TRANSPARENT

GENERAL GUIDANCE ON APPLYING THE NATURAL CAPITAL MANAGEMENT ACCOUNTING METHODOLOGY

NCMA General Guidance

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TRANSPARENT

value balancing alliance

CAPITALS COALITION

wbcsd

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 role of business is changing rapidly with greater emphasis on the social and environmental costs that come with economic activity. The pursuit of unfettered economic growth and the pursuit of a laissez-faire economy is giving way to a transition to a more just and equitable economy that is responsive to its environmental obligations to support well-being. The 2023 Edelman Trust Barometer highlights that communities are looking to businesses to navigate social and environmental challenges [1] as it is seen as the only competent and trusted actor.

The Green Deal has set clear expectations for business to play its part in remaining within acceptable guardrails to protect the natural environment so that it can remain available to all in the future. The events and signs are alarmingly clear that we are in a climate emergency and biodiversity is in a precarious state.

At the core of good stewardship is the need for sound accounting information to support decision making. The aim of this guidance is to assist companies apply the Transparent Methodology and underpin the ambitions of the Green Deal to re-align business models towards a sustainable future. Impact measurement and valuation is an evolving practice and not an end in itself: it is an attempt to quantify and assess the impacts of business on society. This guidance will hopefully contribute to that evolution in practice along with the uptake by businesses in determining their impact on natural capital.

Signatories

Christian Heller, CEO, Value Balancing Alliance
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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.

ACKNOWLEDGEMENTS

This general guidance on applying the NCMA methodology has been developed collaboratively amongst partners. We would like to thank the individuals who have been involved and have proven that collaboration delivers something more than any of us can achieve alone. They have generously contributed their time, expertise, and passion:

For developing the general guidance:
From the Value Balancing Alliance: Mario Abela, Awaz Alfadil, Susanne Klages, Abhishek Kumar, Clara Ulmer, and Michael Verbücheln. From Valuing Impact: Samuel Vionnet and Edgar E. Sacayón.

For contributing to the development of the general guidance:
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LIST OF ACRONYMS

CDP – Carbon Disclosure Project

CO_2 – carbon dioxide

CSRD – Corporate Sustainability Reporting Directive

CSDDD – Corporate Sustainability Due Diligence Directive

CTUh – Comparative Toxic Unit for human

DALYs – disability-adjusted life years

ED50 – median effective dose (the dose of a medication that produces a specific effect in 50% of the population taking that dose)

EEIO – environmentally extended input-output model

EEA – European Environment Agency

EPA – Environmental Protection Agency

EP&L – environmental profit and loss account

EPD – Environmental Product Declaration

ENCORE – Exploring Natural Capital Opportunities, Risks and Exposure

FASST – Fast Scenario Screening Tool

GHG – greenhouse gas

GRI – Global Reporting Initiative

IMF – International Monetary Fund

IO – input-output model

IPCC – Intergovernmental Panel on Climate Change

ISSB – International Sustainability Standards Board

ISO – International Organization for Standardization

JRC – Joint Research Centre

LCA – life cycle assessment

LCI – life cycle inventory

LCIA – life cycle impact assessment

LULUC – land use and land-use change

LULUCF – land use, land-use change and forestry

MEA – Millennium Ecosystem Assessment

MRIO – multiregional input-output

NOx – nitrogen oxides

OEF – Organization Environmental Footprint

PEF – Product Environmental Footprint

PET – polyethylene terephthalate

PPP – purchasing power parity

RFF – Resources for the Future

R&D – research and development

SASB – Sustainability Accounting Standards Board

SCC – social cost of carbon

SNA – System of National Accounts

SEEA – System of Environmental Accounting

UNEP – United Nations Environment Programme

UNEP-WCMC – United Nations Environment Programme - World Conservation Monitoring Centre

USEtox – Characterization factors for human toxicity and freshwater ecotoxicity, based on modeling of environmental fate, exposure, and effect parameters for the substances

VBA – Value Balancing Alliance

VOC – volatile organic compounds

VSL – value of a statistical life

WBCSD – World Business Council for Sustainable Development

WHO – World Health Organization

WWF – World Wide Fund for Nature

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.

As part of the Transparent Project, this general guidance document provides an overview and additional resources in support of the steps needed for the application of natural capital management accounting, including a "management blueprint." Additional documents provide a standardized methodology for natural capital management accounting (the NCMA methodology), and sector-specific guidance to support implementation of the methodology. 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 [2]. Changes to natural capital may affect the extent and condition of natural resources as well as the ecosystem services 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.

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 [3].

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. An 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 and 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

The deterioration of ecosystems, biodiversity loss, and a rapidly changing climate all highlight the role business needs to play in transitioning to more sustainable systems and practices. While there is general recognition of the externalities created by many business models today, at a sectoral level different business activities generate different patterns of impact on the environment making it important to understand the challenges for a specific sector or industry in transitioning to "doing no harm." The process of identifying, measuring, and valuing impacts and dependencies is critical to a successful business in providing the insights necessary to anticipate risks and identify new opportunities. Assigning a value to impacts is the start of the process which needs to be followed by informed decision making that balances people, profit, and planet.

Natural capital accounting involves making significant assumptions and judgments about the future and about the interaction of different systems in creating and destroying value. The principal challenge for natural capital accounting is that there is no comprehensive accounting system to capture and record data. Whilst financial transactions may be useful inputs to measuring impacts (e.g., in identifying energy usage) there are other variables needed to arrive at a monetized value for a given impact. Additional data requirements may include secondary data from suppliers for upstream activities or modeling the downstream impacts of products on consumers.

Basic accounting principles apply regardless of what is being accounted for – whether it is the impact of a business on water scarcity or the costs of overheads. Care needs to be taken to ensure robust procedures are used in controlling data so that results are relevant and reliable since information on impacts is only useful if it forms part of management's decision making.

Measuring and valuing impacts on systems is complex. It is based on scientific understandings and there are many terms that you may be unfamiliar with. An extensive glossary is included at the end of this document to help in understanding the terminology used in impact valuation.

The NCMA methodology focuses on the application of natural capital management accounting.[1] "Methodology" in this context is the "how to" so that there is substance and meaning to valuations that are calculated and reported (internally and/or externally). In that sense, it is no different to other accounting methods whether it is measuring and valuing a financial instrument or the useful life of an asset. What adds significantly to complexity is that impact measurement and valuation employs a different perspective looking at effects to the environment and not cost to the business (if there is one, such as remediation costs). Unlike selling a product where the business receives revenue and the customer receives the product, with impacts there is no reciprocity or equal exchange, which is the nature of externalities that have no price to the business.

Natural capital management accounting needs to be applied systematically to ensure the resulting information is fit for business steering and decision making. Natural capital management accounting as outlined in this guidance covers the following aspects:

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1 The NCMA methodology is to be used in combination with regulatory sustainability requirements and disclosures to improve business decision making and strategy setting. The methodology is not intended to replace regulatory sustainability requirements and disclosures. At the time of developing this document, there is no legal obligation to publicly disclose the results of natural capital accounting focusing on impact measurement and valuation, and it is left to the user of this document to make the decision of publicly sharing results.

