory requirements. This is particularly relevant if you plan to integrate natural capital accounting information into existing external reporting formats such as annual, non-financial, or sustainability reports. These additional principles are also important when aiming for external assurance.

Recommendation: Applying the methodology in practice may include multiple estimations and assumptions. When deciding on these, we recommend following the precautionary principle (e.g., by assuming the most severe impact on nature and society). [111]

The approach outlined in this document is consistent with the principles for future sustainability reporting standards outlined in Article 19b of the proposed revised EU Non-Financial Reporting Directive (NFRD), namely that sustainability information is to be understandable, relevant, representative, verifiable, comparable, and represented in a faithful manner (CSRD 2021 (19b)) [2].

2.4. Basic impact management accounting concepts

Impacts to society are positive or negative contributions to one or more dimensions of well-being (see OECD [8] for an overview of the dimensions).

An **impact driver** is a measurable quantity of a natural resource used or generated by business activities that leads to a change in ecosystem services and/or assets. Impact drivers may be inputs (e.g., volume of sand and gravel used in construction) or non-product outputs (e.g., a kilogram of NO_x emissions released into the atmosphere by a manufacturing facility), sometimes referred to as "residuals."

An **impact pathway** describes how, as a result of a specific business activity, a particular impact driver results in changes in natural capital and how these changes in natural capital affect different stakeholders.

Dependencies are a business reliance on or use of natural capital.

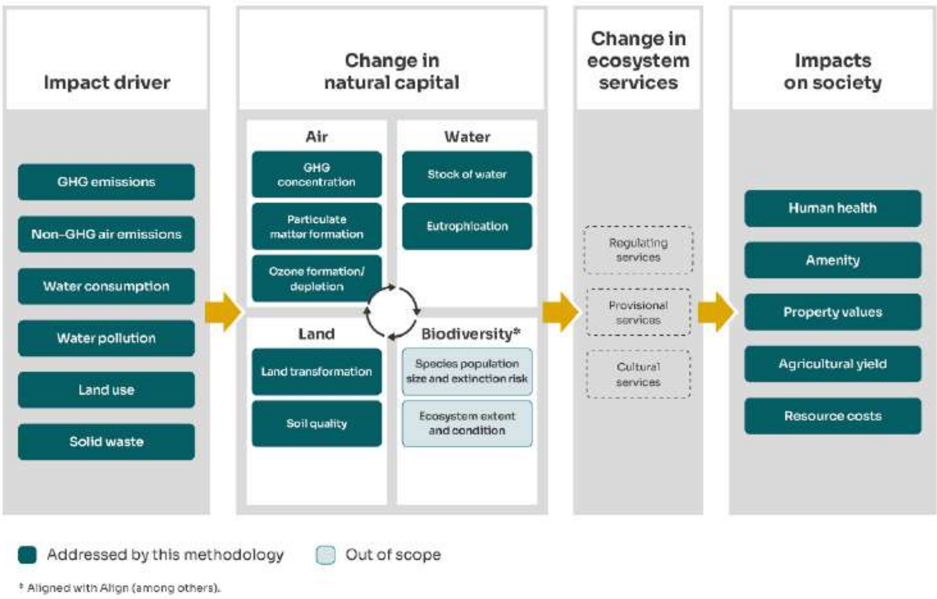
Value perspective is the perspective or point of view from which value is assessed; this largely determines which costs or benefits are included in an accounting. The two main value perspectives, which are also reflected in the concept of "double materiality," are:

- **Value to business**: The costs and benefits to the business, also referred to as internal, private, financial, or shareholder value.
- **Value to society**: The costs and benefits to wider society, also referred to as external, public, or stakeholder value (or externalities).

Valuation technique is the specific method used to determine the importance, worth, or usefulness of something in a particular context. This covers **qualitative** (descriptive, using categories such as high/medium/low), **quantitative** (using physical or other non-monetary units) and **monetary** (using money as the common unit) techniques. The main focus of this methodology is on monetary valuation.

The scope of this document includes the principal natural capital assets of air, water, land and biodiversity, and the ecosystem services they provide. Because businesses measure the drivers that impact these assets and the people depending on them, the methodology is structured according to impact drivers as shown in Figure 2. Impact drivers in blue boxes are addressed in detail in this document, grayed boxes, as well as ecosystem services are not explicitly modeled in this methodology.

Figure 2. Relation between impact drivers, impact pathways, and the value to society perspective



This is an illustration of impact pathways. All ecosystem services are underpinned by ecosystem assets, whereby changes in the assets lead to changes in the ecosystem services, which eventually impact societies.

3. OBJECTIVE AND SCOPE

You will define the objectives and scope of your application in more detail as outlined in this chapter. This will allow you to set up an approach for measuring and valuing impacts at the appropriate level of rigor.

3.1. Objective

The NCMA methodology aims to enable the development of an EP&L-style account that is suitable for:

- Identifying and better understanding environmental hotspots (and related risks and opportunities) associated with the entity's global business model.
- Supporting the strategic orientation of the business towards overall sustainability.

In addition, it can provide a basis for adapting corporate risk management frameworks to include climate- and environment-related impacts and dependencies. (See Annex I for a sample template of an EP&L.)

With these overall aims in mind, clarifying your specific objective will set the initial direction for the necessary data sources and stakeholders to involve from within your entity. Defining the objective will also determine the levels of granularity and robustness needed from your data and whether there is a need to hire external support to assist and consult during the natural capital accounting application.

The methodology represents a means of quantifying and assigning a monetary value to impacts on society as measured by the change in natural capital. Given the nature of what is being measured and interdependencies of complex natural systems, this approach has its limitations as methods continue to evolve and businesses and civil society continue to advance in understanding the impacts of human activities on nature. Unlike financial accounting which can for the most part rely on accounting for transactions and aggregation, natural capital accounting has no analogue to accounting data that can be simply manipulated and so relies on far more estimation, assumptions, and scientific research to understand the impacts on natural capital.

Accordingly, outcomes of natural capital management accounting should be used with care, especially in the early years of implementation, considering, for example, the limitation linked to the impacts and dependencies that are in-scope and those out of scope. Whilst monetary valuation offers a common unit of account that allows consolidating the respective impacts and dependencies related to the main environmental asset categories, additional quantitative and qualitative information should be gathered for those relevant impacts (currently) not captured in the monetized outcomes.

The NCMA methodology is particularly suitable for assessing the overall environmental impacts and dependencies of the entity's business model from a global perspective. You may also want to apply the methodology to additional levels, such as projects and investments (see, for example, the Natural Capital Protocol [1] and the NCMA general guidance for examples). For such uses, it is important to begin by identifying why the natural capital accounting is needed and which purposes it potentially fulfills. For project-based assessment (e.g., assessing and ranking specific investment decisions) or for an in-depth assessment of a particular environmental concern (such as biodiversity, climate, or circular economy) more tailored methodologies may be available (e.g., from the Natural Capital Protocol [1] toolkit or other public and/or private platforms and service providers).

3.2. Scope

Within this methodology, scope considers the accounting application within an entity, specifically looking into the aspects presented below.

3.2.1. Organizational focus

The default organizational focus of this methodology is the corporate entity as a whole covering the whole business, corporation, or group, including all subsidiaries, business units, divisions, different geographies or markets, etc. The corporate entity can be of any size from small to large entities.

The organizational focus (or boundaries) should be in line with your usual financial or management accounting practice (e.g., relating to consolidation rules, joint ventures, equity stakes). This is especially important if planning to use information from your natural capital accounting to support external reporting.

Depending on your business application, you may also want to consider the project, process, business division, and/or product level, for example, when carrying out a scenario analysis or operating in a new geography.

3.2.2. Value-chain boundaries[6]

Your natural capital accounting should cover the full value chain, and distinguish between the following three levels at a minimum:

- **Own operations**: Covers all activities within own operations over which your business has direct control. To ensure connectivity you should use the same scope as for a financial statement. Sometimes this level is also known as "direct" or "gate-to-gate."
- **Upstream**: Covers all activities, resources, and products that your entity has purchased from all suppliers. Sometimes this level is also known as "indirect" or "cradle-to-gate."
- **Downstream**: Covers all activities linked to direct customers (further processing), product use by end consumers, and product end-of-life. Sometimes this level is also known as "indirect" or "gate-to-grave."

Depending on your application you may wish to break down the value-chain levels further, for example differentiating between tier 1 suppliers with whom you have a direct business relationship and further tiers (your suppliers' suppliers) or differentiating between different parts of the downstream value chain. Table 1 provides some examples of activities associated with natural capital impacts along the value chain.

[6] In relation to the "scopes" often used in GHG emissions accounting, "own operations" corresponds to scope 1, "upstream" to scopes 2 and upstream scope 3, and "downstream" to downstream scope 3 categories.

Table 1. Examples of activities associated with natural capital impacts along the value chain

Value-chain level	Example activities associated with natural capital impacts (non-exhaustive)
Own operations	Energy consumption Manufacturing processes Transportation and logistics
Upstream	Extraction / production of raw materials Processing and transformation Transportation and logistics Land-use change and agriculture Capital goods, leased assets
Downstream	Processing of products Transportation and logistics Use of products End-of-life treatment (incineration, landfill, recycling, non-managed)

3.2.3. Value perspective and type of value

Following this methodology, your natural capital accounting should account for the value to society, and the value to business (i.e., the concept of double materiality in line with CSRD [10] expressed in monetary terms.

Recommendation: It is strongly recommended to include further qualitative and quantitative, non-monetary value perspectives in your natural capital accounts to help you better interpret results, the context, and state of the natural capital. You should furthermore clearly communicate any identified limitations to support the resulting decisions.

3.2.4. Accounting period

The natural capital accounting methodology set out in this document seeks to be compatible with the concept and principles of financial accounting. Hence, the natural capital accounting cycle should be in line with the (annual) time period typically used in financial accounts.

One of the ways in which natural capital accounting differs from financial accounting is that in natural capital accounting there is often a time lag between a business activity, an impact driver, and an impact on society. For example, an entity might sell a product in one year (business activity), which is used in the next year leading to GHG emissions (impact driver), which in turn contributes to climate change (impact on society). Your natural capital accounting should cover all impacts associated with activities conducted during the time period of your natural capital accounting (e.g., one financial year) by default. This includes future impacts generated by activities that occur during the time period defined in the scope of your accounting. This means that the downstream impacts associated with the use of sold products should be accounted for in the year that the product is sold. Such future impacts may be discounted.

3.2.5. Impact drivers

For the value to society perspective and as a starting point, the following impact drivers are recommended to be included in your accounting as they cover the natural capital assets of air, water, land, and biodiversity.

- GHG emissions
- Non-GHG air emissions
- Water consumption
- Water pollution
- Land use
- Solid waste

The changes in ecosystem services and their impacts on society are assessed through the valuations of these impact drivers including each a list of indictors, which are further specified in this document.
When a materiality analysis is carried out on these impact drivers and the relevance to your business (notably for the purpose of external reporting and disclosure), any omissions or deviations should be clearly explained and justified. It is moreover strongly recommended that you combine natural capital accounting with social and human capital accounting in your decision making. If it is not possible to quantify social and human impact drivers, it is recommended that you perform at least a qualitative analysis.

Recommendation: It is strongly recommended to cover all six impact drivers initially and use your results as a benchmark to measure the performance of the company over time. Moreover, it is recommended to include additional relevant impact drivers selected on the basis of regulatory requirements if applicable. The results of your natural capital accounting reveal the impacts potentially endured by society, the business, and the ecosystem and could serve as a quantitative materiality tool.

3.2.6. Baselines

The state of natural capital varies significantly over time and by location and intuitively it is possible to consider some "baseline" or "pristine" state prior to exploitation and damage resulting from industrialization. This would be pertinent to producing a natural capital "balance sheet" and determining an opening balance. In this methodology the principal focus is on understanding the flow (similar to an EP&L) which is the change from one accounting period to the next (T_1 to T_2) and this calculation does not require the assessment of a base. This is no different to the artificial nature of annual accounting periods for the calculation of financial profit for a business: the only completely accurate assessment of a business's profit is over its lifetime (T_0 to T_N) and the same holds true for nature.

3.2.7. Scenarios

A first outcome of natural capital management accounting is to improve awareness amongst corporate decision makers about the way in which the business model relates to the environment. When applying natural capital management accounting for strategic analysis decision making, it is often useful to define scenarios using different parameters or assumptions in comparison to your considered case. These "what-if" scenarios can inform strategic orientation and related planning. They could be "interventions" or real alternatives being considered (e.g., for comparing alternative materials used in a particular product) such as:

- "exploratory" scenarios assessing possible unexpected futures,
- "vision" scenarios describing explicitly desirable or undesirable futures, or
- "counterfactual" scenarios which describe a plausible alternative state of a site and its environmental conditions that would result if the entity did not operate (see NCMA general guidance).

In developing scenarios, environmentally extended input-output data may serve to establish the counterfactual scenario (i.e., the geographical and/or sectoral benchmark against which the tailored NCMA can be assessed).

4. MEASURE AND VALUE

To measure and value your natural capital impacts *on society,* you need to complete three steps (see chapter 5 Dependencies and value to business perspective, for valuing the impacts on the business):

- **Measure your impact driver** (Step 05 of the Natural Capital Protocol [1]).
- **Measure the change in state of natural capital** as a result of your impact driver (Step 06 of the Natural Capital Protocol [1]).
- **Value the impact this change in capital has on society** (Step 07 of the Natural Capital Protocol [1]).

Some aspects of natural capital accounting are cross-cutting and need to be applied consistently across all impact drivers (e.g., allocation of impacts, discounting for the future). Other aspects are specific to the impact driver under consideration. To help you undertake the three steps to measure and value natural capital impacts, this section contains:

- **General rules** applying to the measurement and valuation of natural capital. You should apply these when measuring and valuing <u>any</u> impact driver.
- **Specific rules** to complete the assessment of specific impact drivers. You should apply these when measuring and valuing each of the relevant impact drivers defined in this document.

4.1. Principal accounting modules

4.1.1. Measure your impact driver

A system of accounting requires data that can be manipulated into information that can be used for decision making. In management accounting there are typically "cost drivers" that will influence the cost of producing a unit of output. With natural capital the chain of causation is more complex and impact drivers give rise to a sequences of "effects" know as impact pathways. For example, polluting a local river (impact driver) affects water quality which in turn gives rise to a series of impacts on society. Data are only worthwhile if the information contained is reliable and can be used to inform options that entities can take to minimize or improve the impact on society. In some cases, data will be available through the financial accounting system – for instance water consumption as measured through water utility accounts by local providers. In other cases, data may need to be estimated or drawn from official sources that measure water quality downstream from operations. This is not vastly different to financial accounting where the valuation of land could be made through a professional valuation or estimated using official land prices. With any data the primary consideration is whether once aggregated it is "fit-for-purpose" given how the information is intended to be used.

Data

Impact drivers are typically measured in terms of physical quantities. You will need to decide which type of data source to use from the available options:

- **Primary data:** available internally in your business
- **Secondary data**: available publicly, or commercially
- Combination of primary and secondary data

Primary data can, in theory, deliver the most precise results and match your business activities most closely. In many cases for companies with international value chains, primary data may be complex or require significant resources to collect, particularly if you do not already capture these data in your systems. In some cases, you may be able to extrapolate from a smaller sample of primary data, provided that you are able to define a representative sample.

Secondary data should be used in cases where direct measurement of impact drivers is not practical. You can use different techniques that rely on secondary data, including the direct application of results from other situations, as well as adjusted estimates based on modeling. Common sources of secondary data include modeling techniques such as environmentally extended input-output models (EEIO), life cycle assessment (LCA) databases (see NCMA general guidance to learn more about EEIO and LCA use), and published, peer-reviewed literature. Table 2 provides considerations when selecting your type of data source. See Annex II for more detail on these.

Table 2. Considerations for selecting (secondary) data sources

Scientific validity	• Do the data come from a reputable source? • Have the data undergone a (scientific) peer review?
Quality assurance, controls	• Are all primary data sources and modeling assumptions used in the data source clear – and are they representative for my needs? • What kind of verification/validation/assurance process has the data source undergone (if any)? • Has this been documented (i.e., is there any assurance statement available)?
Temporal reference	• Which base/reference year does the data source refer to – and is this representative for my purposes? • Which time period do the data refer to (month/year/etc.)? • Do the data reflect seasonal variations (if relevant)? • Are data adjustments needed (inflation, year)?
Geographic specificity	• Does the data source offer a worldwide breakdown to (sub-) country level? • Does it adequately reflect local variations?
Technological representativeness	• Does the data source reflect the technology or processes relevant for my business?
Practical issues	• Does the data source cover all impact drivers or a limited number of them? • Is the data source updated regularly? • Can I work with the data format or is specialist software required? • Can I use the data source directly or are additional modeling steps required (e.g., mapping data to categories in my systems)? • What are the costs of using the source (if any)? • Can I make any adjustments to the data myself, or will I need to rely on external support for this? • Are there any formal issues to consider (e.g., copyright, licensing)?

Attribution (allocation) of impact drivers to business activities

In some cases (e.g., when accounting for downstream impacts from the use of sold products) impact drivers and impacts may not be attributable to your business activities alone. For example, an entity producing intermediate goods that are further processed into an end product will need to account for the impacts associated with this end product, even if the entity is not solely responsible for the impact. This is also true for processes generating more than one product (multiple, co-, or by-products).

There are a number of different ways of partitioning or allocating inputs, outputs, and impacts in such cases of multifunctionality, for example, based on physical relationships (mass, volume, energy use) or other relationships (such as economic value). The choice of allocation method can significantly impact the results of your accounting. ISO 14044 [11] presents a hierarchy of solutions to deal with allocation, while the EU Organization / Product Environmental Footprint (OEF/PEF) methodology provides further specific guidance [12]. You should be transparent about the allocation rule you apply.

Estimates and proxies

You may also use estimates based on intermediate or proxy indicators. These provide a useful shortcut which must then be combined with other information to measure or estimate the impact driver. For example, you may not be able to measure GHG emissions directly but could calculate them based on energy use and published emission factors.

The use of estimates and proxies should be well documented to facilitate reproducibility, and selection of estimates and proxies should follow the precautionary principle.

Competencies and resource requirements

Unless you have in-house specialists, you may need to seek external support, especially when using environmentally extended input-output models or life cycle assessment databases. You should ensure that there is consistency of data models across different impact drivers to ensure that results are consistent. For example, if choosing to model parts of your upstream supply chain using a particular EEIO model or LCA database for GHG emissions, you should use the same model for non-GHG air emissions as well as other indicators. Any deviation from this should be justified.

4.1.2. Measure changes in the state of natural capital

Changes in natural capital are what lead to impacts on ecosystem services, and eventually society. These will be highly dependent on the impact driver and impact area you are considering. For example, emitting non-GHG air emissions may lead to an increased local concentration of pollutants and hence reduced air quality. The degree to which emissions reduce air quality will be dependent on a range of factors, including local weather/climatic conditions, the presence of other substances, etc. This section is therefore kept fairly short and abstract – but more detail is found for each impact driver in sections 4.2.1-4.2.6.

To measure changes in the state of natural capital, you should complete the following actions:

- **Identify changes in natural capital associated with your business activities and impact drivers for each value-chain level.** Box 1 provides some considerations to guide you when identifying and selecting changes in natural capital to include in your accounting.
- **Select methods for measuring change.** Table 3 describes available methods for measuring and estimating changes in natural capital, including a brief description of each approach and considerations for their selection. You should select one of these methods. For appropriate choice of method, consider:
    - The level of detail required
    - Practicality within the available time and resources
    - The geographic scope under consideration

Box 1. Considerations for identifying and selecting changes in natural capital to include in accounting

You may find it helpful to map the relevant indicators chosen in Step 05 of the Natural Capital Protocol [1] to their impact driver categories and identify the likely subsequent changes in natural capital. For examples, see table 6.1 in the Natural Capital Protocol [1] (p. 69).

The selection of specific changes in natural capital to include in your accounting will depend on available data, the cost of sourcing or modeling additional data, suitable methods, and the time and other resources available for your accounting.

The changes in natural capital to consider should be informed by your application and required level of rigor.

Your choice of method should be appropriate to the level of rigor required for your accounting. When selecting your model and sources you should:

- Confirm that methods used consider local conditions to a suitable degree.
- Understand the limitations of methods used and check that they are suitable for your impact valuation purposes.

Please note that measuring the change in the state of natural capital is equivalent to the quantification of environmental impacts using environmental impact categories.

Table 3. Types of methods for measuring changes in natural capital and description of their approach

Type of method	Description of method and considerations
Direct measurement methods	Measure changes directly, without using mathematical calculations.
Generalized modeling methods	Applicable to a generalized context and therefore less detailed and lower resolution than direct measurement methods. Widely available and based on established approaches such as life cycle impact assessment and characterization factors (Annex II). Can provide a first estimate to help you understand the limitations and convenience of direct measurement approaches or more detailed modeling methods.
Detailed modeling methods	Developed for a specific context and are therefore more detailed and higher resolution. Typically built on scientific studies in a particular field.
Specific bespoke modeling methods	Can be used on a case-by-case basis to supplement standardized modeling methods. Where limited data exist, databases can be used to model response to certain impact drivers.

4.1.3. Value impacts on society

The value to society perspective in the NCMA methodology focuses on an approach to value the consequences of the positive and negative contributions of business activities to human well-being in monetary terms.[7] Users interested in conducting qualitative valuation will find some guidance in the Natural Capital Protocol [1].

Assessing the value of impacts on society requires an understanding of how changes in natural capital are linked to impact areas such as human health, or change in property values. This will be highly dependent on the impact driver and impact area under consideration. For example, the impact on society of reduced air quality will be far greater if it occurs close to densely populated areas, and the degree to which individuals contract diseases may also depend on their overall health. The degree to which people and nature are affected will be dependent on a range of factors, including local geography, population density, type of ecosystems, etc.

There are different techniques to measure the impacts of a business on society and the choice of valuation method will significantly affect the results of your accounting. This section provides general rules – but more detail relevant to each of the impact drivers is found in sections 4.2.1-4.2.6.

To complete the valuation, you should quantify the effect that the change in natural capital has on human well-being and translate this into monetary terms. This involves the following actions:

1. **Define the consequences of impacts.** You will find the impacts of each impact driver included in the relevant section (4.2.1-4.2.6).
2. **Select appropriate technique(s) to quantify the impacts on society**

   In many cases, you will need to quantify impacts first in physical terms based on changes in natural capital. In some cases, you will be able to skip this step and apply monetary valuation directly.

[7] For an overview of monetary valuation techniques, refer to e.g., [109].

3. **Select appropriate monetary valuation technique(s) to value the impacts on society in monetary terms**

   You will then apply a method to value physical impacts in monetary terms. For other impacts, you will be able to apply monetary valuation directly without measuring impacts in physical terms. Again, you will find specifics in sections 4.2.1-4.2.6.

There are four main groups of valuation techniques[8] used to assess an impact on well-being in monetary terms, each leading to different results (see Box 2).

Box 2. Valuation techniques recommended in this methodology

1. **Market prices**

   This includes several related approaches:

   - Prices paid for goods and services traded in markets (e.g., timber, carbon, value of water bill or pollution permit).
   - Other internal/financial information (e.g., estimated financial value of liabilities, assets, receivables).
   - Other interpretations of market data (e.g., derived demand functions, opportunity costs, mitigation costs/aversive behavior, cost of illness).

2. **Cost-based approaches**

   Replacement cost approach: The cost of replacing natural capital with an artificial substitute (product, infrastructure, or technology). May be estimated, observed, or modeled.

   Damage costs avoided: The potential costs of property, infrastructure, and production losses due to natural capital degradation, treated as a "saving" or benefit from conserving natural capital. May be estimated, observed, or modeled.

3. **Revealed preference approaches**

   Hedonic pricing: Based on the observation that environmental factors are one of the determinants of the market price of certain goods (e.g., the environmental quality of a neighborhood affects the prices of properties located there). This technique models variations in market prices, controlling for other variables to isolate the environmental factor of interest. The extent to which price varies with this factor reveals its value.

4. **Stated preference approaches**

   Contingent valuation (CV): Infers ecosystem values by asking individuals their maximum willingness to pay (or willingness to accept compensation) for a specified change in the relevant non-market good or service from natural capital.

   Choice experiment (CE): Individuals are presented with alternative goods/options with different characteristics (i.e., various attributes or levels, such as distance, number of species present, or some other aspect of natural capital), as well as different prices. They are asked to choose their preferred option, from which the value of the relevant non-market good or service from natural capital may be inferred.

[8] See also Natural Capital Protocol [1], p. 88 and 114 onwards.

For each impact driver, you should use the valuation techniques indicated in the relevant detailed section of this document (sections 4.2.1-4.2.6).

Recommendation: You may wish to apply different valuation techniques generating different sets of results (e.g., first set of results using damage cost, the second with revealed preferences) to provide complementary insights.

Note: You can find illustrative examples of outputs resulting from measuring and valuing in Annex I and in the all NCMA sector-specific implementation guidances.

The following four sub-sections provide guidance on specific topics to consider when valuing any of the impact drivers considered in this methodology (see NCMA general guidance for further explanations):

- Adjustments and value transfer
- Valuing impacts on human health
- Accounting for future impacts
- Accounting for planetary boundaries

4.1.3.1. Adjustments and value transfer

In practice, you may not be able to access valuation data that cover all possible situations (e.g., because a study with monetary valuation data refers to a specific country, ecosystem, or time period). In this case, you can use value transfer. Value transfer consists of valuing an impact driver in one context based on valuation evidence (identified using one or more of the techniques discussed) determined in another context. Specific adjustments should be made to account for differences between the two contexts. For more details, see Annex III.

You should apply the following rules independent of the type of impact or impact driver:

- **Adjust for foreign exchange rates**: For impacts valued using different currencies, the exchange rate needs to match the time period defined in the scope of the study. Use data published by the World Bank, IMF, or similar recognized institutions. Depending on the business application, it may be useful to use five-year rolling averages to avoid currency conversion artifacts.
- **Adjust for inflation**: When using data sets for valuation developed in the past, these should be adjusted to the time period considered in the scope of the study. You should use official sources of inflation such as the IMF or the World Bank.
- **Adjust for Purchasing Power Parity (PPP) (optional)**: You may adjust for purchasing power parity in your accounting, but in this case you will need to communicate this adjustment clearly with the results of the study.

In any case, adjustments should be consistent across all impact drivers unless there are other provisions specified in the relevant impact driver section of this methodology. Deviations from this guidance should be justified.

4.1.3.2. Valuing impacts on human health

Often, the external impacts of environmental damage on individuals are negative physical and mental health outcomes. For this reason, valuing health impacts is common practice for most impact drivers. Valuing impacts on human health involves considering (premature) mortality as well as morbidity (disease). In general, monetary valuation of health impacts involves quantifying health impacts and then applying a suitable valuation approach.

Metrics to quantify health impacts

Different metrics can be used to quantify impacts on health. You should decide which metric is fit for purpose, taking into account the specific guidance for each impact driver. The options are:

- Number of cases
- A normalized metric, such as Disability-Adjusted Life Years (DALY) or years of life lost (YLL) (see Box 3). Due to the way how health data is reported across the world, this approach is yet not always practical.

Box 3. Normalized metrics of health

Some commonly used normalized metrics of health as defined by the World Health Organization are as follows [13]:

Years of Life Lost (YLL)

Years of life lost (YLL) is a measure of premature mortality that takes into account both the frequency of deaths and the age at which death occurs.

Disability-Adjusted Life Years (DALY)

A DALY is equivalent to one lost year of "healthy" life. The sum of DALYs across a population affected by different impact drivers (e.g., air or water pollution) measures the gap between the health status with and without the occurrence of these impact drivers. DALYs for a disease or health condition are calculated as the sum of the years of life lost (YLL) due to premature mortality in the population and the years lost due to disability (YLD) for people living with the health condition or its consequences.

Assigning a value to premature mortality

The idea of associating a monetary value with human life is a challenging and contentious topic. Life is priceless, at least when considered from the complex perspective of an individual [14]. However, the value of life has been used by policymakers around the world when deciding whether regulations to reduce the likelihood of fatalities are worth the costs of implementing them. The need to inform policy decisions has led to a significant amount of research into an appropriate value to be used. To quantify the impact of changes in natural capital on society therefore requires an application of this research to estimate the value to society of negative externalities that lead to fatalities or increase the likelihood of fatalities.

Box 4 describes the different approaches to assess the value of impacts on (premature) mortality [15].

Box 4. Valuation approaches for mortality

- **Value of a statistical life (VSL)** presents the value a given population places ex ante on avoiding the death of an unidentified individual. VSL is based on the sum of money each individual is prepared to pay for a given reduction in the risk of premature death, for example from diseases linked to air pollution [14], p.13. Value of a statistical life estimates are typically based either on a stated preference or the revealed preference approach:
    - In the stated preference approach, individuals are presented with hypothetical options to reduce risk of mortality and asked to make choices (e.g., willingness to pay for a new medical treatment).

- In the revealed preference approach, individuals' behavior in actual markets is observed to estimate their willingness to pay for a reduction in their mortality risk (e.g., increased pay required to compensate employees for accepting jobs with a higher risk of death).

Policymakers in different parts of the world make different choices on the estimation approach. You should be consistent in your choice of VSL approach and document your source clearly.

- **Value of a statistical life year (VSLY)** is the method for valuing in monetary terms premature mortality in the form of reduced life expectancy. There are a number of studies from which to derive a value for the VSLY. Annex III provides examples of available sources.

Note that there are additional ways in which human life and mortality have an impact on society, such as costs for healthcare systems, decreased productivity, etc., but these are not covered by willingness to pay approaches.

Your choice of valuation approach will depend on the health impact metric used. Table 4 summarizes the valuation approaches that you should use depending on the health metric selected for assessing impact.

Table 4. Valuation approach for premature mortality to be used for each health metric

Health metric	Valuation approach
Number of cases	Value of a statistical life (VSL)
Disability-Adjusted Life Years (DALY)	Value of a statistical life year (VSLY)
Years of life lost (YLL)	Value of a statistical life year (VSLY)

<u>Valuing morbidity</u>

Your choice of valuation approach will depend on the health impact metric used. Table 5 summarizes the valuation approaches that you should use depending on the health metric obtained in the impact assessment.

Table 5. Valuation approach for morbidity to be used for each health metric

Health metric	Valuation approach
Number of cases	Variable, depending on type of disease
Disability-Adjusted Life Years (DALY)	Value of a statistical life year (VSLY)

Recommendation: We acknowledge these approaches assign lower values to lives in lower-income countries and for the moment we haven't identified more robust approaches, but we would like to highlight the ethical concerns surrounding this discrepancy. Human health should be valued equally across the globe. We furthermore recommend following a conservative approach of using the highest value of a statistical life across the entire value chain. Additionally the human life valuation should not be used for trade-off decision making and compliance to human rights laws must be ensured.

4.1.3.3. Accounting for future impacts

Economic theory suggests that money and utility available now are valued more than money and utility available in the future.

When assessing impacts on society happening in the future, you should discount them. This can be done using the social discount rate to convert impacts into their present value, allowing a comparison between costs and benefits that happen in different moments of time. The **social discount rate** is a parameter that reflects the value for society of future costs and benefits compared to present ones.

The present value of future impacts should be estimated using the following formula:

$$PV = \sum_{t=0}^{n} \frac{V_t}{(1+r)^t} = \frac{V_0}{(1+r)^0} + \frac{V_1}{(1+r)^1} + \cdots + \frac{V_n}{(1+r)^n}$$

Where:

PV is the present value of an impact,

V_t is the value of an impact at year t,

r is the social discount rate,

n is the time horizon of the impact

When performing an accounting, treat future impacts consistently across all impact drivers (i.e., use consistent discount rates). See Annex III for more detail on the breakdown of the discount rate.