- Defines the minimum six **impact drivers** to measure and to be considered when accounting for natural capital from a corporate perspective (i.e., which indicators and impact drivers to include)
- Points to **key resources and methods** to measure the impact drivers and models that estimate the change in natural capital (if applicable) and value the impacts to society in monetary terms
- Shows links between business applications and provides recommendations on the use of natural capital accounting results

The purpose of this NCMA general guidance document is to provide guidance on the practical implementation of impact measurement and valuation for businesses.

2.1. About the NCMA general guidance

The NCMA methodology aims to improve internal decision making by developing management accounting information relevant to the natural capital impacts and dependencies within a company's business model. The aim of this guidance document is to distill the steps and key elements related to practical application of the methodology in response to insights gained from the project's review panels, piloting, public consultation, and technical discussions conducted.

This guidance document provides a sector-agnostic approach to implementing the NCMA methodology focusing on the value to society perspective based on impact measurement and valuation. In other words, it focuses on the impact materiality of the double materiality concept.

The document sets out the steps and actions to apply, measure, and value the impacts a business has on society (e.g., GHG emissions across the value chain). The Transparent Project has also developed complementary sector-specific guidelines for the following sectors:

- Agri-food
- Apparel
- Chemicals

2.2. About the intended users

Similar to the NCMA methodology, this general guidance document is primarily intended for those responsible for preparing management information to support internal decision making at the corporate level (see NCMA methodology).

2.3. General management accounting principles

The NCMA methodology is based on general management accounting principles such as relevance, rigor, and replicability (see NCMA methodology). When applying the methodology, we advise following these principles to ensure that the methodology is applied in a sensible manner.

2.4. Basic impact management accounting concepts

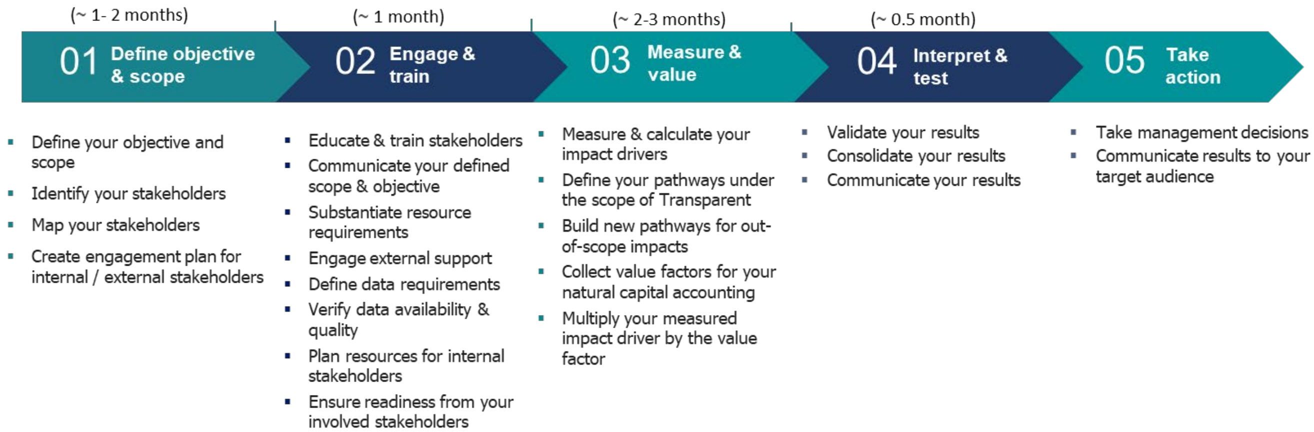
Please refer to the NCMA methodology for further detail on terminology including "impact," "impact driver," "impact pathway," and "valuation techniques."

3. OBJECTIVE AND SCOPE

The NCMA methodology provides a means of creating a holistic framework that can steer sustainability strategies, policies, and actions and give context to existing initiatives. Setting up natural capital accounting (such as through an Environmental Profit and Loss Statement) will take time. It will be important to leverage skills across the business and engage with the external assurance provider early on to develop a roadmap and adequately resource it. Experience from businesses that have implemented the methodology has highlighted the need for establishing a cross-functional team with clear and effective project management discipline.

To set up your natural capital accounting we recommend you divide the process into five different phases as illustrated in Figure 1 and described below (inspired by the Natural Capital Protocol [4]). The approximate durations included here can help in your planning but you will need to adapt your timeline to better reflect the state and needs of your business.[2]

Figure 1: Planning your natural capital management accounting



1. Define objective and scope (~ 1-2 months, beginning as early as possible):
   - Define your objective and scope (especially if accounting will not be used to develop an EP&L of your entity).
   - Identify and classify your internal and external stakeholders, and then develop a stakeholder engagement plan.

2. Engage and train (~ 1 month):
   - Engage stakeholders from various functions within your organization including procurement, finance, human resources, sustainability, external support, etc.; provide

[2] The suggested duration is based on the piloting experience of different companies. Duration will depend on company-specific factors such as experience, data availability, etc.

training to internal stakeholders whenever needed and share and discuss with them the objective and scope of your accounting and their role in achieving the objective(s).

- With the support of your stakeholders, clearly define data requirements and verify data availability and quality.
- Identify the need for external support and engage the necessary external capacity.

3. Measure and value (~2-3 months):

   - Collect the data needed to measure your impact drivers.
   - For impact drivers covered in the NCMA methodology, use the methodology to define your impact pathways. For material impact drivers out of scope of the NCMA methodology, define the impact pathway and collect data to model it.
   - Collect value factors for your natural capital accounting.[3]
   - Multiply your data for impact drivers by the selected value factors to assess the monetary value of your impacts.

4. Interpret and test the results (~ 0.5 month):

   - Conduct plausibility checks and sensitivity analyses, to validate results with key internal and external stakeholders.
   - Consolidate results, and re-check, validate, and verify the data in preparation to communicate your results.

5. Take action:

   - Take management decisions and pursue relevant actions based on your results.
   - Communicate results and actions to your target audience.

3.1. Objective

The NCMA methodology was created to enable the development of EP&L-style accounts but may also be applied for other objectives. It is essential to clearly define the objective(s) of your natural capital accounting by clarifying why it is needed, and which answers it will provide. Table 1 provides scenarios for the use of natural capital accounting.

Your chosen objective will help to determine which stakeholders should be engaged. Your stakeholder engagement plan should consider who will be required to collect and work with the necessary data, as well as any other internal or external stakeholders needed to support accounting activities.

[3] Other approaches to value impacts in monetary units exist, but this guidance focuses on the use of value factors to increase the comparability of results.