4.1.3.4. Accounting for planetary boundaries

The methodology helps in understanding societal consequences of business activities that are not already accounted for in the calculation of an entity's profit.[9] As such, it can provide complementary information to evaluate an entity's performance against its pre-defined targets and thresholds (i.e., in line with planetary boundaries). Depending on the valuation approach chosen, the monetary valuation can additionally account for planetary boundaries (see, for example, section 4.2.1 on GHG emissions). However, at the time of writing, these valuation approaches are not yet readily available for all impact drivers. In addition, planetary boundaries can complement the accounting by stressing which impact drivers are likely to be priced first.

4.2. Specific accounting modules by impact driver

Throughout sections 4.2.1-4.2.6 covering specific rules for each of the impact drivers, you should continue to apply the general rules discussed in section 4.1.

[9] In some cases, entities may have to pay restorative costs to compensate for environmental damage. There may also be other instances, such as a carbon tax, where some costs are "priced in" in the determination of an entity's profit.

4.2.1. GHG emissions

4.2.1.1. Impact pathway and brief description

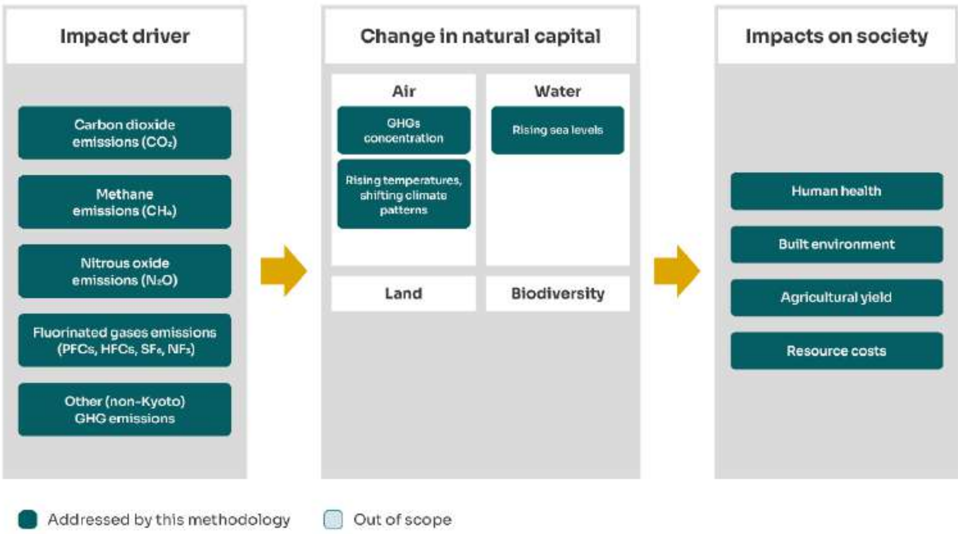
The earth's atmosphere shields us from harmful radiation, provides us with air to breathe, and traps enough heat from the sun to enable the planet to support complex forms of life. Scientists have long been aware of this essential "greenhouse effect." However, in recent decades, they have become increasingly concerned about changes in the composition of the Earth's atmosphere and the potential of these changes to increase the amount of heat trapped.

The data now conclusively show that the Earth is warming and has been for some time. Scientists are confident that the net effect of human activities – and the resulting increase in atmospheric greenhouse gas (GHG) concentration – has contributed to this warming. This is discussed in detail in Intergovernmental Panel on Climate Change (IPCC 2013, 2018) reports [16] [17]. Emissions of CO_2, other GHGs, aerosols, and ozone precursors affect the radiation absorption properties of the atmosphere. This has both short- and long-term effects.

Even in the absence of humans, Earth has a naturally occurring carbon cycle in which carbon is exchanged between different living organisms and the environment through natural processes. Some processes (e.g., photosynthesis) remove GHGs from the atmosphere, while others (e.g., respiration or decomposition in the soil) emit carbon into the atmosphere. Since the industrial revolution, human activity has modified the carbon cycle by adding sources (e.g., burning fossil fuels) and removing sinks (e.g., changes in land use, especially deforestation). This has led to an increasing concentration of GHGs in the atmosphere, which results in an increase in the greenhouse effect. This, in turn, changes the Earth's climate.

The steps of the impact pathway for GHG emissions are shown in **Figure 3**.

Figure 3. High-level impact pathway for GHG emissions



Note: Changes in natural capital that are not explicitly modeled are not displayed in the figure.

4.2.1.2. Measure your impact driver

Box 5 describes some key sources of GHG emissions that are relevant to natural capital accounting within a business context.

Box 5. Typical sources of GHG emissions

Any activity that disrupts the Earth's natural carbon cycle effectively changes the concentration of GHG emissions in the atmosphere.

Anthropogenic sources of (fossil) GHG emissions are mostly related to the burning of fuel, including in energy generation, transportation, and heating. Other chemical or mechanical processes may also lead to the emission of GHGs.

Typical activities associated with GHG emissions include:

- Fuel burning in industry and power generation
- Fuel burning in transportation (air, sea, road)
- Chemical processes (this is often especially significant for non-CO_2 GHG emissions)

Whilst the local impacts of climate change may differ, it is the global concentration of GHGs in the atmosphere that drives climate change.

To measure your impact driver, you need to measure the mass of GHG emissions emitted to air. Table 6 presents the list of quantitative indicators for the main GHG pollutants that you should measure.

Table 6. Quantitative indicators to measure GHG emissions

Tons of carbon dioxide (CO_2)
Tons of methane (CH_4)
Tons of nitrous oxide (N_2O)
Tons of perfluorocarbons (PFCs)
Tons of hydrofluorocarbons (HFCs)
Tons of sulfur hexafluoride (SF_6)
Tons of nitrogen trifluoride (NF_3)
Optional: other (non-Kyoto) GHGs

Since climate change is primarily driven by the global concentration of GHGs in the atmosphere, you do not need to collect further location- or context-specific information, unless this is useful to you for other purposes.

Not all GHGs contribute equally to climate change. Some, such as methane, have shorter lifetimes and contribute to near-term effects, whereas others, such as CO_2, have long lifetimes and contribute to longer-term effects. This is expressed in Global Warming Potential and Global Temperature change Potential (see Box 6, [16].)

Box 6. Global Warming Potential (GWP) and Global Temperature change Potential (GTP)

Greenhouse gases absorb energy and slow the rate at which energy escapes to space. The key ways in which gases differ from each other are in their ability to absorb energy (their "radiative efficiency") and how long they remain in the atmosphere (their "lifetime").

Global Warming Potential (GWP) allows comparison of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emission of one ton of a gas will absorb over a given period of time, relative to the emission of one ton of carbon dioxide (CO_2). The usual time period for GWPs is 100 years (GWP100).

An alternate metric is the Global Temperature change Potential (GTP). While the GWP is a measure of the heat absorbed over a given time period due to emission of a gas, the GTP is a measure of the temperature change at the end of that time period (also relative to CO_2). The calculation of GTP is more complicated than that of GWP, as it requires modeling how much the climate system responds to increased concentrations of GHGs (climate sensitivity) and how quickly the system responds (based in part on how the ocean absorbs heat).

UNEP (2017) [18] recommends assessing short- and long-term change separately, with GWP100 recommended for short-term impacts and GTP100 for long-term impacts.

4.2.1.3. Measure changes in the state of natural capital

The following actions are needed to complete this step:

1. **Identify changes in capitals associated with your business activities and impact drivers.**

   The impact pathway of climate change is very broad and complex in that it involves multiple regional and global impacts and extends from the shorter term into the more distant future. Changes to natural capital arise from the increased concentration of GHGs in the atmosphere and include rising mean temperatures, shifting climate patterns, sea-level changes, and desertification, as well as loss of habitat, which may lead to movement of species. The effect of GHG emissions depends primarily on their lifetime in the atmosphere (see Box 6).

   As a default (minimum) requirement, this methodology requires you to assess global impacts for a reference period of 100 years based on Global Warming Potential (rather than Global Temperature change Potential).

   Depending on your business application, you may also be interested in local effects. These are likely to be more relevant when investigating impacts on business and dependencies, rather than impacts on society.

2. **Measuring change.**

   You will not need to measure all changes to natural capital directly, as this is implicitly covered in the Global Warming Potential as well as the valuation approach (social cost of carbon, see Box 7). For this step you will convert the effect of other GHG emissions to that of CO_2 equivalents using the Global Warming Potential GWP100, following guidance in Table 7. Ensure that you use the most recent scientific evidence from the Intergovernmental Panel on Climate Change for the Global Warming Potential (GWP).

Table 7. Changes in natural capital to measure for GHG emissions

Indicator (impact driver)	How to measure change in natural capital
GHG emissions (CO_2, CH_4, N_2O, PFCs, HFCs, SF_6, NF_3, and, optionally, other (non-Kyoto) GHGs)	You do not need to measure changes in natural capital directly, as these are implicit in climate models. Short-term: Global Warming Potential with a reference period of 100 years (GWP 100), based on most recent scientific evidence from the Intergovernmental Panel on Climate Change (e.g., IPCC 2018) [17] Optional: other reference periods Long-term (optional): Global Temperature change Potential (GTP)

4.2.1.4. Value impacts on society

Complete the following actions to value the consequences of your impacts on society:

1. **Define the consequences of impacts on society**

   Impacts on society include impacts to human health (e.g., due to heat stress, malnutrition), the built environment (e.g., damages from extreme weather events or rising sea levels), agricultural yield (e.g., losses in crop growth), and resource costs (e.g., increased production costs) (see impacts on society in Figure 3). These impacts are the consequences of changes in the ecosystem services as listed in Table 8 below. Please note that changes in ecosystem services are usually not modeled explicitly; however, describing ecosystem service changes can help you to understand how society is impacted.

Table 8. Impacts on society from GHG emissions

Change in ecosystem services	Impacts on society
• Global climate regulation services • Local climate regulation services • Flood control services	• Human health • Built environment • Agricultural yield • Resource costs

2. **Select appropriate technique(s) to quantify the impacts on society**

   To assess the impact on society you should use a model that reflects the complexities identified by climate science and does not single out individual impacts. You should specify which model has been selected. See also IPCC (2013, 2018) [16] [17] regarding climate models, and the Network for Greening the Financial System for climate scenarios (NGFS, 2022 [19]).

3. **Select appropriate technique(s) to value the impacts on society in monetary terms**

   For monetary valuation of impacts on society, we recommend using a valuation approach that addresses the global impacts caused by GHG emissions. Always document your key assumptions (particularly around ethical choices), as well as the source (see the NCMA general guidance for recommended valuation sources).

   Below we present the most commonly used GHG valuation approach in policy making, which is the social cost of carbon.

Box 7. Social cost of carbon

The social cost of carbon (SCC) is an estimate, in monetary terms, of the economic damages that would result from emitting one additional ton of carbon dioxide into the atmosphere. It is widely used by policy makers and other decision makers to understand the economic impacts of decisions that would increase or decrease GHG emissions.

The SCC is calculated in four steps using specialized computer models:

1. Predict future emissions based on population, economic growth, and other factors.
2. Model future climate responses, such as temperature increases and sea-level changes.
3. Assess the economic impact of these climatic changes on agriculture, health, energy use, and other aspects of the economy.
4. Convert future damages into their present-day values and sum to determine total damages.

These four steps provide a baseline value for the damages caused by emissions. The modeling process is then repeated after including a small amount of additional emissions to determine the impact on the total cost of emission-related damages. The increase in damages from the additional emissions provides an estimate of the SCC (see e.g., Nordhaus 2014 [20]; IPCC 2018 [17]).

It should be noted that not all policy makers use the same SCC. Variations arise from modeling choices that in part reflect ethical choices, particularly around equity and how to value the cost to future generations.

Another approach used is marginal abatement costs that are computed from a cost-effectiveness analysis. This analysis computes the costs of carbon as its shadow price when reaching a predefined climate goal and can thus incorporate science-based targets (e.g., a 1.5° goal (IPCC 2018 [17], NGFS 2022 Climate scenarios [19])).

4.2.2. Non-GHG air emissions

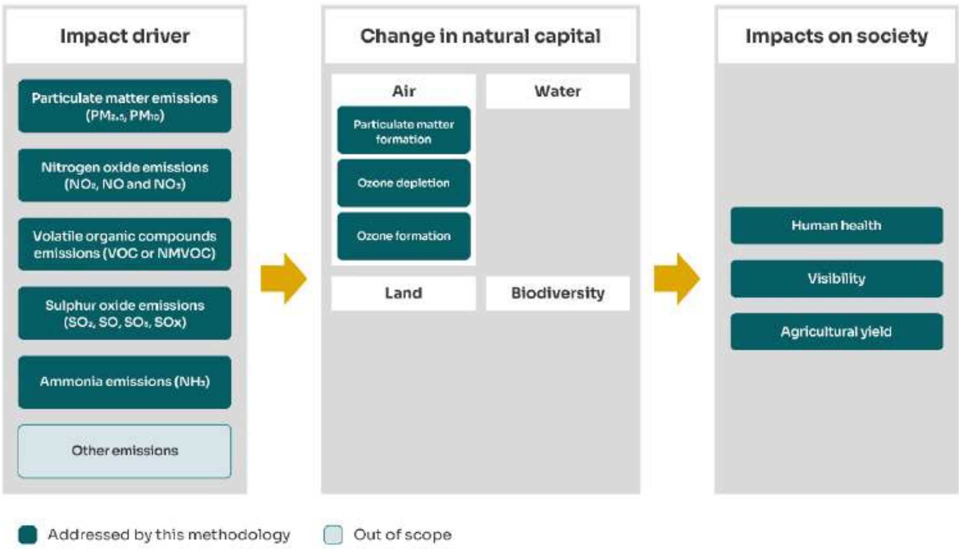
4.2.2.1. Impact pathway and brief description

Release into the air of non-GHG air emissions changes the concentration of pollutants and hence ambient air quality, which affects human health (e.g., contributing to respiratory infections and heart disease), biodiversity, and the extent and condition of habitats and ecosystem services. This in turn can lead to further impacts on society, for example through changes in agriculture and associated loss in productivity leading to higher prices for consumers.

Unlike greenhouse gas emissions, which contribute to climate change on a global scale, the impacts of air pollution are principally local or regional. Local or regional factors, such as weather conditions and population density, influence the magnitude and severity of impacts from air pollutants. Non-GHG air pollutants can be subdivided into "primary pollutants," which directly cause negative impacts, and "secondary pollutants," which originate from the reaction between primary pollutants and other gases in the atmosphere under certain conditions, and which subsequently have negative impacts.

The impact pathway for non-GHG air emissions is shown in **Figure 4Error! Reference source not found.**.

Figure 4. High-level impact pathway for non-GHG air emissions



Note: Changes in natural capital that are not explicitly modeled are not displayed in the figure.

4.2.2.2. Measure your impact driver

Box 8 describes some key sources especially relevant to non-GHG air emissions that you should consider.

Box 8. Typical sources and activities related to non-GHG air emissions

There are both natural and anthropogenic sources of air pollutants. Anthropogenic sources are mostly related to the burning of fuel, including in energy generation, transportation, and heating. Other chemical or mechanical processes may also lead to the emission of air pollutants.

Typical activities associated with non-GHG air emissions include:

- Industrial fuel burning
- Private use of fuel, such as in household cookstoves
- Deforestation and land-use change
- Agriculture, in particular dust and the use of fertilizers and pesticides
- Transportation (air, sea, land)

Mobile sources generally disperse differently than stationary sources. Therefore, the impact associated with air pollutants depends not just on the type of pollutant but also the type of source. This point is not always covered by available models.

To measure your impact driver, you need to measure the mass of non-GHG air emissions released to air. Table 9 presents the list of quantitative indicators for the main non-GHG air pollutants that you should measure.

Table 9. Quantitative indicators to measure non-GHG air emissions

Tons of fine particulate matter ($PM_{2.5}$)
Tons of coarse particulate matter (PM_{10})
Tons of nitrogen oxides (NO_2, NO, and NO_3)
Tons of volatile organic compounds (VOC or NMVOC)
Tons of sulphur oxides (SO_2, SO, SO_3, SO_x)
Tons of ammonia (NH_3)

To perform the next steps, you will need to collect further information on the context of the emission sources (location, neighboring population density, altitude of emissions, moving or stationary source, etc.). Box 9 provides further considerations on models, service providers, and sub-indicators.

Box 9. Models, service providers, and sub-indicators

Natural capital accounting is most accurate when changes in natural capital can be measured directly. This is often not possible or feasible. However, based on scientific research typical (empirical) patterns can be reflected in data models. Various service providers have developed models that define a specific context and sub-indicators for impact drivers, which are sometimes called "emission compartments."

If working with an external data provider, your choice of model should be based on the considerations for selecting (secondary) data sources discussed in section 4.1.1.

4.2.2.3. Measure changes in the state of natural capital

Implementing models to reflect changes in natural capital, as well as impacts on society arising from these changes, takes expert knowledge and you are very likely to need external support for this. It is likely that you will not perform the following actions directly yourself.

The following actions are needed to complete this step:

1. **Identify changes in capitals associated with your business activities and impact drivers.** You need to measure changes in air quality resulting from your non-GHG air emissions. Table 10 presents the list of changes in air quality that should be assessed.

Table 10. Changes in natural capital to measure for non-GHG air emissions

Indicator (impact driver)	Change in natural capital
Tons of particulate matter ($PM_{2.5}$)	Change in fine particulate matter concentration
Tons of particulate matter (PM_{10})	Change in coarse particulate matter concentration
Tons of nitrogen oxides (NO, NO_2, NO_x)	Formation of NO_3^-, contributing to change in fine particulate matter concentration (secondary $PM_{2.5}$) Formation of ozone O_3, leading to increasing ozone concentration
Volatile organic compounds (VOCs)	Formation of ozone O_3, leading to increasing ozone concentration
Tons of sulphur dioxide (SO_2)	Formation of sulphates SO_4-, contributing to change in fine particulate matter concentration (secondary $PM_{2.5}$)
Tons of ammonia (NH_3)	Formation of ammonium NH_4+, contributing to change in fine particulate matter concentration (secondary $PM_{2.5}$)

2. **Measuring change.** To complete this action, you should use a modeling approach. This can be done using:

    i. a bespoke air dispersion model that accounts for local meteorological conditions and type of emission source (e.g., stationary/mobile, high/low altitude), or

    ii. pre-existing models, such as from life cycle inventories or similar data sources that provide characterization factors for a set of predefined contexts. Pre-existing models may either be based on dispersion models (good practice) or use proxies to characterize different contexts.

4.2.2.4. Value impacts on society

Complete the following actions to value the consequences of your impacts on society:

1. **Define the consequences of impacts** (see impacts on society in Figure 4).

   These impacts are the consequences of changes in the ecosystem services as listed in Table 11. Please note that changes in ecosystem services are usually not modeled explicitly; however, describing ecosystem service changes can help you to understand how society is impacted.

Table 11. Impacts on society from non-GHG air emissions

Change in ecosystem services	Impacts on society
• Local climate regulating services • Air filtration services • Biomass provisioning services • Recreational services	• Human health • Visibility • Agricultural yield

2. **Select appropriate technique(s) to quantify the impacts on society**

   You should first quantify impacts in physical terms, based on changes in natural capital. Then select a method to value your impacts in monetary terms [21].

   To perform quantitative valuation (in physical terms), select and apply one of the quantitative valuation techniques outlined in Table 12, for each of the impacts assessed.

Table 12. Techniques to value impacts on society from non-GHG air emissions

Impact category	Quantification technique
Human health	Dose-response functions. These types of functions account for the reaction of a population to exposure to pollution in the atmosphere. Characterization factors from life cycle assessment implicitly use dose-response functions so can also be used where the level of granularity is fit for purpose.
Visibility (optional)	No need to model explicitly. Implicitly covered by monetary valuation technique.
Agricultural yield (optional)	Dose-response function to determine the effects of air pollutants on loss of crop production.

3. **Select appropriate technique(s) to value the impacts on society in monetary terms**

   Monetary valuation: Once you have completed the quantitative valuation, select and apply one of the monetary valuation techniques outlined in Table 13 for each of the impacts assessed.

Table 13. Monetary valuation techniques for impacts on society from non-GHG air emissions

Impact category	Monetary valuation technique
Human health	Stated or revealed preference approaches
Visibility (optional)	Stated or revealed preference approaches
Agricultural yield (optional)	Market prices

4.2.3. Water consumption

4.2.3.1. Impact pathway and brief description

Water plays a central role in ecosystems: without water, almost no life on earth could survive. Fresh water, in particular, is an essential resource for human health, agriculture, and nature but its supply is limited in some regions of the world and at certain times of the year [22]. This has led to significant global concern regarding the state of freshwater resources, which are subject to significant pressure from increasing water demand, with pressures projected to be exacerbated by climate change.

Water depletion affects humans and ecosystems. The impact of water depletion on humans depends on the local demand structure (domestic, industrial, and agricultural, as well as environmental). In extreme cases, water scarcity can lead to compensation processes: where domestic access to water is limited, people might resort to lower-quality water sources, leading to sanitation and hygiene issues (water access, sanitation, and hygiene, WASH), which can have an impact on human health. Reducing the use of lower-quality water sources is currently a priority of governments in collaboration with intergovernmental organizations. Water scarcity (most likely) may also lead communities, through local governments, to invest in (costly) water-supply infrastructure such as water treatment or desalination plants, which may drive up the cost of supply and subsidization [23].

As well as having immediate social and economic impacts, unmet water demand within ecosystems can lead to a loss of habitat, with further impacts on biodiversity, loss of ecosystem services such as freshwater fisheries, and further impacts to social and produced capitals.

Box 10 explains the difference between water consumption, water use, and water scarcity.

Box 10. Water consumption, water use, and water scarcity

It is important to distinguish between water use (or withdrawal) and water consumption.

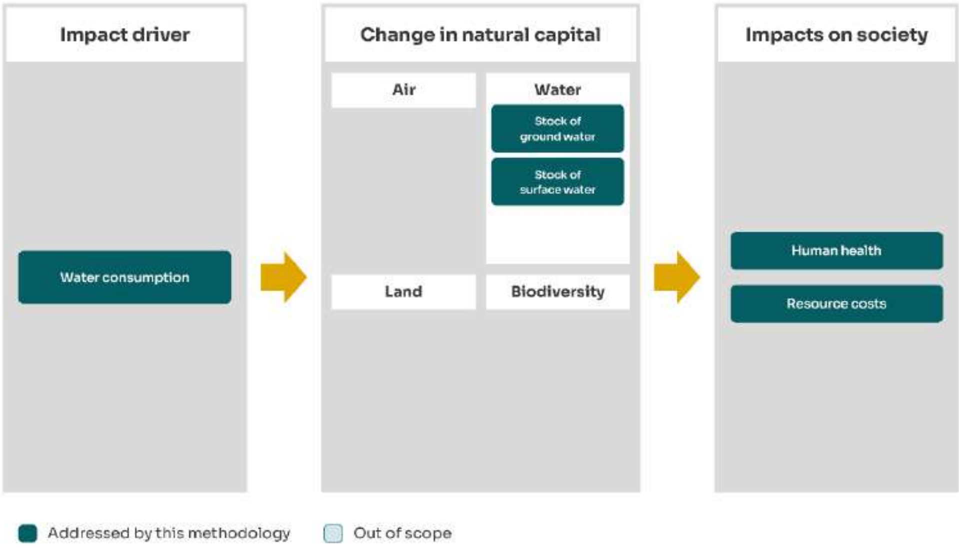
WRI [24] defines the two measures as follows:

- Water use "describes the total amount of water withdrawn from its source to be used. Measures of water usage help evaluate the level of demand from industrial, agricultural, and domestic users."
- Water consumption "is the portion of water used that is not returned to the original water source after being withdrawn. Consumption occurs when water is lost into the atmosphere through evaporation or incorporated into a product or plant (such as a corn stalk) and is no longer available for reuse."

Depleting water from a system generally leads to water scarcity, which is the lack of available water to meet demand, where demand can be both from humans and the natural environment.

Section 4.2.3 addresses the impact of water consumption. Impacts associated with discharge (and pollutants) are addressed in section 4.2.4. The steps of the impact pathway for water consumption are shown in **Figure 5Error! Reference source not found.**.

Figure 5. High-level impact pathway for water consumption



Note: Changes in natural capital that are not explicitly modeled are not displayed in the figure.

4.2.3.2. Measure your impact driver

To measure your impact driver, you need to measure the volume of water consumption. Table 14 presents the list of quantitative indicators that you should measure.

Table 14. Quantitative indicators to measure water consumption

Volume (m^3) of water consumption
Optional: volume of water withdrawn

The extent to which water use contributes to water stress or scarcity may vary by location and season. To complete the next steps, you should collect additional information on context, including geography, season/time of year, and information on scarcity or other demands.

The degree of regional specificity should be in line with your accounting goals. For a (rough) hotspot analysis, country-level averages of water stress may be sufficient. If you are active in areas that you know are water scarce, more detail at the watershed or sub-watershed level may be appropriate. Box 11 provides guidance on estimating water consumption.

Box 11. Guidance on estimating water consumption

To measure water consumed, it may be helpful to create a water balance by measuring water withdrawal (input) and subtracting water released (output). Your water balance should include types of withdrawal per source (e.g., groundwater, river, municipal water supply), especially if the water is released back to a different watershed.

Beyond the sources mentioned in section 4.1.1, secondary data specifically for water are available from national statistics databases, AQUASTAT by the FAO [25], WaterStat by the Water Footprint Network (WFN) [26], and other sources. (See NCMA general guidance for additional sources.)

When using secondary data sources, you should consider that they may provide data on only water withdrawal. Water consumption can be derived from withdrawal using standard consumption rates from literature. These consumption rates can vary significantly even within the same sector, as they depend on technology use, local climate, and other parameters. For example, water consumption rates associated with irrigation can vary from 20% to 80% depending on the type of technology (sprinkler, flooding, drip, etc.), the crop considered, and climate (tropical, temperate, etc.).

4.2.3.3. Measure changes in the state of natural capital

Implementing models to reflect changes in natural capital, as well as impacts on society arising from these changes, takes expert knowledge and you are very likely to need external support for this. It is likely that you will not perform the following actions directly yourself.

The following actions are needed to complete this step:

1. **Identify changes in capitals associated with your business activities and impact drivers.** You need to measure changes in water availability resulting from your water consumption. Table 15 presents the list of changes in natural capital that should be assessed.

Table 15. Changes in natural capital to measure for water consumption

Impact driver	Change in natural capital
Water consumption	Stock of surface water Stock of groundwater

2. **Measuring change.** To complete this action, you should use a modeling approach. This can be done using:

    (i) bespoke hydrological models to assess the changes in natural capital resulting from water consumption, accounting for local environmental conditions.

    (ii) pre-existing models, such as from life cycle inventories or similar data sources, that provide characterization factors for a set of predefined contexts.

Pre-existing models may either be based on hydrological models (good practice) or use proxies to characterize different contexts. Contextual information should be taken into account to measure change. Box 12 provides some considerations regarding contextual information to be considered.

Box 12. Contextual information on water consumption

Water scarcity (depletion of the stocks of groundwater and surface water) depends both on the supply or rate of regeneration of water, and on the demand from all user groups. Depending on the local context, there may be significant variations in seasonal water availability.

Depleting water from a given water body will reduce the availability to other water users (including ecosystems), whose needs may no longer be met. In general, the less water that remains, the more other users will be deprived. This includes both human and environmental demand, and may reduce the functioning of ecosystems, especially in riparian areas. Water scarcity is not just a question of ecosystem extent: depleting groundwater at an unsustainable rate may also lead to inflow of saline water, indirectly affecting the quality of soil systems and biodiversity.

Water stress or scarcity is highly dependent on the specific context, including the local hydrology, human activities, and climatic conditions / seasonal variations in precipitation, as well as the state of the local environment. Sources of data and pre-existing models include AQUASTAT by FAO [25], WaterStat by the Water Footprint Network (WFN) [26], AWARE (Available Water Remaining) [27], the Water Risk Filter by WWF [28], Aqueduct Water Risk Atlas by the World Resources Institute [29], and others (see NCMA general guidance for additional sources).[10]

4.2.3.4. Value impacts on society

Complete the following actions to value the consequences of your impacts on society:

1. **Define the consequences of impacts.**

Impacts on society include health impacts (e.g., malnutrition due to reduced food availability or waterborne diseases due to tapping unsecure water supplies) and resource costs (e.g., increased costs of water supply) (see impacts on society in Figure 5). These impacts are the consequences of changes in the ecosystem services as listed in Table 16. Please note that changes in ecosystem services are usually not modeled explicitly; however, describing ecosystem service changes can help you to understand how society is impacted.

Table 16. Impacts on society from water consumption

Change in ecosystem services	Impacts on society
• Water purification services	• Human health
• Water flow regulation services	• Resource costs
• Water supply services	
• Biomass provisioning services	
• Recreational services	

[10] See the MIT Shift Capital Toolkit for more tools for assessing water use. This is an interactive database that helps businesses find the right tool to measure and value natural capital as they use the Natural Capital Protocol [1].

2. **Select appropriate technique(s) to quantify the impacts on society**

You should first quantify impacts in physical terms, based on changes in natural capital. Next, select a method to value your impacts in monetary terms.

To perform quantitative valuation (in physical terms), select and apply one of the quantitative valuation techniques outlined in Table 17, for each of the impacts assessed.

Table 17. Techniques to quantify impacts on society from water consumption

Impact category	Quantification technique
Human health	The linkage between water scarcity and human health is an extreme case and depends on a society's capability to adapt economically. In the extreme case, water consumption can lead to a lack of water for domestic users, the use of alternative (lower quality) water supply and the spread of waterborne diseases (worst case scenario). This impact is likely to occur in locations with absence of basic water management practices in place. It is recommended that you estimate impacts on human health via a measure of water stress and DALYs (per cubic meters). To estimate impacts in terms of DALYs, you can either use characterization factors from life cycle assessment models, or econometric data, where the level of granularity is fit for purpose.
Resource costs	No need to model explicitly. Implicitly covered by monetary valuation technique.

3. **Select appropriate technique(s) to value the impacts on society in monetary terms**

   Monetary valuation: Once you have completed the quantitative valuation, select and apply one of the monetary valuation techniques outlined in Table 18, for each of the impacts assessed.

Table 18. Monetary valuation techniques to value impacts on society from water consumption

Impact category	Monetary valuation technique
Human health	Stated or revealed preference approaches
Resource costs	Cost-based approaches, including approaches like: Projected costs of supply (based on market prices), replacement costs, opportunity costs, subsidy costs of water Note: For future costs (e.g., due to resource depletion), the social discount rate needs to be applied

4.2.4. Water pollution

4.2.4.1. Impact pathway and brief description

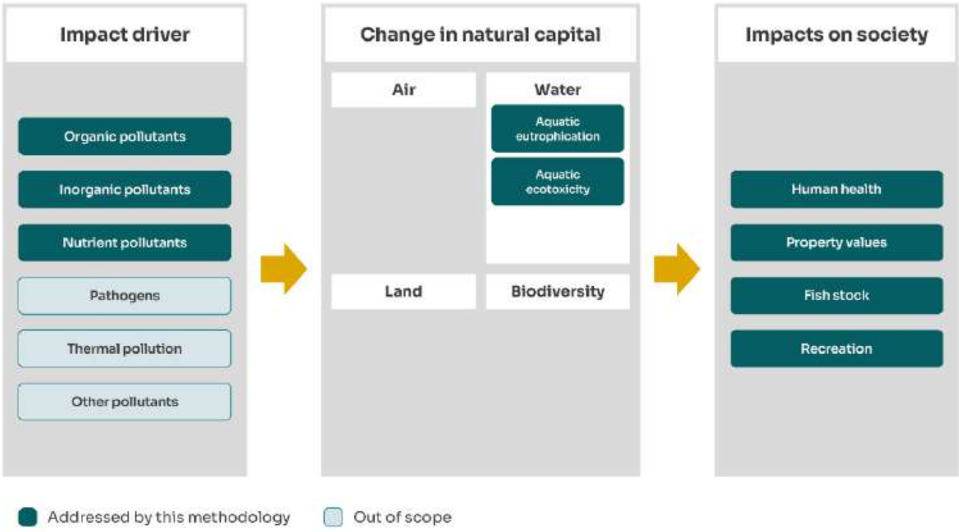
Clean water is an essential resource for human, animal, and plant life as well as an indispensable resource for the economy. There is significant global concern regarding the state of fresh and saline water resources, as human discharge of substances affects the quality of water bodies. Water bodies include inland, transitional, and coastal waters; surface and groundwaters; and the oceans and they may all transcend national boundaries (Water Framework Directive 2000 [30]). Despite improvements in some high-income countries, water pollution is on the rise globally (e.g., UNEP 2021 [31]). Pollution and the degradation of water bodies can adversely affect human well-being and, thereby, carry additional societal costs.