Table 1: Sample applications of using the NCMA methodology in decision-making[4]

Decision-making areas	Examples	Uses
Awareness raising at executive level	• Consider natural capital as an important financial issue at board level and deliberate its link with the existing business model (tangible language for business audience) • Understand impacts in relation to resource availability	• Presented in internal reports
Risk management	• Assess the nature and magnitude of environmental impacts and their associated business risks and opportunities • Inform strategy and planning • Assess risk of how a tax or other charge (e.g., carbon tax) would impact the profitability of a business model (i.e., potential impact on long-term viability) • Inform hotspot analysis to identify potential risks in the value chain to ensure the compliance of suppliers and service providers	• Presented with company risk management assessments
Scenario analysis	• Compare and select from alternative options (e.g., growth strategies or divesting assets) while considering their natural capital impacts; helps to identify potential constraints and future risks • Prioritize and target investment	• Presented in strategic business planning
Capital investments	• Select location of new sites (subject to certain minimum robustness and quality assurance standards)	• Presented with investment report
Supply-chain management	• Choose among suppliers, sourcing countries, etc. • Implement supplier questionnaires and codes of conduct	• Presented with supply-chain plans
R&D/product development	• Choose materials, resources, and portfolio prioritization based on product impacts • Compare between designs and better understand total risks/opportunities to estimate total product value	• Presented to research and development teams
M&A	• Decide on acquiring an existing business	• Presented with M&A management presentation
Strategic orientation	• Assess natural capital impacts to determine whether a business activity creates positive or negative impacts	• Presented with environmental impact report
Communication	• Provide relevant results/data to internal or external stakeholders • Provide relevant information to investors and customers	• Presented in external/ internal communication materials

[4] The table, based on the piloting feedback of companies, is indicative rather than exhaustive.

3.2. Scope

Defining the objective(s) of your natural capital accounting facilitates your process of defining/selecting the scope of your application. You should define the following aspects:

3.2.1. Organizational focus

You should identify the parts of your business to include in your natural capital accounting based on your previously identified objective and the decisions you wish to inform through your results.

The default organizational focus of the 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. As the methodology is scalable, it allows you to perform your natural capital accounting for different functions and levels such as:

- **Entire organization level:** Covers all your business activities, geographies, and markets. Commonly used for assessing the impacts of the entire business.
- **Process level:** Covers a specific process within your business, such as operations, management, strategy, research & development, etc. Commonly used for assessing the impact of a business unit or department.
- **Project level:** Covers a specific project including all activities, sites, processes, etc. Commonly used for risk management and business steering.

Product level: Focuses on specific goods and/or services. Commonly used in risk management and scenario analysis.

> **Recommendation:** When externally reporting natural capital accounting, it is recommended that you align your organizational boundaries with your financial and/or management reporting, sustainability reporting, or regulatory requirements as appropriate.

3.2.2. Value-chain boundaries

The NCMA methodology divides the value chain into three levels that can be further broken down and expanded depending on your defined objective and selected scope. Since some companies are more vertically integrated than others, upstream, downstream, and own operations should be defined on a case-by-case basis.

- **Own operations:** Covers all activities within your 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, services, and products that your company 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."

Recommendation: It is recommended that you map the building blocks of the value-chain scope that you choose to cover. Flow diagrams display processes to show exchanges in the economy, from one activity to another. Within each process, there are exchanges with the environment (e.g., use of water and land, GHG emissions, pollutant emissions). These diagrams will help you to identify which data are required for natural capital accounting and will help in structuring and interpreting results.

In the case of an existing circular economy model, you can present results of natural capital accounting related to the circular model separately (e.g., under a section titled "circular economy model" as a separate component within the downstream value-chain) and with no netting of the results. For an example of what this could look like, see Table 2.

Table 2: Sample table for including results from circular economy models

	Value chain levels						
	Upstream – Tier 1	Upstream – Tier 2	Upstream – Tier 3	Own Operations	Downstream	Downstream (Circular economy model)	Total (mill.)
GHG emissions							

Example: The combustion of fuel for energy consumption leads to GHG emissions and non-GHG air emissions, and the production of goods has an impact on land use, water pollution, and water consumption. Depending on your application you may wish to break down the value-chain levels further, for example differentiating between tier 1 suppliers (direct business relationship) and further tiers (your suppliers' suppliers) or differentiating between different parts of the downstream value chain. Table 3 provides some examples of activities associated with natural capital impacts along the value chain.

For examples of activities associated with natural capital impacts along the value chain, see Table 3. For a comparison with other existing frameworks, see Table 4.

Table 3: 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) • Investments, leased assets, franchises, etc.

Recommendation: We recognize that companies might apply the methodology gradually to their value chain, and the scope strongly depends on the decision to be informed. Many companies start with assessing their own operations and assess upstream impacts during a later stage. We want to stress that understanding the impacts along the entire value chain is necessary for understanding the impact of corporate activities. In case you do not have primary data, using secondary data sources can help you to estimate the potential impacts of your

Table 4: Value-chain boundaries and relation with boundaries defined in other protocols/frameworks

Value-chain levels		Upstream	Own operations	Downstream
Equivalent definitions in other frameworks and protocols	GHG Protocol equivalent [5]	Scope 2 + upstream Scope 3	Scope 1	Downstream Scope 3
	LCA equivalent [6]	Cradle-to-gate	Gate-to-gate	Gate-to-grave

3.2.3. Value perspective and type of value

Please see the NCMA methodology for more details, no additional guidance provided.

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. If you define a different objective, you should define the time period accordingly, e.g., annual, periodic, monthly, a defined number of years.

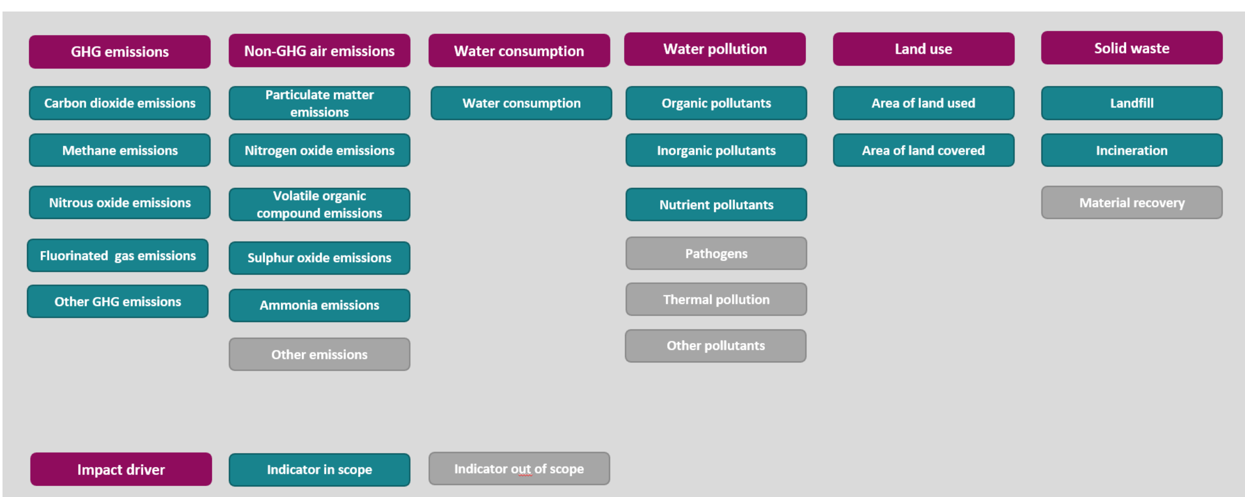
Natural capital accounting can inform short-, medium-, and long-term decisions and can be used to assess present, future, and past business activities, as the impacts associated with business activities can be short, medium, or long term. This allows companies to use different temporal data (noting the time period should be consistent between all impact drivers within scope), including historical, present, or estimated future impacts.