The most significant water-pollutant categories (in terms of societal cost) are [32]:

- **Organic pollutants:** These are chemical substances primarily composed of carbon, hydrogen, and oxygen and may include petroleum, dyes, pesticides, surfactants, and pharmaceuticals. They are of concern due to their toxicity, semi-volatile nature, low water solubility, high bioaccumulation, and non-biodegradability under normal environmental conditions leading to environmental degradation and impacts on human health [33]. Of particular focus are persistent organic pollutants (POPs) which are addressed through the 2001 Stockholm Convention on POPs.
- **Inorganic pollutants**: Inorganic toxic substances, including heavy metals and chemical compounds, that may persist or cause undesirable changes in the natural environment, bioaccumulate in the food web, and have adverse effects on human health.
- **Nutrient pollutants**: Nitrogen (N) and phosphorus (P) are basic building blocks of plant and animal proteins. In elevated concentrations, they can cause a range of negative effects, such as algal blooms (eutrophication) that lead to a lack of oxygen in the water, affecting water quality, fish yields, and the availability of a wide range of products and services provided by ecosystems.
- **Pathogens**: Pathogens in water include viruses, bacteria, protozoa, and helminths (in the form of eggs) [34]. They may lead to numerous waterborne diseases, such as cholera and typhoid. Coliforms are a broad class of bacteria, some of which are harmful, disease-causing organisms, such as *Escherichia coli* (*E. coli*). These can be released or encouraged to grow through discharges of inadequately treated sewage.
- **Thermal pollution**: Discharges of water above or below the ambient temperature of natural water bodies can change the ecological balance for aquatic species.
- **Other pollutants** include suspended solids and radioactive pollutants. Endocrine disruptors are also flagged for concern and may include industrial chemicals (e.g., polychlorinated biphenyls (PCBs)) and synthetic pharmaceuticals.

Pollutants may enter water bodies through municipal and industrial point sources (e.g., sewage outfalls) or non-point sources (e.g., diffuse runoff from farmland or rain) [32]. The steps of the impact pathway for water pollution are shown in Figure 6.

Figure 6. High-level impact pathway for water pollution



Note: Changes in natural capital that are not explicitly modeled are not displayed in the figure.

4.2.4.2. Measure your impact driver

To measure your impact driver, you need to measure the mass of pollutants released into water caused by your business activities.

Table 19 presents the list of quantitative indicators for the recommended effluents that you should measure following the EU PEF methodology environmental footprint impact categories (EPLCA 2019) [35], the WHO international guideline for drinking water quality (WHO 1971) [36] and the OECD Data Sheets for Surface Water Quality Standards [37].

Please note that water quality laws (at local, national, regional, and global levels) differ and will be more specific about the compounds that should be monitored within each category and provide pollutant thresholds. For example, the EU Water Framework Directive [107] outlines the Priority Substances (45 compounds) that EU member states should monitor and regulate.

Table 19. Quantitative indicators to measure water pollution

Mass of inorganic pollutants: heavy metals, chemical compounds (kg)
Mass of nutrients: Nitrogen (kg N_{eq}) and phosphorus (kg P_{eq})[11]

[11] Nutrients can either be reported as the whole compound or as the principal element (e.g., nitrate may be reported as NO_3- or N). Local laws may determine which you will be measuring.

If you want to expand your quantitative indicators to other physical, chemical, and biological parameters, you can measure [38]:

- Physico-chemical indicators: dissolved oxygen (mg/L), pH, temperature, salinity
- Organic pollutants: Biological oxygen demand (BOD)
- Pathogens: coliforms (e.g., Escherichia coli)
- Turbidity: (you will need to convert from Nephelometric turbidity units (NTU) to mg/L)
- Hardness: (mg/L of calcium CA and magnesium mg/L)

To perform the next steps, you will need to collect further information on the context of the pollutants and the water bodies into which they are released (especially location, existence of wastewater treatment, etc.). See Box 13 for further information on this.

Box 13. Guidance on measuring indicators for water pollution

For primary data collection: To measure water pollution from point-source discharges, effluent discharges from in-line measurement are the most accurate data. However, aside from large, regulated facilities in high-income countries, this is rarely a practical approach.

As an alternative, the drivers of water pollution can be measured to indirectly estimate discharges.

For example, the quantity and type of chromium used together with specifics on the tanning method employed can be used to calculate the load and toxicity of discharges that result from the tanning of a hide. Similarly, typical loading factors can be used for phosphorous runoff associated with pastoral agriculture.

When using (standard) life cycle inventory data sets, you should always consider whether these include wastewater treatment as a separate process step (see NCMA general and sector-specific guidance for secondary data sources to use).

4.2.4.3. Measure changes in the state of natural capital

Implementing models to reflect changes in natural capital, as well as impacts on society arising from these changes, takes expert knowledge and you are very likely to need external support for this. It is likely that you will not perform the following actions directly yourself.

The following actions are needed to complete this step:

1. **Identify changes in capitals associated with your business activities and impact drivers.** You need to measure changes in water quality as well as secondary effects resulting from your effluents. Table 20 presents the list of changes to natural capital that should be assessed.

Table 20. Changes in natural capital to measure for water pollution

Impact driver	Change in natural capital
Nutrients Inorganic pollutants	• Aquatic ecotoxicity • Aquatic eutrophication

2. **Measuring change.** To measure change you should use a modeling approach. This can be done using:

(i) a bespoke hydrological dispersion model that accounts for specific local conditions or

(ii) pre-existing models, such as from life cycle inventories or similar data sources that provide characterization factors for a set of predefined contexts. Pre-existing models may either be based on dispersion models, chemical fate and exposure functions (good practice) or use proxies to characterize different contexts.

4.2.4.4. Value impacts on society

Complete the following actions to value the consequences of your impacts on society:

1. **Define the consequences of impacts on society.**

   Impacts on society include human health (e.g., illnesses or premature death due to decreased water quality), property values (e.g., loss in value due to changes in water quality), fish stock (e.g., changes in fish yield), and recreation (e.g., loss of recreation due to poor water quality) (see impacts on society in Figure 6). These impacts are the consequences of changes in the ecosystem services as listed in Table 21. Please note that changes in ecosystem services are usually not modeled explicitly; however, describing ecosystem service changes can help you to understand how society is impacted.

Table 21. Impacts on society from water pollution

Change in ecosystem services	Impacts on society
• Water purification services	• Human health
• Water supply services	• Property values
• Biomass provisioning services	• Fish stock
• Recreational services	• Recreation

2. **Select appropriate technique(s) to quantify the impacts on society**

   You should first quantify impacts in physical terms, based on changes in natural capital. Next select a method to value your impacts in monetary terms.

   To perform the quantitative valuation of the impacts on society (in physical terms), select and apply one of the quantitative valuation techniques outlined in Table 22 for each of the impacts assessed.

Table 22. Techniques to quantify impacts on society from water pollution

Impact category	Quantification technique
Human health	Dose-response functions. These types of functions quantify the likelihood of reaction within a population resulting from exposure to a certain level of pollution in water. Characterization factors from life cycle assessment implicitly use these functions so these can also be used where the level of granularity is fit for purpose.
Property values	No need to model explicitly. Implicitly covered by monetary valuation technique.
Fish stock	No need to model explicitly. Implicitly covered in monetary valuation technique.
Recreation	No need to model explicitly. Implicitly covered by monetary valuation technique.

3. **Select appropriate technique(s) to value the impacts on society in monetary terms**

   Monetary valuation: Once you have completed the quantitative valuation, select and apply one of the monetary valuation techniques outlined in Table 23 for each of the impacts assessed.

Table 23. Monetary valuation techniques to value impacts on society from water pollution

Impact category	Monetary valuation technique
Human health	Stated or revealed preference approaches
Property values	Stated or revealed preference approaches
Fish stocks	Stated or revealed preference or production function approaches
Recreation	Stated or revealed preference approaches

4.2.5. Land use

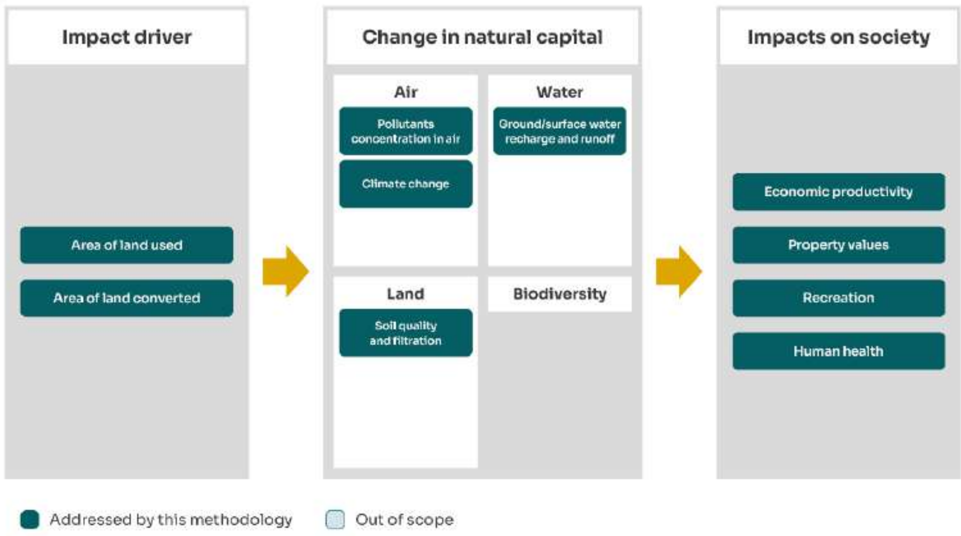
4.2.5.1. Impact pathway and brief description

Land use, and by extension seabed use, refers to human intervention or management of a given area of the solid surface of the Earth. It includes activities undertaken (e.g., conversion to farming, building infrastructure) and institutional arrangements put in place (SEEA 2012) [3]. Use of and change to land and seabed are some of the main drivers of biodiversity loss and degradation of a broad range of ecosystem services (MEA 2005 [39]).[12] This includes the degradation of soil quality or marine sediments which further affects ecosystem services (UNEP 2017 [18]).

The value of land and seabed to society is largely determined based on the surface type and the ecosystems it supports. This is described in terms of land cover, the physical and biological material covering the Earth's surface including natural vegetation and abiotic (non-living) components.

The steps of the impact pathway for land use are shown in **Figure 7**.

Figure 7. High-level impact pathway for land use



Note: Changes in natural capital that are not explicitly modeled are not displayed in the figure.

4.2.5.2. Measure your impact driver

To measure your impact driver, you need to measure the area of land (or seabed) used and/or area converted. Table 24 presents the list of quantitative indicators for the main land (or seabed) cover types you should measure.

[12] Seabed and marine life are largely affected by the impact drivers water pollution and GHG emissions, and therefore not considered in this section.

Table 24. Quantitative indicators to measure land use

Area of land (or seabed) used (ha) is the area of land (or seabed) occupied by activities driven by business (e.g., used for agriculture or other raw materials or for living/working space). Use of an area implies the existence of some human intervention or management. As a result, land used is not in the same state as it was prior to the business's activities but has been converted as a result of business activities.
Area of land (or seabed) converted (ha) is the area of land where land cover (the observed physical and biological cover of the Earth's surface including natural vegetation and abiotic (non-living) components) is changed through activities driven by business. An example is an area of seabed reclaimed to form land.

To perform the next steps, you will need to collect further information on the context and the type of land (or seabed) used (especially location, type of land cover/ecosystem, etc.). See Box 14 for further information on this.

Box 14. Guidance on measuring indicators for land use

Land-use (or seabed-use) activities associated with the entity's upstream, own operations, and potentially downstream activities can be found within the entity's internal management systems and upstream land (or seabed) use can be requested from suppliers. If the land or seabed associated with your entity has multiple uses/users, we recommend you allocate the land use based on your economic share of the overall land output (economic allocation), or you allocate your share based on the weight of materials associated with your business in comparison to the total weight of output from the land (weight allocation).

Recommendation: Regarding the changes caused by the land (or seabed) use of your entity, spatial information on the extent of an entity's activities can be extracted from data sources such as, Google Earth [40], using GIS [41] or other satellite tools such as Sentinel- [42] or WorldView-3 [43].

Since certain materials / crops are typically produced in specific locations; you could use trade statistics to determine the likely location of origin if you lack specific information.

4.2.5.3. Measure changes in the state of natural capital

The following actions are needed to complete this step:

1. **Identify changes in capitals associated with your business activities and impact drivers.**

   You need to measure changes in the extent and quality of different types of land cover, as well as the associated ecosystem function. Table 25 presents the list of changes to natural capital that should be assessed.

Table 25. Changes in natural capital to measure for land use

Impact driver	Change in natural capital
Land converted	Ecosystems are a dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit. Converting land cover can affect all aspects of this, leading to changes notably including: • Pollutants concentration in air • Climate change • Change in soil quality and filtration • Ground/ surface water recharge and runoff
Land use	Land (or seabed) that is occupied today by the business was converted from its original state by previous or current users. Consequently, your measurement of changes should compare the current use to a pre-defined baseline. The baseline can be the natural ecosystem of the region, for example, or following the recommendations of the Science Based Targets Network, use a fixed cut-off year, no later than 2020 [44]. The baseline should be clearly communicated. You should complement the analysis by a qualitative description of the state of the ecosystem and its services.

2. **Measuring change.** To complete this action, you can use a combination of direct measurement and modeling approaches to value the impacts on society following the impact pathway.

4.2.5.4. Value impacts on society

Complete the following actions to value the consequences of your impacts on society:

1. **Define the consequences of impacts on society** (see impacts on society in Figure 7). These impacts on society are the consequences of changes in the ecosystem services as listed in Table 26. The land-use activities of companies can particularly influence the ecosystem services provided by the used or converted land. Thus, changes in ecosystem services play a central role in how this methodology determines and values impacts on society.

Table 26. Impacts on society from land use

Change in ecosystem services	Impacts on society
• Nursery population and habitat maintenance services • Soil erosion control • Coastal protection • Pollination • Climate regulating services (local / global) • Biomass provisioning services • Recreational services	• Economic productivity • Property values • Recreation • Human health (optional)

2. **Select appropriate technique(s) to quantify the impacts on society**

To perform quantitative valuation (in physical terms) you should select and apply one of the quantitative valuation techniques outlined in Table 27, for each of the impacts assessed.

Table 27. Techniques to quantify impacts on society from land use

Impact category	Quantification technique
Property values	No need to model explicitly. Implicitly covered by monetary valuation technique.
Economic productivity	No need to model explicitly. Implicitly covered by monetary valuation technique.
Recreation	No need to model explicitly. Implicitly covered by monetary valuation technique.
Human health (optional)	Land-use activities and human health can be indirectly linked through effects of ecosystem changes on GHG emissions, and pollutants in air and water. Therefore, impacts on human health could be measured via the methods listed in section 4.2.1 GHG emissions, section 4.2.2. Non-GHG air emissions, and section 4.2.4. Water pollution.