Recommendation: If you are assessing your corporate footprint for internal or external reporting, the accounting period should match your financial accounting to ensure consistency.

3.2.5. Impact drivers

In the value to society perspective of the methodology, the focus is on the measurement and valuation of impacts due to changes in natural capital, and the resulting changes in ecosystem services. Figure 2 provides an overview of impact drivers and indicators covered in the methodology. The six impacts drivers (GHG emissions, non-GHG air emissions, water consumption, water pollution, land use, solid waste) are shown in the first row, and the related indicators, used to measure the impact driver, are listed below the relevant impact driver.

Figure 2: Impact drivers and indicators included in the NCMA methodology and guidance documents



Your business activities are most likely linked to multiple impact drivers. Based on your defined objective(s), selected scope, and value-chain boundaries, you will identify your key business activities associated with and leading to natural capital (environmental) impacts.

For first-time preparers, we recommend carrying out your natural capital accounting for all six impact drivers within the scope of the methodology, as this will assist you to:

- Identify where data gaps exist, and necessary processes to close gaps
- Create a baseline to measure your future natural capital accounting against
- Monitor your performance and evaluate your progress

Subsequently, in future periods to reassess impact drivers for your business you will need to conduct, revise, or adjust your materiality assessment as needed.When conducting your materiality assessment, it is important to assess the materiality of the impact drivers across the entire value chain. Some impact drivers may have a small impacts upstream, but have considerably higher impacts within the own operations or downstream value-chain levels.

Table 5 lists sources to support you in conducting your materiality analysis. Please note that the list is indicative, and not exhaustive.

Table 5: List of materiality assessment sources

Materiality assessment source	Developer	Description	Open source/licensed
GRI Materiality Disclosures service [7]	GRI	Supports companies in identifying their material topics	Paid
SASB Materiality Finder [8]	International Sustainability Standards Board (ISSB)	Covers: Natural capital Social & human capital Governance Business model & innovation	Free
Datamaran [9]	Datamaran	Data-driven platform	Free/Paid
ENCORE [10]	The Natural Capital Finance Alliance, UNEP-WCMC	Covers: Natural capital	Free
The Novartis Materiality Assessment Toolkit [11]	Novartis, Center for Corporate Reporting, F.A.Z Institut	Covers: Natural capital Social & human capital Governance	Free
Sustainability Materiality Matrices Explained [12]	NYU Stern Center for Sustainable Business	An introduction to the process of conducting materiality assessment	Free

If your materiality assessment identifies additional impact drivers as being material to your business, we recommend you expand your natural capital accounting beyond the six impact drivers covered in the NCMA methodology to include them. You can further expand your accounting to incorporate social and human capital impacts on society (see Value Balancing Alliance methodology [13]). Based on the results of your materiality assessment the omission and/or addition of any impact drivers and impact pathways should be justified and communicated clearly for internal and external users.

Applying the methodology periodically (on a regular basis and not as a one-time exercise) provides a means of identifying the most important (most material) impact drivers for your business over time. We recommend you couple the results of your natural capital accounting, over time and multiple iterations, with your materiality assessment, reporting requirements, disclosures, and any relevant initiatives to develop a rich understanding of the material topics for your business covering all value-chain levels. We recommend that your materiality assessment is not purely qualitative.

Example: During the piloting phase of this project, companies stated that using the results of natural capital accounting helped them to understand the impacts of their businesses beyond what is currently included within regulatory requirements, and it raised attention to impacts that will potentially be felt by society. This awareness helped them to prioritize areas to improve within their businesses.

When applying the double materiality perspective of the Corporate Sustainability Reporting Directive (CSRD), the NCMA methodology provides further insights to the impact materiality element of double materiality.

Applying the NCMA methodology also supports implementation of the Corporate Sustainability Due Diligence Directive (CSDDD) through monitoring corporate sustainability performance along your value chain, and the incorporation within the company's risk management and mitigation systems.

Recommendation: If your current materiality assessment is using one of the sources mentioned above, we recommend using the same source to achieve consistency. In case you are not yet using one of these sources, the ENCORE tool might be helpful for your materiality assessment due to its alignment with the EU Business @ Biodiversity Platform thematic report: Biodiversity data. The ENCORE tool illustrates and describes the material impacts caused by various business sectors, sub-industries, and production processes on natural capital [109].

3.2.6. Baselines

Natural capital accounting involves two steps where the comparison to a baseline is explicitly or implicitly included. These are: (1) measuring changes in the state of natural capital, and (2) the valuation of impacts. Depending on your chosen approach (i.e., whether you use value factors, or model impact pathways directly), you will either select baselines or need to understand them. In both cases, we recommend being transparent about baselines used. Depending on your business application, you may want to define additional baselines to test the robustness of your results.

3.2.7. Scenarios

When applying natural capital accounting for decision making, it is often useful to define scenarios that differ from normal operations specifically in the case of "interventions". For more information on how scenario analysis is performed, please see chapter 6 – Using the results.

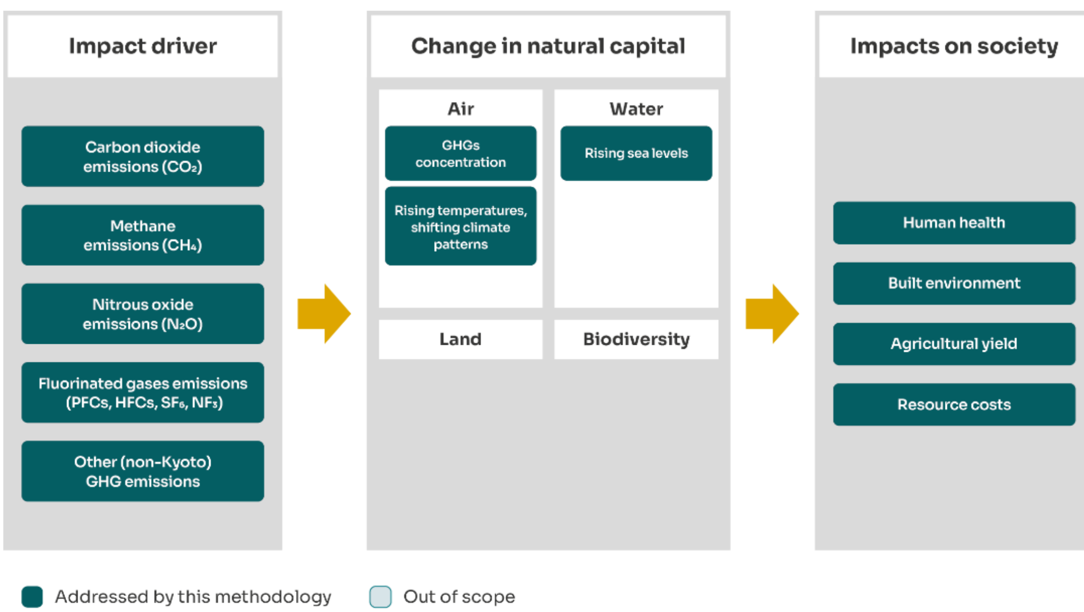
4. MEASURE AND VALUE

After defining the objective and scope, you will measure and value the impacts of your business activities on society. To complete this step, you will need to map and understand the impacts of your business activities on society based on impact pathways.

An impact pathway describes how, as a result of specific business activities within your company (scope), a particular impact driver results in changes in natural capital, which then leads to a change in ecosystem services (not explicitly modeled) which in turn impacts society. This is illustrated in Figure 3 which describes the relationship between impact drivers and impacts on society, with GHG emissions being an exemplary impact driver. (More detail on impact drivers can be found in section 3.2.5 of this document.)

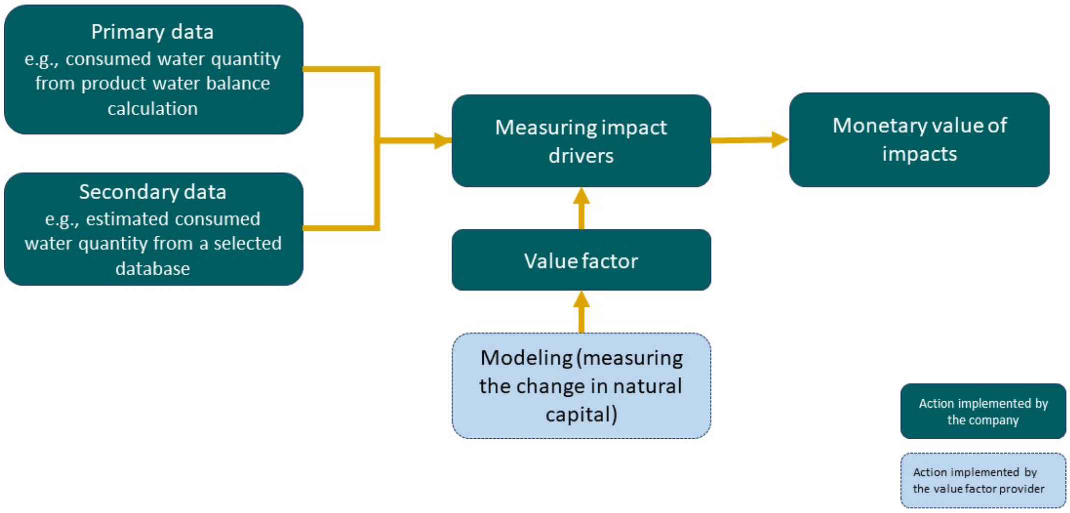
In practice, the modeling steps outlined in the figure usually do not need to be performed directly. Using value factors, most of the modeling is implicitly included, which simplifies the application significantly and is recommended especially for smaller entities. The more practical approach using value factors is shown in Figure 4.

Figure 3: Impact pathway for GHG



The figure displays the impact pathway for GHG emissions (taken from the NCMA methodology). Changes in natural capital that are not explicitly modeled are not displayed in the figure.

Figure 4: Calculation logic when using value factors to estimate monetary value of impacts



4.1. Principal accounting modules

In this section we provide the necessary steps and considerations for applying the methodology to account for your natural capital impacts on society.

4.1.1. Measure your impact driver

Data

After mapping your business activities against the impact drivers, you will need to measure the impact drivers. Each impact driver is measured using quantitative indicators to provide physical quantities. The NCMA methodology provides you with a list of the main indicators to measure for each impact driver.

Recommendation: If you have identified additional indicators that are material to your business activities within your materiality assessment, it is recommended that you include those indicators in your natural capital accounting. These should be accompanied with an explanation/justification stating the relevance of the additional indicators to your business activities.

We recommend that you initially review the data collected for your sustainability management system and any sustainability reporting, as these may fulfill some of the data requirements needed for your natural capital accounting. For example, GHG emissions for sustainability reporting requirements are calculated using CO_2 equivalents. These CO_2 equivalents can be translated into a monetarily valued impact in dollars using the social cost of carbon with the corresponding unit of dollars/CO_2 equivalents.

As the data used in your sustainability reporting is potentially internally and externally audited, this provides you with information on the validity and robustness of the data used in your natural capital accounting and will help you determine if you need to implement any modifications, collect additional data, or plan for additional efforts/resources for your natural capital accounting.

For each impact driver, you will need to decide on the data sources to use. The data sources could be:

- Primary data
- Secondary data
- A combination of primary and secondary data

To choose your data sources, you will need to consider the costs and required accuracy of the data. In many cases, companies look at natural capital accounting as an iterative process (i.e., starting with secondary data and populating your accounting with primary data over time).

Primary data

Primary data can be defined as data collected specifically for an assessment [4]. Typically, primary data is available for all activities central to the business – including own operations or other value-chain levels depending on the set-up of internal data collection processes.

A comprehensive list of primary data points can be found in the following standards:

- Product category rules (EPD system, PEF/OEF European Union) [14]
- ISO 14040: 2006 Environmental Management – Life cycle assessment – Principles and framework [15]
- ISO 14044: 2006 Environmental Management – Life cycle assessment – Requirements and guidelines [16]
- ISO 14046: 2014 Environmental Management – Water footprint – Principles, requirements, and guidelines [17]
- ISO 14064-1: 2018 Greenhouse gases – Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals [18]
- GHG Protocol [19]
- GHG Protocol: Land Sector and Removals Guidance (under development) [20]

Primary data for your own operations can be available internally in your business (and sometimes also for direct suppliers). This information will usually provide you with the most accurate results, closely matching your business activities. You may also collect primary data, but in many cases doing so can be difficult and complex. If collecting primary data, you will need to ensure the data are collected correctly and in alignment with your intended use.

In most cases, company standardized formations such as Excel-based spreadsheets are used to collect information (for own operations, suppliers, and customers). To obtain access to supplier data, you may want to include this in your supplier contracts, specifying the type of data needed and its intended use to ensure data reliability. Working with suppliers who have sustainable certifications would facilitate data verification and validation and auditing processes. Data requirements should be aligned with technological representativeness, geographical scope, temporal coverage, completeness, and reliability.