3. **Select appropriate technique(s) to value the impacts on society in monetary terms.**

   Monetary valuation: Once you have completed the quantitative valuation, select and apply one of the monetary valuation techniques outlined in Table 28 for each of the impacts assessed.

Table 28. Monetary valuation techniques to value impacts on society from land use

Impact category	Monetary valuation technique
Property values	Stated or revealed preference approaches
Economic productivity	Productivity change methods
Recreation	Stated or revealed preference approaches
Human health (optional)	Stated or revealed preference approaches

An important consideration regarding land use is the temporal dimension. Many natural areas were converted long ago and have changed uses and ownership many times since. Ecosystem services are flows, such that if their provision is reduced, that reduction is felt every year until the land is restored. You should account for ecosystem service reduction in the current year relative to your chosen baseline and assign this reduction in value to the current occupant of the land, irrespective of whether that occupant was directly responsible for the land's conversion. To value the land, you should use marginal values that reflect the marginal value of the land converted and couple it with a qualitative assessment of the ecosystem condition.

4.2.6. Solid waste

4.2.6.1. Impact pathway and brief description

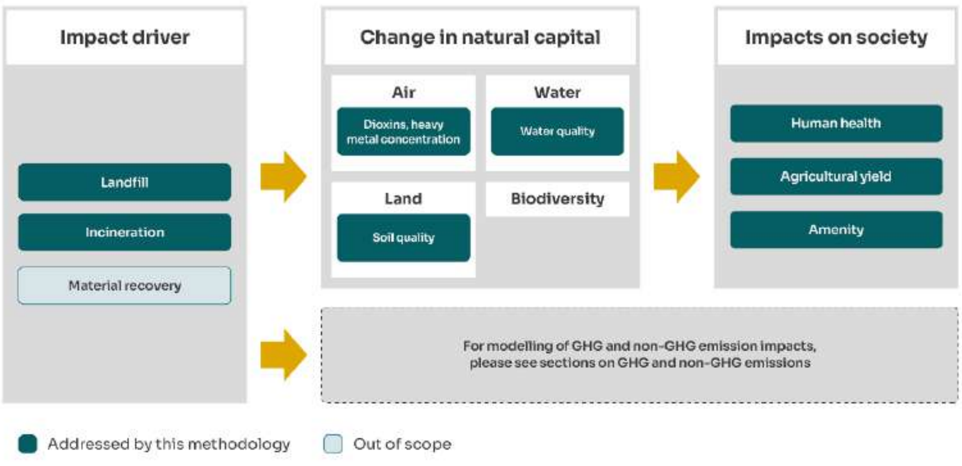
Corporate activities in all sectors generate waste. The generated waste can be in gaseous, fluid, or solid form. In this document gaseous waste is covered in the section on non-GHG air emissions, fluid waste is covered in the section on water pollution, and this section considers solid waste. The disposal of solid waste can lead to a range of changes to natural capital that adversely affect human well-being, thereby carrying a cost to society. This section is concerned with the impacts of waste disposal. It does not evaluate the costs associated with design or production inefficiencies that may be indicated by the presence of waste.

For solid-waste disposal, the type of waste (e.g., hazardous, non-hazardous) and the method of its disposal (incineration, landfill, or material recovery) are key factors that dictate how natural capital is affected as well as the type and magnitude of impacts.[13]

Recommendation for circular economy models: Given that recycling essentially closes the loop in a linear value chain (e.g., from virgin raw material extraction to end-of-life treatment) and provides raw materials for a business, we recommend that material recovery (and energy recovery) be treated as averted waste generation and that it be reflected separately. Recycled waste should be treated as zero waste generated, while accounting for the negative impacts due to the energy use and the processes needed to recycle, recover, or reuse the waste.

The steps of the impact pathway for solid waste are shown in **Figure 8**. **Error! Reference source not found.**

Figure 8. High-level impact pathway for solid waste



Note: Changes in natural capital that are not explicitly modeled are not displayed in the figure.

[13] In cases where solid waste is sent to open dump sites, it may be carried into marine water (e.g., via rivers) and lead to additional impacts. Please note that these impacts are currently out of scope of the methodology.

4.2.6.2. Measure your impact driver

To measure your impact driver, you need to measure the mass of waste disposed. Table 29 presents the list of quantitative indicators for the main land cover types you should measure.

Table 29. Quantitative indicators to be measured

Mass of waste disposed to landfill or marine dump sites (kg)
Mass of waste incinerated (with/without energy recovery) (kg)
Mass of waste material recovered (kg)

You will moreover need to measure the composition, including organic content, and classify waste as hazardous and non-hazardous according to regulatory classifications and thresholds. To perform the next steps, you will need to collect further information on the context in which the waste is disposed and the type of stringency with which waste management is enforced (e.g., location, weather conditions).

4.2.6.3. Measure changes in the state of natural capital

Implementing models to reflect changes in natural capital, as well as impacts on society and business arising from these changes, takes expert knowledge and you are very likely to need external support for this. It is likely that you will not perform the following actions directly yourself.

Solid waste disposal that is incinerated or sent to landfill generates GHG emissions. To quantify these, you will need to estimate the GHG emissions resulting from the waste you have generated (e.g., by using the Intergovernmental Panel on Climate Change Waste Model (IPCC 2000 [45])). After performing this step, refer to section 4.2.1 GHG emissions to assess the change in natural capital and perform the valuation step.

Similarly, solid waste disposal to incineration will result in non-GHG air emissions that you will need to quantify. To quantify these, you can use incineration emission factors (e.g., provided by IPCC (2000) [45]. After performing this step, refer to section 4.2.2 Non-GHG air emissions to assess the change in natural capital and perform the valuation step.

For impacts on society due to leachate released from waste disposed to landfill and disamenity from waste incinerated or disposed to landfill, you will need to perform the following steps:

1. **Identify changes in capitals associated with your business activities and impact drivers.** Table 30 presents the list of changes to natural capital that should be assessed.

Table 30. Changes in natural capital to measure for solid waste

Indicator (impact driver)	Change in natural capital
Waste to landfill (managed)	Changes in soil and water quality Changes in odor, noise, and visual amenity
Waste to incineration	Changes in dioxin and heavy metal concentrations in air Changes in odor, noise, and visual amenity

2. **Measuring change.** To complete this action, you should use a modeling approach**.** Your modeling approach should incorporate:

- Landfill: Modeling of leachate effects due to landfill should account for the amount and composition of waste (e.g., hazardous / non-hazardous waste), the pathway by which leachate escapes the landfill (e.g., impermeable liner, distance to waterways), and the likelihood that leachate will impact society (e.g., proximity to sensitive ecosystems).
- Incineration: Modeling of dioxin and heavy metal concentrations in air should be based on incineration emission factors.
- Disamenity due to landfill and incineration: It is recommended that impacts are valued directly in monetary terms without the need for a quantitative physical impact metric.

4.2.6.4. Value impacts on society

Complete the following actions to value the consequences of your impacts on society:

1. **Define the consequences of impacts** (see impacts on society in Figure 8). These impacts are the consequences of changes in the ecosystem services as listed in Table 31. Please note that changes in ecosystem services are usually not modeled explicitly; however, describing ecosystem service changes can help you to understand how society is impacted.

Table 31. Impacts on society from solid waste

Change in ecosystem services	Impacts on society
• Local climate regulation services • Air filtration services • Water purification services • Biomass provisioning services • Water supply services • Recreational services	• Human health • Amenity • Agricultural yield

2. **Select appropriate technique(s) to quantify the impacts on society**

   You should first quantify impacts in physical terms, based on changes in natural capital. Then you should select a method to value your impacts in monetary terms.

   To perform quantitative valuation (in physical terms) you should select and apply one of the quantitative valuation techniques outlined in Table 32, for each of the impacts assessed.

Table 32. Techniques to quantify impacts on society from waste

Impact category	Quantification technique
Human health	Dose-response function
Agricultural yield	Source-pathway-receptor relationships to assess the likelihood and severity of agricultural impacts from leachates from landfills
Amenity	It is recommended that impacts are valued directly in monetary terms without the need for a quantitative physical impact metric

3. **Select appropriate technique(s) to value the impacts on society in monetary terms.**

   Monetary valuation: Once you have completed the quantitative valuation, select and apply one of the monetary valuation techniques outlined in Table 33, for each of the impacts assessed.

Table 33. Monetary valuation techniques to value impacts on society from solid waste

Impact category	Monetary valuation technique
Human health	Stated or revealed preference approaches
Agricultural yield	Market prices, e.g., clean-up costs
Amenity	Stated or revealed preference approaches, e.g., hedonic pricing

5. DEPENDENCIES AND VALUE TO BUSINESS PERSPECTIVE

Within the scope of the NCMA methodology, we define dependencies as the business reliance on or use of natural capital. Although businesses and societies are equally dependent on natural capital through the use of ecosystem assets and ecosystem services, within the following sections we focus on how business could value their dependencies on natural capital through the use of ecosystem services [6].

In the value to business perspective, we focus on all final ecosystem services as listed below. Some of these items may already be accounted for by the entity where a transaction or event has occurred resulting in a change on an asset in the balance sheet. Other factors such as risks to the loss of services should be included in the entity's enterprise risk management where the impact to the business on its future financial performance is considered material. Accordingly, while elements may already be accounted for, these may only be partial assessments of the loss (or gain) in the value to business.

Supporting ecosystem services are currently considered out of scope. Final ecosystem services include and are defined by the UN SEEA [46], p.130 as follows:

- Provisioning services: those ecosystem services representing the contributions to benefits that are extracted or harvested from ecosystems.
- Regulating and maintenance services: those ecosystem services resulting from the ability of ecosystems to regulate biological processes and to influence climate, hydrological, and biochemical cycles, and thereby maintain environmental conditions beneficial to individuals and society.
- Cultural services: the experiential and intangible services related to the perceived or actual qualities of ecosystems whose existence and functioning contributes to a range of cultural benefits.

Table 34 provides more detail on the ecosystem services considered, following the classification of the UN SEEA 2022 [47]

Table 34. Ecosystem services as classified by UN SEEA (2022, p.44) [47]

Provisioning services	
Biomass provisioning services	Crop provisioning services
	Grazed biomass provisioning services
	Livestock provisioning services
	Aquaculture provisioning services
	Wood provisioning services
	Wild fish and other natural aquatic biomass provisioning services
	Wild animals, plants, and other biomass provisioning services
Water supply	
Regulating services	
Global climate regulation services	Sequestration component
	Retention component
Local climate regulation services	
Air filtration services	
Soil and sediment retention services	Soil erosion control services
Water purification services	Retention and breakdown of nutrients
Water flow regulation services	Baseline flow maintenance services
	Peak flow mitigation services
Flood control services	Coastal protection services
Pollination services	
Nursery population and habitat maintenance services	
Cultural services	
Recreation-related services	Travel related
	Local

To value the business's dependency on ecosystem services (dependencies), several valuation approaches need to be applied:

- **Market price valuation:** reflecting the amount of money the business is willing to pay to acquire access to the ecosystem services from willing sellers (public or private entities) [48].

  Market price valuation reflects the transactions (acquisition prices) between the business and various stakeholders (private owners, municipal and national governments, communities, etc.) in terms of economic activities. If no direct market prices exist, estimates based on similar markets, or based on the increase in production costs, can serve as proxies [46].

  Market price valuation is applicable in the case the business is directly dependent on the use of provisioning services and cultural services.

Recommendation: It is important to note that market price valuation is an underestimate of the true value of the ecosystem service.

For this reason, we recommend coupling all the different valuation approaches proposed and presenting them together to provide a more holistic picture of how the business is dependent on natural capital through ecosystem services.

- **Production (loss) cost:** With depleting ecosystem services, companies face higher costs of production, which leads to higher prices, and thus fewer consumers being willing to purchase a produced product. As a result, companies can lose market share (cf. UN SEEA).

  In extreme cases, the complete depletion of an ecosystem service can result in the complete loss of production. For marginal losses of ecosystem services, the marginal loss in production should be estimated.

- **Replacement cost valuation:** The unsustainable use of ecosystem services for business activities leads to the depletion of those services and the underpinning ecosystem assets, and the crossing of planetary boundaries.

  Replacement cost valuation estimates the cost of replacing a specific ecosystem service or services with similar ecosystem service/s (potentially in a different geography) or with man-made technologies. For example, a wetland providing water purification services can, in the short term, be substituted for using a water treatment facility [49] [50] [51].

  Replacement costs do not provide a technically correct measure of the economic value of ecosystem services. The user needs to take into consideration willingness to pay (WTP) and willingness to accept (WTA) the change in the valued ecosystem service/s covered in the value to society perspective.

  Moreover, replacement costs are usually valued using the least costly, man-made replacement technologies providing an underestimate of the actual value of the ecosystem service.

  Replacing an ecosystem service with the same service in a different location or technology should not be an indication of the real value of the ecosystem service, but more of an estimate of the lowest value of said service when looked at separately. The true value is much higher when taking into account the context of impacted supporting ecosystem services and planetary boundaries [52].

- **Restoration cost valuation:** Businesses depending on depleted ecosystems and ecosystem services need to value the costs required to restore the ecosystem and the depleted services.

  Restoration cost valuation equates the cost of an ecosystem service to the expense of measures required to mitigate negative effects resulting from the depletion of the ecosystem service where the business is responsible for degrading the ecosystem service. For example, the restoration cost valuation of wood provisioning and carbon sequestration services could be equated with the cost of reforestation of a location where these services had been depleted due to the deforestation caused by an entity in the timber industry [47] [53].

Depending on the ecosystem service the business is dependent on, all valuation approaches are applicable and presented in the same order stated above. For example, a business dependent on fish provisioning service will follow the subsequent steps to value the impacts on the business:

- The market price of fishing (how much the entity is paying to fish at a specific location)
- The production price for selling the fish product
- The price to replace this ecosystem service once depleted
- The price to restore this ecosystem service once depleted

For regulating ecosystem services, direct market prices and production prices are difficult to observe, and the valuation of these services might be restricted to replacement and restoration costs. We nevertheless want to stress that companies depend on these ecosystem services and need to consider their impacts and dependencies (double materiality) in a qualitative manner.

Recommendation: To understand your entity's dependencies on ecosystem services and assets, you can use the ENCORE tool [112]. The tool provides an overview of the dependencies and impacts related to business activities based on sector, sub-industry, and potentially production process.

6. USING THE RESULTS

This section builds on the Apply Steps outlined in the Natural Capital Protocol [1]. For readers more familiar with the terminology of life cycle assessments, this corresponds to the “interpretation” stage.

Once the natural capital accounting process is complete you need to interpret the results taking into consideration the level of confidence that your modeling assumptions permit.

6.1. Interpret and test the results

There will always be some estimation or approximation involved in natural capital accounting. To understand what level of confidence you can have in your results, you will need to interpret and validate them. This includes reviewing your modeling assumptions and validating your data inputs.

To interpret and test results, you should: (i) test your key assumptions, (ii) collate results, and (iii) validate the accounting process. You may also consider seeking (external) assurance or verification, particularly if planning to disclose your accounting publicly.

6.1.1. Test key assumptions

To test your key assumptions, you should consider carrying out a sensitivity or scenario analysis. You should also review your modeling assumptions and how they might limit the conclusions to be drawn.

Sensitivity analysis involves testing how changes in assumptions or key variables affect accounting results. There are different methods of carrying out a sensitivity analysis, many of which require knowledge of statistics. All methods are designed to help you understand the degree of confidence you can have in your results, without overstating their accuracy.

Scenario analysis involves testing alternative scenarios to explore the variation in assessed impacts if different decisions were taken. These alternative scenarios could be, for example, different interventions, exploratory scenarios, vision scenarios, or absence of corporate activities.

6.1.2. Collate results

To interpret your results, you first need to compile your resulting data in a way that is appropriate to your natural capital accounting. This is likely to involve some form of analytical approach or framework such as cost-benefit analysis, multicriteria analysis, or environmental profit and loss account (EP&L). Collating results provides a means of standardizing calculation methodologies. Additionally, as has been noted with regard to current sustainability reporting practices, when companies present results in non-standardized ways this makes comparisons difficult.