Recommendation: It is worth noting that primary data collection doesn't necessarily measure the impact driver per se, but it supports to quantify the impact driver. Often, primary data is available on process inputs (e.g., energy consumption) or outputs (e.g., distances travelled). As a consequence, primary data are often connected to secondary data or models to estimate the impact driver.

Example: The climate change impact derived from the transportation of certain goods by truck will require primary data on the distance of transport (in km) and the load (in tons). An emission factor, from a secondary database, expressed in $kgCO_2e/km/ton$ will be used as a multiplier to the primary data.

Secondary data

At the beginning of your natural capital accounting journey, you may have to start with secondary data sources if no other data are available within your company, and with time move to primary data collection. Starting with secondary data sources will help identify the areas in the value chain (and impact drivers) where primary data collection needs to be prioritized.

Secondary data are available publicly, or commercially, and typically used when direct measurement of your impact drivers is impractical or not available. When using secondary data you should take into consideration the underlying conditions, assumptions, conversion factors, etc. to ensure data are suitable for your natural capital accounting use.

Common sources of secondary data include but are not limited to:

- Life Cycle Assessment databases (LCA)
- Product Environmental Footprint (PEF) and Organizational Environmental Footprint (OEF) [21]
- Environmentally extended input-output analysis (EEIO) [22]
- Peer-reviewed literature

Table 6 provides some considerations to assist you in selecting data sources. If using secondary data such as peer-reviewed literature, you may need to adapt the data by scaling it, changing the geographical location, and/or physicochemical relationships to better reflect the selected scenario and scope where other data sources are not available. [23] [24] [25]

Table 6: Considerations for data source selection for applying NCMA

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 of 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 to my business?
Practical issues	• Does the data source cover all impact drivers or a limited number of them? • Is the data source updated regularly? • Is it possible to work with the available data format or is specialist software required? • Is the data source freely available or how much does it cost?

Environmentally extended input-output model (EEIO), top-down

Where it is difficult to obtain primary data, reference to economic models on the transactions between economic sectors can be established by looking at input-output (IO) tables and performing an IO analysis. Input-output modeling represents a top-down approach, meaning that global- or national-level data are used to derive the outputs of an industry or product group.

An IO model is a quantitative economic model that represents the interdependencies between different sectors of a national economy or different regional economies. These models are usually specific to a national or regional economy in modeling the flows between sectors (for example between the health sector and the chemical sector). If multiple regions and countries are covered, the tables are sometimes also called multi-regional input-output (MRIO) tables.

Natural capital impact drivers can be estimated via IO modeling through the introduction of satellite accounts in the IO table. When environmental data are included in an IO table using satellite accounts, it is called an environmentally extended input-output (EEIO) table.

EEIOs are used to estimate the impacts related to the upstream and downstream value-chain levels based on primary financial data, which are translated to economic, socio-economic, and environmental impacts based on the information in the satellite accounts. For a simplified introduction to EEIO modeling, see Annex II.

If you are at the start of your natural capital accounting journey and have no data collection processes for your impact drivers along your upstream value chain, using EEIO models is a very efficient way. Using EEIO models will provide you with a starting point to understand the impacts of your business activities, and the impact drivers where primary data collection needs to be prioritized.

Using EEIO modeling requires primary data from the company, usually procurement data, and this information is collected from the company's accounting or financial department. The data should be detailed per individual expense per country of effective spend, per activity/sector, matching the sector available in the input-output database. Thus, the use of EEIO modeling always comes with some primary data collection.

Advantages to using EEIO:

- Uses publicly available input-output tables to deduce production activities and flows of goods and services between different sectors and countries
- Offers suitable alternative for cases where no company-specific data are available
- No double counting of impacts, impacts are allocated between sectors
- Captures trade in secondary products, by dividing the economy into sectors, where each sector produces goods and services for the sector itself and other sectors
- Can be used to assess the entire upstream value chain

Limitations to using EEIO:

- Assumes that each sector produces a single good or service. This issue is reduced with an increased level of resolution in the model
- Does not account for impacts caused by consumers who are involved in purchases that are outside of economic sectors (informal economies)
- EEIO models are not available for every country, rest-of-the-world aggregates are provided for countries for which national data are not available
- EEIO publication and updates could be infrequent (e.g., every 5 years)
- Disparity in data collection and standardization process in different countries
- Increased uncertainty in environmental impacts estimation over large spatial scales, and between sectors using a mix of modeled estimates and empirical data [26]
- A comprehensive MRIO database fulfilling all the requirements of a rigorous impact assessment does not exist to the best of our knowledge

- Results could become obsolete when databases are updated, or new tables are provided [27]
- Results are the average impacts per sector, which might, for example, be inaccurate for your direct suppliers (e.g., if your direct suppliers have lower emissions than average, this will not be reflected)

Decision making based on EEIO data:

Using EEIO models can inform decision-making areas such as:

- Risk management:
    - By assessing the potential magnitude of natural capital impacts
    - Preliminary hotspot analysis of the potential risks within the value chain
- Monitoring corporate natural capital impacts:
    - Assessing where the business potentially creates positive or negative impacts

When valuing impacts in monetary terms by applying the methodology based on EEIO, we recommend using the Leontief model since it is widely accepted for estimating upstream impacts. [28]

Selecting an EEIO model:

To select a suitable EEIO table, the following criteria should be considered:

- Country coverage
- Sector coverage
- Satellite accounts coverage
- Applicability
- Update cycles
- Transparency

Annex III provides a list of EEIO tables recommended for use when applying the methodology. The different models have different country coverages, sector granularity, and socioeconomic and environmental satellite accounts and indicators. Moreover, the suitability of the model depends on the industry, the company specifics, and the defined scope.

Life Cycle Assessment models and database, bottom–up

Life cycle assessment is used to evaluate and quantify the environmental impact drivers associated with a product, process, and an organization, covering the value-chain levels defined in the scope of the natural capital accounting (e.g., upstream + own operations + downstream = cradle-to-grave). LCA represents a bottom-up approach, meaning an approach relying on product and process designs.

Advantages to using LCA:

- Widely used tool for assessing impacts
- Available application standards such as ISO 14040 [6] and ISO 14044 [16]
- Provides an overview of the environmental impacts (quantified impact drivers) caused by a product, process, or organization

Limitation to using LCA:

- Resource-intensive approach
- Variation in LCA approaches, studies, and databases provides different results depending on the underlying assumptions
- Interpretation of the results might be difficult

Decision making based on LCA:

Using LCA supports informing decision-making areas such as:

- Assessing product impacts:
    - Portfolio management of produced products
    - Supply-chain management
    - Scenario analysis

- Corporate footprint (if few different products are produced):
    - First high-level insight into corporate footprint based on products produced. Usually feasible in the case of smaller product portfolios

Selecting an LCA database:

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 methodology, as they may help estimate impact drivers associated with a given (unit) product or process (e.g., emissions from 1 kg 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 [29] allows searching for data sets across different providers.

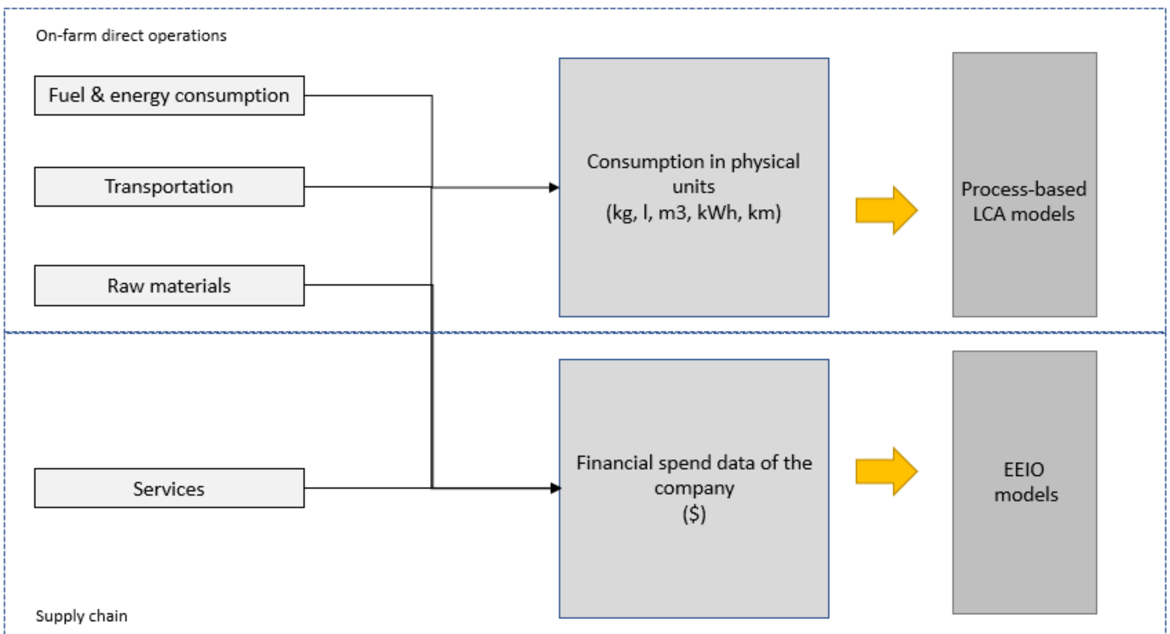
In Annex IV, we provide a list of LCA sources recommended for use when applying the NCMA methodology.

Hybrid model

Environmentally extended input-output analysis and LCA assessments can be used in combination. This is usually called a hybrid approach. For example, process-based LCA data can be used to measure the impacts from direct operations of a company while input-output models can be used to estimate the impact at supply-chain level with financial spend data. An exemplary hybrid approach using physical units for the assessment of impacts from direct operations and financial spend data to assess the impacts from contracting services at the supply-chain level is presented in Figure 5.

Using a hybrid model, it is important to ensure consistency across the different data sources and across the different impact divers.

Figure 5: Hybrid approach



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. In this case, you may need to distribute the inputs and the outputs between products, services, and business activities considered in the scope of your natural capital accounting.

If possible, you can avoid this kind of allocation if the multifunctional process can be subdivided into subprocesses. In that case, each amount of input and output can be identified as belonging to specific subprocesses, which either belong completely to the system under study or are completely outside the system under study [30].

Two typical types of allocation that can be used are:

- Physical allocation (e.g., weight, volume): here you allocate your share of impact based on the weight of materials associated with your business in relation to the total weight of output from production processes
- Economic allocation: here you allocate the impacts based on your economic share of the overall production output

We recommend being transparent in documenting the allocation rule you apply.

4.1.2. Measure changes in the state of natural capital

Your quantified impact drivers will lead to changes in natural capital (air, water, land, and biodiversity) that will eventually impact society.

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 and the presence of other substances.

It usually takes expert knowledge to model the changes in natural capital (environment) caused by your business activities, but it is unlikely that you will perform the following step explicitly. In most cases, you will select impact drivers and matching monetary value factors that include the modeling step implicitly. [31] Thereby, monetary value factors reflect the societal impact resulting from a change in natural capital and its ecosystems services as modeled in the impact pathways.

Recommendation: Usually, value factors reflect the consolidated values of impacts to society in multiple impact pathways of your impact driver. If you want to measure and value your business activities' impacts on the more granular impact-pathway level, you will likely need to model the changes in the natural capital explicitly (on your own) to obtain the value factor on an indicator level. If you decide to take an impact pathway-level approach, this requires the use of multiple models with different levels of complexity and different underlying conditions leading to reduced comparability of results and requiring that additional resources be dedicated to the natural capital accounting application.

In Annex V we provide a short list of methods which allow estimation of changes in the state of natural capital that will make it possible to value impacts in monetary terms.

4.1.3. Value impacts on society

After measuring your impact drivers, you calculate the monetary values of your impacts by multiplying the measured impact drivers in physical quantities (e.g., tons of CO_2) by a value factor (e.g., \$/ton CO_2), which reflects the societal impact due to a change in natural capital and its ecosystems services as modeled in the impact pathways.

The value factors are calculated using different valuation approaches as laid out in the NCMA methodology. [32]

To obtain impacts valued in monetary terms, you will need to match your impact driver, measured in physical quantities, to a value factor. The units used for the impact driver and value factor should match such that when the two are multiplied the result is a monetary unit. For example, to value water consumption impacts in monetary units:

$$\text{consumed water (in } m^3) \, * \, \text{monetary valuation coefficient (in} \frac{\$}{m^3} m^3)$$

To achieve the match, you may need to link your data on impact drivers to the unit of the value factors. This can include that the structure and granularity of your value factors can differ from your data structures (e.g., some of your data could be available only on a regional level and not a country level, or when using modeling techniques like EEIO, your selected IO dataset dictates the covered regions and countries that need to match your value factors).

You will need to map your data to the value factors, by performing several steps of data transformation such as merging, aggregating, filtering, enriching, or splitting and converting your data into a suitable format to link it to the value factors.

Although regional monetary value factors are preferable over global monetary value factors, there are current limitations in data sources. Most available value factors have been developed for Europe, global aggregations, and high-income countries. Additional disaggregation to reflect your application context is potentially needed.

There are frameworks and standards available that cover multiple valuation techniques and approaches, and some of which provide value factors. Annex VI provides information on available methodologies and monetary value factors that can be used.

Recommendation: Value factors should be periodically updated to reflect up-to-date conditions. We recommend checking for updates that could have occurred since your last natural capital accounting and adjusting for any changes.