6.1.3. Validate and verify the accounting process and results

While validation and verification may cover either the accounting process or the results or both, the benefits of rigorous validation and verification can be significant:

- Validation of the accuracy and completeness of your results may be required by internal colleagues involved in making the decision that your accounting is intended to inform.
- Verification can provide confidence to various stakeholders that the data and methodologies used are fit for purpose and that the accounting results are sufficiently robust to be used as a basis for business decisions and/or external communication.

For these reasons, you should validate and verify your accounting process and results. Depending on the application of the accounting, this can be carried out by internal or external reviewers.

6.2. Take action

After calculating your natural capital accounts, your last step will be to act upon them, and to communicate with your relevant stakeholders.

6.2.1. Apply and act on results

Depending on your objective, your actions in response to your accounting are likely to differ. For example, you could use the results to track your impacts on society over time, or to prioritize actions to address hotspots that you have identified.

6.2.2. Communicate results

You may want to communicate your results internally or externally. Your communicated results should be at an appropriate level of detail and include information on key modeling assumptions as well as limitations.

The appropriate level of detail depends on the intended use of the results. It might include some aggregation of monetized impacts over time, and across regions and ecosystem services. When aggregating, we advise that you adhere to some general rules following the recommendations by IEF 2022 [54] and UN SEEA 2022 [53]:

- Aggregation should not include elements of different types of social impact valuation techniques, such as the well-being of individuals and their human rights. If you choose to display these impacts jointly, make sure that the more granular information is available as well to allow decision makers to distinguish between impacts.
- Aggregating impacts in different regions and over time can be done if the components to assess the impacts are measured consistently (i.e., by estimating the values and aggregating those based on the same or comparable methods).
- Aggregating impacts of different ecosystems services requires the consistent estimation measurement of physical boundaries, stakeholders, and time horizons. Furthermore, a consistent ecosystem (service) classification and valuation approach should be given (e.g., when aggregating impacts across regions).

- Within the same topic, impacts generated by different sources can be aggregated (e.g., non-GHG air emissions from different products produced).
- Within the same topic (e.g., non-GHG air emissions), you can aggregate different impacts on society if these are valued separately (e.g., health impacts, visibility).
- Across topics (e.g., non-GHG air emissions and water consumption), aggregation should only be done if the impacts are additionally shown on a more granular level.
- Aggregation should only be done if the same stakeholders are affected. If different stakeholders are affected, the impacts can be aggregated only if they are also shown on a more granular level.
- Aggregation should in general only be done within the same value-chain level. If impacts are aggregated across value-chain levels, impacts should be attributed to the companies responsible for them.

In general, we advise to be careful when aggregating impacts, making sure that decision makers are not misled by aggregated impacts that could include impacts on different stakeholders.[14] We furthermore strongly advise against computing a total impact (i.e., aggregating all impacts), especially without displaying more granular information.

Box 15 provides further information on reporting requirements.

Box 15. Natural capital and reporting requirements

At the time of writing, financial accounting and accounting for other capitals (natural, social, human) are treated as separate domains. Conceptually, further work will be needed to link the two. This is explored in a report by the Capitals Coalition [55].

In general, corporate reporting requirements depend on your location. Whilst there are no specific mandatory provisions on using natural capital accounting for external disclosures, there are overlaps with both financial and non-financial reporting.

In the EU, the Corporate Sustainability Reporting Directive will require companies to report on environmental aspects following a "double materiality" definition. Natural capital accounting may be a useful tool for this.

[14] If the NCMA methodology is combined with the assessment of positive impacts on society (e.g., from training provided or wages paid), we strongly advise against netting negative and positive impacts.

ANNEX I. POTENTIAL RESULTS TEMPLATES

Below, we include templates that can be used to display your results. Moreover, Figure 11 displays how an EP&L intensity can be tracked over time against a predefined target. Please note that there is not yet consensus on how results should best be displayed. For a list of case studies published by corporates, please see the overview by the Capitals Coalition [56], and the pilot studies by the Value Balancing Alliance [57].

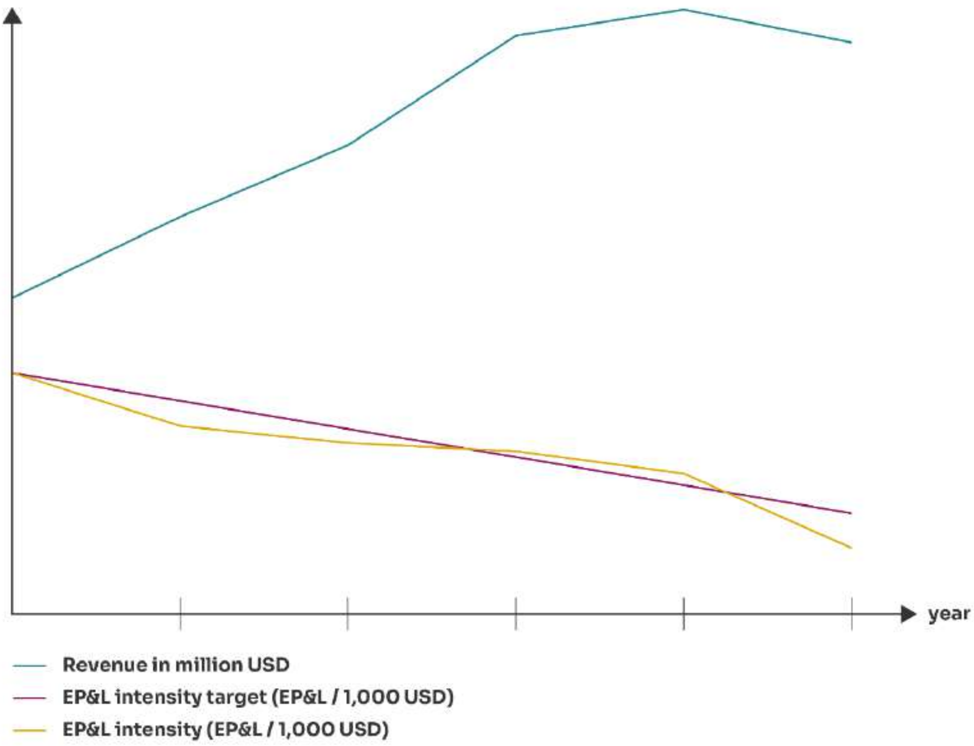
Figure 9. Environmental Profit & Loss template

		Value chain boundaries						
		Upstream – Tier 1	Upstream – Tier 2	Upstream – Tier 3	Upstream – Tier 4	Own operations	Down-stream	Total (mill.)
Impact drivers	GHG emissions							
	Non-GHG air emissions							
	Water consumption							
	Water pollution							
	Land use							
	Solid waste							

Figure 10. Integrated Profit & Loss template

Capitals		**Value chain stages**		
	Impact drivers	**Upstream**	**Own operations**	**Downstream**
Produced	Net income amortization and depreciation			
Human & social	Taxes Wages & benefits Capacity building Health & safety			
Environmental	GHG emissions Non-GHG air emissions Water consumption Water pollution Land use Solid waste			

Figure 11. EP&L intensity



ANNEX II. DATA SOURCES AND APPROACHES

This Annex contains further information on data sources and approaches that your natural capital accounting may build on:

1. Life cycle assessment
2. Environmentally extended input-output modeling (see NCMA general and sector-specific guidances for more information)

II.1 Life cycle assessment (LCA)

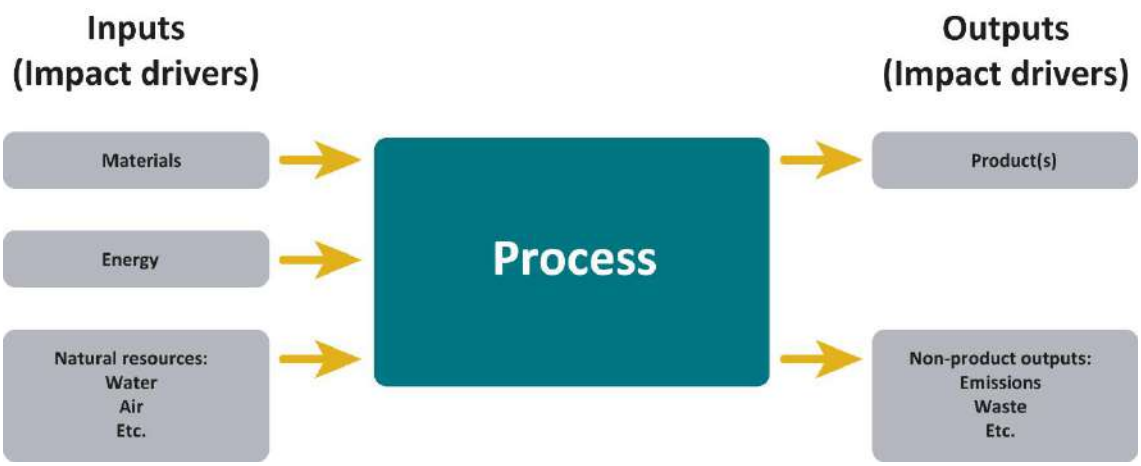
II.1.1 About LCA

Life cycle assessment (LCA) is a technique used to assess the environmental (i.e., natural capital) effects of a company, product, or service through all stages of its life cycle, from material extraction to end-of-life (disposal, recycling, or reuse) (for guidance on LCA assessments, see e.g., UNEP, 2017 [23]). This is codified in two ISO standards, ISO 14040 [58] and ISO 14044 [11]. It should be noted that the definition of "impacts" used in LCA differs from that used in natural capital accounting following the Natural Capital Protocol [1], which is the definition used in this document.

Life cycle assessment is implemented through four stages: (i) Goal and Scope; (ii) Inventory analysis; (iii) Impact assessment; and (iv) Interpretation.

One of the key steps is the creation of a life cycle inventory (LCI), which reflects flows to and from nature for a product system. As such, LCA relies on a bottom-up approach, analyzing inputs (e.g., resource use) and outputs (e.g., emissions to air) of specific processes such as electricity production, material production or processing, transportation (see also **Error! Reference source not found.** 12).

Figure 12. Inputs, process, and outputs in life cycle inventory



Life cycle impact assessment (LCIA) links a life cycle inventory to environmental impact categories and indicators. LCIA consists of the classification and characterization of impacts, as well as normalization and weighting. According to ISO 14040 [58] , normalization and weighting are optional, whereas they are mandatory according to PEF and OEF (EPLCA 2019 [43]). Life Cycle Impact Assessment roughly corresponds to the quantification of changes in the stock of natural capital, as well as the valuation step as outlined in this methodology.

Methods for categorizing life cycle impacts are usually published by academic institutions and cover a wide range of impact categories. It should be noted that, while similar, LCA impact categories are not the same as "impacts" as defined in the Natural Capital Protocol [1].

LCA impact categories can be either "midpoints" or "endpoints." In LCA, midpoints usually (though not exclusively) reflect individual environmental concerns and hence changes to specific aspects of natural capital. Endpoints reflect impacts further along a cause-chain effect (impact pathway). Typical midpoints include climate change, eutrophication, land use, mineral and fossil resource depletion, acidification, ozone depletion, terrestrial and marine ecotoxicity, ionizing radiation, photochemical ozone formation, water depletion, human toxicity. Endpoints are usually categorized as the three areas of protection: human health, ecosystem health, and natural resources. Following the impact pathway logic used in this document, LCA midpoint "impacts" are more closely related to changes in natural capital, whilst LCA endpoint "impacts" are closer to the impacts used here (e.g., ISO 14040 [58], European Commission 2010 [59]).

To quantify LCA "impacts," characterization factors are used, which are published by academic institutions and the UN Life Cycle Initiative [60]. Characterization factors may refer to midpoints or to endpoints. Endpoints are usually more uncertain than midpoints.

For instance, in LCA, climate change impacts are characterized at midpoint level through the Global Warming Potential. The endpoint for climate change in LCA would be the direct measure of human health and ecosystem impact, which is more complex to assess and more uncertain.

II.1.2 Practical use of LCA in natural capital accounting

LCA model and database providers have a vast array of standard product systems and data sets, reflecting the "typical" conversions of inputs to outputs through a process. This covers both unit processes modeling an individual process, as well as more complex system data sets aggregating multiple unit processes.

Such standard data sets are often a useful basis for natural capital accounting following this NCMA methodology, as they may help estimate impact drivers associated with a given (unit) product or process (e.g., emissions from 1kg of PET produced, or from 1 ton-km of transportation). Data sets offered by LCA database providers refer to specific geographic, temporal, and technological conditions. Therefore, you may need to adapt data sets to your needs (e.g., using different energy inputs for different locations, or combining unit processes to create new aggregate systems). Unless you have specific in-house LCA expertise, you are likely to need external support for this. The Global LCA Data Access website allows searching for data sets across different providers.

II.1.3 Product Environmental Footprint (PEF) and Organization Environmental Footprint (OEF) method

The European Commission (including the Joint Research Centre, JRC IES) has been working towards the development of a harmonized methodology for the calculation of the environmental footprint of products and organizations, building on LCA approaches.

The final impact assessment method, applied for the Product Environmental Footprint (PEF) and Organization Environmental Footprint (OEF), was published as an Annex to the Commission Recommendation on the use of common methods to measure and communicate the life cycle environmental performance of products and organizations. It covers 16 environmental categories defined at midpoint level. Detailed documentation on the PEF/OEF method has been published online by the EU Commission (EPLCA 2019) [43].

II.1.4 Life Cycle Initiative

The Life Cycle Initiative is a public-private, multi-stakeholder collaboration, including governments, businesses, and scientific and civil society organizations. Hosted by UN Environment, the Life Cycle Initiative is an interface between users and experts of life cycle approaches.

It provides a global forum for a science-based, consensus-building process to support decisions and policies towards the shared vision of sustainability as a public good, delivering an opinion accepted by multiple stakeholders on sound tools and approaches.

In 2013 the Initiative launched a global process to standardize life cycle impact assessment (LCIA) categories and indicators. It should be noted that some of the categories defined through this process are theoretical, in the sense that there are no or only limited models available that implement them. The data and frameworks can be accessed online [64].

II.2 Environmentally extended input-output models (EEIO)

II.2.1 About EEIO

In economics, an input–output model is a quantitative economic model that represents the interdependencies between different sectors of a national economy or different regional economies. Traditional input-output (IO) tables summarize the exchanges between major sectors of an economy [61]. In an IO model, one unit of demand (in a given currency) in one sector and region triggers demand in other sectors and regions.

For example, output from the footwear manufacturing sector results in economic activity in associated sectors, from cattle ranching, manufacturing, and logistics to accounting services. Therefore, an IO model offers an econometric approach for modeling the full value chain.

Multiregional input-output (MRIO) tables further summarize the exchanges between different economies, thereby offering some regional specificity.

Environmentally extended input-output models (EEIOs) are based on traditional economic models and integrate satellite accounts – information on the environmental data (e.g., emissions) of each sector within input-output tables (see [62] [63] [64]). This allows estimating environmental impact drivers based on monetary flows, across the whole value chain, using what is essentially a top-down approach.

II.2.2 Practical use of EEIO in natural capital accounting

EEIOs can be used to estimate a business's impact drivers by using the entity's financial data (i.e., procurement data) and an EEIO table. In practical terms, categories used in internal data capture need to be mapped to sectors and countries in the EEIO table to conduct the EEIO modelling. The results essentially reflect sector averages, which may limit their usefulness to your business application.

As with LCA, you are likely to need external support when applying EEIO modeling. There are a number of different providers available whose solutions are based on different underlying models. These may differ in terms of:

- Satellite accounts (i.e., which impact drivers they can quantify)
- Sector resolution

- Geographic resolution
- Temporal reference (i.e., when the underlying data were last updated and to what extent trade flows at that time are still representative today)

Table 35 provides examples of which data sources may be useful for which value-chain level.

Table 35. Data sources for different value-chain levels

Value-chain level	Example of data sources
Own operations	Direct measurement or proxy indicators (such as energy and fuel use) Secondary data sources (e.g., life cycle assessment databases or emission factors)
Immediate / key suppliers	Supplier questionnaires requesting information about environmental data or proxy indicators (e.g., energy or fuel consumption) Environmentally extended input-output analysis (EEIO) LCA databases
Upstream supply chain	Environmentally extended input-output analysis (EEIO) gives an approximation of impact drivers based on purchasing data LCA databases for more process-specific data Other secondary data sources, including government and industry reports (e.g., Intergovernmental Panel on Climate Change (IPCC), International Energy Agency)
Downstream (further processing, use phase, end of life)	Environmentally extended input-output analysis (EEIO) using your sales data, coupled with modeling of consumer habits (e.g., energy use, water use) and end of life (EoL) scenarios Life cycle assessment (LCA) databases Other secondary data sources, public reports / studies / country statistics (e.g., on waste disposal)

ANNEX III. TECHNICAL ADDITIONS FOR VALUATION OF IMPACTS

This Annex provides further technical description of some aspects related to the valuation of impacts. These are related to:

1. Existing sources of the Value of a Statistical Life Year (VSLY)
2. Breakdown of the discount rate
3. Value transfer

III.1 Existing sources of the Value of a Statistical Life Year

There are many sources which provide Values of Statistical Life Year [65] [66] [67] [68] .

Table 36 provides some examples of Value of a Statistical Life Year widely used in policy analysis. [69]

Table 36. Example of guideline Value of a Statistical Life Year estimates used by public agencies [69] p.27, referring to [72], [14] , [68], [70]

National or regional agency user	Value of a Statistical Life Year (VSLY)
United Kingdom – Department of Environment and Rural Affairs (DEFRA)	24,000 (acute) 46,000 (chronic)
Norway – Ministry of Finance	49,000
Australia – Office of Best Practice Regulation (OBPR)	111,000
European Commission – Directorate General for the Environment	82,000-184,000

Note: All values adjusted to year 2011 prices using national or regional (Euro area) consumer price index and converted to U.S. dollars at purchasing power parity rates.

III.2 Breakdown of the discount rate

As described by HMT [71], the social discount rate (SDR) has two components: the time preference (ρ) and the wealth effect (μg), as indicated in the following expression:

$$SDR = \rho + \mu g$$

Time preference (ρ)

This component captures the preference for current consumption, assuming no change in per capita consumption. This comprises the sum of two components: the pure time preference (δ) and the catastrophic risk (L):

$$\rho = \delta + L$$

- **Pure time preference** (δ) represents the desire to have income or well-being today rather than in the future, assuming that no catastrophes will happen. Empirical studies show that this rate could be 0-1% [72].

  Valuing the well-being of future generations as equal to our own can be considered ethically defensible and aligned with notions of intergenerational equity commonly found in the climate change literature.

  Consequently, this methodology recommends using a pure time preference (δ) equal to 0, as default, as this ensures that potential risks related to natural capital impacts and dependencies are not hidden.

- **Catastrophic risk (L)** reflects the changes in consumer preference as consequence of unpredictable risks happening, such as "catastrophic" or "systemic" risk (L). In alignment with HMT [74], we recommend using L = 1%.

Wealth effect (μg)

Following HMT [74], this component captures the loss of utility of future consumption, as consumption tends to increase due to increases in per capita income. This component should be excluded from the social discount rate (μg=0) when assessing the risk to health and life.

The wealth effect comprises the multiplication of two components: the marginal utility of consumption (μ) and the expected growth rate of future real per capita consumption (g):

- **Marginal utility of consumption (μ).** Empirical studies show that this rate could be 1-1.5% (see [78], [73], [74]).
- **Expected growth rate of future real per capita consumption (g).** This information is published by public statistical offices and depends on each country and on the duration and specific time period considered to calculate the rate. Users should make clear which time period was considered (i.e., from 1950-2020), as well as the country/countries considered for the rate chosen.

Box 16 provides the recommended values to be used for these components when using the NCMA methodology.

Box 16. Recommended default values of social discount rate

The social discount rate and its components have been subject to academic debates where two main approaches are distinguished:

1. **Descriptive approach:** here the SDR is aligned with market data in terms of long-term average real return on capital and saving rates (see e.g., [75] [76]).
2. **Prescriptive approach:** here the choice of the SDR and its components is an ethical one, where future generations are equalled to the current one, and the only justification for a slightly positive pure time preference rate is the possibility of human extinction [77]. This approach emphasizes the market's inability to reflect ethical decisions related to climate change.

For the purposes of this methodology, these are the values recommended following a prescriptive approach (HMT [74]):

- Valuing the well-being of future generations as equal to present generation can be considered ethically defensible and aligned with notions of inter-generational equity commonly found in the climate change literature. Therefore, the pure rate of time preference (ρ) is set to zero.
- The elasticity of marginal utility from consumption μ reflects the desire to smooth consumption across generations, placing greater weight on intergenerational equality. However, a higher μ would also imply stronger redistribution preferences within the current generation [78]. As for the pure rate of time preference, the choice is an ethical judgement. It is common practice to assume $\mu = 1$.
- The growth rate of consumption g is then the only reason to discount future impacts. It is not an ethical decision but a question of expectations about future states of the world. In principle, it depends on the constituency considered. Nonetheless, a global value is set, as is common practice for example in climate change analyses. We assume a global consumption growth rate of 2% in line with long-term growth rates (HMT [74]).

Users of this methodology should use the same social discount rate across all impact areas. Generally speaking, and following the conducted survey [79] [74], an SDR between 1 – 3.5% is recommended by experts. We strongly recommend conducting a sensitivity analysis to test the assumptions of your SDR and increase transparency.

It might be suitable to apply an SDR that is declining over time, to account for rates changing over time [74].

III.3 Value transfer

Value Transfer, commonly known as benefit transfer, is the process of using values from existing studies and research conducted at one or multiple sites over a given time period to estimate the values for other sites and time periods.

For monetary values, value transfer can be either unit value transfer, where the results of a single valuation study are applied to predict the valuation in a different site/s, or value function transfer using the information, data ,and characteristics (value function) from one study or multiple studies (See [80], [53]).

Unit value transfer:

Transfers one value estimate or a set of value estimates from existing studies to estimate a value for a different site, it can be divided into:

Unadjusted unit value transfer: Using the value from the study set in a specific site and context and applying it to estimate the value in an alternative site/s. This approach to value transfer is simple and easy to apply but doesn't capture the differences between the characteristics of the study site and the alternative site [81] [82].

Adjusted unit value transfer: The limitations of unadjusted unit value transfer are usually amended and adjusted for purchasing power parity-adjusted income, allowing for comparisons (i.e., adjustments) between the original study and the estimated value in a different site/s [83] [84] [85].

Value function transfer:

Transfers the value estimate from existing studies using a function of a range of physical features and socioeconomic characteristics to estimate the value in an alternative site/s. The two main types of value function transfers are [53]:

- Single site function transfer: estimates values using a value function estimated from data of an existing study.
- Meta analysis function transfer**:** transfers the value by conducting a statistical analysis of the results of a large group of studies, with value functions using meta-equations that statistically synthesize information from the group of studies [86].

We refer the reader to review the Monetary Valuation of Ecosystem Services and Assets for Ecosystem Accounting document by the System of Environmental-Economic Accounting (UN SEEA [53]) to learn generally about the different value transfer approaches to apply when using valuations from existing studies in different contexts.

ANNEX IV. PLASTIC WASTE QUANTIFICATION

Plastic waste accounts for approximately 10% of discarded waste worldwide, and for a great proportion of the debris aggregating in aquatic ecosystems [87].

Instead of being considered as a single pollutant, plastics comprise a wide variety of polymers and their respective additives which contribute to their heterogeneity. There are two primary ways by which plastics enter the environment – as visible macroplastics (size > 5mm) or mostly invisible microplastics (size 5mm – 1 µm) [88].

Most companies find it difficult to quantify the amount of plastic waste created as a result of their business activities, contributing to macro- and microplastic pollution. The amount of plastic waste lost (created through business activities and not eventually processed through waste treatment facilities) is often not accounted for, but impacts the ecosystem and society.

A number of recent projects have worked to quantify the impacts of plastic pollution, namely:

- Plastic Leak Project [PLP] [89]
- Marine Impacts in LCA [MARILCA] led by Global Life Cycle Assessment indicators and Methods [GLAM] [90] [91]
- The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection [GESAMP], Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean 2019 [92]

We refer the user to these listed projects to quantify the amount of plastic waste leaked to the environment. This should be coupled with the impact measurement and valuation methodology described in section 4.2.6 to value the impacts on society using secondary impact drivers.

GLOSSARY

Baseline	In the Natural Capital Protocol [1] , the starting point or benchmark against which changes in natural capital attributed to your business' activities can be compared.
Biodiversity	The variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems [93].
Business application	In the Natural Capital Protocol [1] , the intended use of the results of your natural capital assessment, to help inform decision making.
Counterfactual	A form of scenario that describes a plausible alternative situation, and the environmental conditions that would result if the activity or operation did not proceed (adapted from [94]).
Economic value	The importance, worth, or usefulness of something to people—including all relevant market and non-market values. In more technical terms, the sum of individual preferences for a given level of provision of that good or service. Economic values are usually expressed in terms of marginal/incremental changes in the supply of a good or service, using money as the metric (e.g., $/unit).
Ecosystem	A dynamic complex of plants, animals, and microorganisms, and their non-living environment, interacting as a functional unit. Examples include deserts, coral reefs, wetlands, and rainforests [95]. Ecosystems are part of natural capital.
Ecosystem services	The most widely used definition of ecosystem services is from the Millennium Ecosystem Assessment [96]: "the benefits people obtain from ecosystems." The MEA further categorized ecosystem services into four categories: • Provisioning: Material outputs from nature (e.g., seafood, water, fiber, genetic material). • Regulating: Indirect benefits from nature generated through regulation of ecosystem processes (e.g., mitigation of climate change through carbon sequestration, water filtration by wetlands, erosion control and protection from storm surges by vegetation, crop pollination by insects). • Cultural: Non-material benefits from nature (e.g., spiritual, aesthetic, recreational, and others). • Supporting: Fundamental ecological processes that support the delivery of other ecosystem services (e.g., nutrient cycling, primary production, soil formation).
Environmentally extended input-output models (EEIO)	Traditional input-output (IO) tables summarize the exchanges between major sectors of an economy [61]. For example, output from the footwear manufacturing sector results in economic activity in associated sectors, from cattle ranching to accounting services. Environmentally extended input-output models (EEIOs) integrate information on the environmental impacts of each sector within IO tables [62] [63] [64]).

Externality	A consequence of an action that affects someone other than the agent undertaking that action, and for which the agent is neither compensated nor penalized. Externalities can be either positive or negative [97].
Impact	See "natural capital impact."
Impact driver	In the Natural Capital Protocol [1], an impact driver is a measurable quantity of a natural resource that is used as an input to production (e.g., volume of sand and gravel used in construction) or a measurable non-product output of business activity (e.g., a kilogram of NO_x emissions released into the atmosphere by a manufacturing facility).
Impact pathway	An impact pathway describes how, as a result of a specific business activity, a particular impact driver results in changes in natural capital and how these changes in natural capital affect different stakeholders.
Life cycle assessment	Also known as life cycle analysis. A technique used to assess the environmental impacts of a product or service through all stages of its life cycle, from material extraction to end of life (disposal, recycling, or reuse). The International Organization for Standardization (ISO) has standardized the LCA approach under ISO 14040 [58]. Several life cycle impact assessment (LCIA) databases provide a useful library of published estimates for different products and processes.
Materiality	In the Natural Capital Protocol, an impact or dependency on natural capital is material if consideration of its value, as part of the set of information used for decision making, has the potential to alter that decision [98] [99].
Materiality assessment	In the Natural Capital Protocol [1], the process that involves identifying what is (or is potentially) material in relation to the natural capital assessment's objective and application.
Measurement	In the Natural Capital Protocol [1] , the process of determining the amounts, extent, and condition of natural capital and associated ecosystem and/or abiotic services, in physical terms.
Monetary valuation	Valuation that uses money (e.g., $, €, ¥) as the common unit to assess the values of natural capital impacts or dependencies.
Natural capital	The stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people [100] [101].
Natural capital assessment	The process of measuring and valuing relevant ("material") natural capital impacts and/or dependencies, using appropriate methods.
Natural capital dependency	A business reliance on or use of natural capital.
Natural capital impact	The negative or positive effect of business activity on natural capital.
Natural Capital Protocol	A standardized framework to identify, measure and value direct and indirect impacts (positive and negative) and/or dependencies on natural capital.
Organizational focus	In the Natural Capital Protocol [1], the part or parts of the business to be assessed (e.g., the company as a whole, a business unit, or a product, project, process, site, or incident). For simplicity, these

	are grouped under three general headings as below: • Corporate: assessment of a corporation or group, including all subsidiaries, business units, divisions, different geographies or markets, etc. • Project: assessment of a planned undertaking or initiative for a specific purpose, and including all related sites, activities, processes, and incidents. • Product: assessment of particular goods and/or services, including the materials and services used to produce these products.
Price	The amount of money expected, required, or given in payment for something (normally requiring the presence of a market).
Primary data	Data collected specifically for the assessment being undertaken.
Qualitative valuation	Valuation that describes natural capital impacts or dependencies and may rank them into categories such as high, medium, or low.
Quantitative valuation	Valuation that uses non-monetary units such as numbers (e.g., in a composite index), area, mass, or volume to assess the magnitude of natural capital impacts or dependencies.
Scenario	A storyline describing a possible future. Scenarios explore aspects of, and choices about, the future that are uncertain, such as alternative project options, business as usual, and alternative visions.
Scoping	In the Natural Capital Protocol [1], the process of determining the objective, boundaries, and material focus of a natural capital assessment.
Secondary data	Data that were originally collected and published for another purpose or a different assessment.
Spatial boundary	The geographic area covered by an assessment, for example, a site, watershed, landscape, country, or global level. The spatial boundary may vary for different impacts and dependencies and will also depend on the organizational focus, value-chain boundary, value perspective, and other factors.
Stakeholder	Any individual, organization, sector, or community with an interest or "stake" in the outcome of a decision or process.
Temporal boundary	The time horizon of an assessment. This could be a current "snapshot", a 1-year period, a 3-year period, a 25-year period, or longer.
Validation	Internal or external process to check the quality of an assessment, including technical credibility, the appropriateness of key assumptions, and the strength of your results. This process may be more or less formal and often relies on self-assessment.
Valuation	In the Natural Capital Protocol [1], the process of estimating the relative importance, worth, or usefulness of natural capital to people (or to a business), in a particular context. Valuation may involve qualitative, quantitative, or monetary approaches, or a combination of these.
Valuation technique	The specific method used to determine the importance, worth, or usefulness of something in a particular context.

Value (noun)	The importance, worth, or usefulness of something.
Value perspective	In the Natural Capital Protocol [1], the perspective or point of view from which value is assessed; this largely determines which costs or benefits are included in an assessment. • Business value: The costs and benefits to the business, also referred to as internal, private, financial, or shareholder value. • Societal values: The costs and benefits to wider society, also referred to as external, public, or stakeholder value (or externalities).
Value transfer	A technique that takes a value determined in one context and applies it to another context. If contexts are similar or appropriate adjustments can be made to account for differences, value transfer can provide reasonable estimates of value.
Value-chain boundary	The part or parts of the business value chain to be included in a natural capital assessment. For simplicity, the Natural Capital Protocol [1] identifies three generic parts of the value chain: upstream, direct operations, and downstream. An assessment of the full lifecycle of a product would encompass all three parts. • Upstream (cradle-to-gate): covers the activities of suppliers, including purchased energy. • Direct operations (gate-to-gate): covers activities over which the business has direct operational control, including majority-owned subsidiaries. • Downstream (gate-to-grave): covers activities linked to the purchase, use, reuse, recovery, recycling, and final disposal of the business's products and services.
Verification	Independent process involving expert assessment to check that the documentation of the assessment is complete and accurate and gives a true representation of the process and results. "Verification" is used interchangeably with terms such as "audit" or "assurance."

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