When valuing your impact drivers, you will need to consider the following points:

Recommendation: To achieve consistency in your accounting, you usually need to apply the same adjustments across all impact drivers, regions, etc.

a) Adjustments and value transfer

Since it is difficult to find value factors for all possible ecosystems, areas, and nations where business activities take place, you might want to use value transfer to estimate the monetarily valued impacts of business activities in areas that are not covered by your selected value factors.

Value transfer is the process of using existing (empirical) value estimates from one or more research contexts to predict and simulate values in other contexts. For example, an impact valued in monetary terms could be available from a study addressing the value in a specific context (i.e., country, socioeconomic group, demographic, ecoregion, etc.). It is possible to use this information as a starting point and adjust it to be applied to different locations, and socioeconomic contexts.

When valuing impacts to society it is important to adjust for environmental conditions, meteorological conditions, and population densities. For more information, see Annex III of the methodology.

Recommendation: If you use value transfer, this should be communicated clearly including information on how it has been applied.

Furthermore, you might need to adjust for the following factors:

- 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, International Monetary Fund (IMF), or similar recognized institutions. Depending on the business application, it may be useful to use five-year rolling averages to avoid currency conversion artefacts.
- 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 World Bank.
- You might need to account for seasonal changes in your business activities (e.g., production cycles) and spatial differences and define the relevance of these changes and differences for your natural capital accounting.
- 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.

b) Valuing impacts on human health

Often, the external impacts of environmental damage on individuals are negative physical and mental health outcomes. This step of valuing impacts on human health is frequently already included in the value factor you apply. If you need to perform adjustments, please refer to the methodology for additional considerations.

c) Accounting for future impacts

The environmental impacts of business activities can manifest both at the time the activities are conducted and also in the future, which mandates to account for future generations in order to limit negative consequences.

Economic theory suggests applying a discount rate converting the potential costs and benefits of future impacts to their present value. For information and guidance on the social discount rate, please refer to Annex III of the NCMA methodology.

d) Accounting for planetary boundaries

The NCMA methodology provides a way to measure and better understand the societal consequences of business activities that are not already accounted for in the calculation of an entity's profit. 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.

Example: For GHG emissions, companies need to consider the internationally set thresholds and commitments of the 1.5-degree goal to avoid established climate change tipping points.

4.2. Specific accounting modules by impact driver

This section covers the general logic for calculating the impacts to society associated with each impact driver using illustrative examples. For a comprehensive overview and understanding of all potential impact pathways considered for the six impact drivers covered in the methodology, please refer to the NCMA methodology document.

When valuing your impacts on society, you will potentially follow one of two options:

Option one: Using monetary value factors

When directly using monetary value factors to estimate your natural capital impact on society, apply the following steps:

Step one: Measure your impact drivers. Quantify the measurable amount of the impact driver as inputs or non-product outputs of business activities (e.g., emissions, waste).

Step two: Value your impacts on society in monetary terms, by multiplying measured impact drivers by a value factor.

Recommendation: The unit of your selected value factor will guide you in how to measure your impact drivers (i.e., based on input or output).

Option two: Calculating impacts resulting from specific impact pathways

It is common that a value factor is a consolidated value resulting from multiple impact pathways. If you are interested in measuring your impact on society by focusing on specific impact pathways, you will need to apply the following steps:

Step one: Measure your impact drivers.: Quantify the measurable amount of the impact driver as inputs or non-product outputs of business activities (e.g., emissions, waste).

Step two: Model how selected impact pathways result in changes in natural capital and then impact society (see NCMA methodology document, measuring the change in the state of natural capital for each impact driver).

Step three: Value your impacts on society in monetary terms by monetizing the quantified impacts on society (e.g., based on the value of a statistical life (VSL), DALYs, agricultural yields, etc.).

Recommendation: Following option one allows you to use value factors from reliable sources that are science based. Such value factors undergo regular maintenance and updating processes, and their use provides you with verifiable and comparable results.

When choosing option two, please refer to the NCMA methodology document for a comprehensive view of the modeling step (i.e., measuring the change in the state of natural capital).

In the next sections we follow option one, illustrating a simplified process for valuing your impacts to provide you with an initial understanding of practical implementation of the methodology for corporate accounting.

4.2.1. Greenhouse gas (GHG) emissions

We recommend that you use the Greenhouse Gas (GHG) Protocol to map your business impacts throughout your entire value chain. The GHG Protocol establishes comprehensive global standardized frameworks to measure and manage GHG emissions from private and public sector operations, value chains, and mitigation actions. [19]

Alternative data sources include: [5]

- EEIO models: Can be used to measure your upstream GHG emissions
- LCA approaches: Can be used for estimating your own emissions (e.g., distance travelled, energy consumed, etc.)
- GHG inventories (Excel), coupled with emission factors from the IPCC, Emission Factor Database (EFDB) [33] [34]
- Other online tools such as The GHG Emissions Calculation Tool [35] Greenhouse Gas Emissions Calculator [36], and GHG calculator [37] [38]

Be attentive to potential double counting when using multiple approaches.

For GHG emissions due to electricity use, it is important to differentiate between the different mixes and sources to avoid double counting. Similarly, for GHG emissions from transportation, you might need to quantify fuel consumption in a first step. In this case, it is also important to consider the specific circumstances (e.g., the type of vehicle, type of fuel, distance travelled, and number of loads and returns).

For GHG emissions due to the application of synthetic and organic fertilizers, we recommend following the PEF/OEF guidance as it provides a straightforward approach to quantify field emissions from fertilizer application as well as emission factors for water and air [39].

[5] Please note that all lists in these sections are not exhaustive.

For estimating GHG emissions from land use, several guidance documents exist. The Quantis 2019 guidance "Accounting for natural climate solutions" gives advice for measuring GHG emissions from land use across upstream activities [34]. The European Environment Agency's indicator on "greenhouse gas emissions from land use, land-use change and forestry" comprises historical and projected emissions estimates from land use, presented at the EU level [40] In addition, the GHG Protocol is developing "Land Sector and Removals Guidance" which will provide further information [20].

Example: Using GHG Protocol definitions, company A measured its GHG emissions for the upstream and own operations value-chain levels using primary data and estimated its downstream emissions using LCA.

The measurement and valuation of GHG emissions for in-scope company activities followed the following steps:

Step one: Measure the GHG emissions.

Step two: Value your GHG emissions (calculate your impacts in monetary values).

Recommendation: Users should exclude carbon offsetting from their calculation.

As described in the NCMA methodology, you can use for example the social costs of carbon, or marginal abatement costs, as value factor.

4.2.2. Non-GHG air emissions

To measure the impact driver non-GHG air emissions (in tonnes), you will need to calculate the following quantitative indicators and to ensure compliance with regulatory thresholds for non-GHG air emission levels.

Indicator	Metric (tonnes)
Fine particulate matter	$PM_{2.5}$
Coarse particulate matter	PM_{10}
Nitrogen oxides	NO_2, NO, NO_3 and NO_x
Volatile organic compounds	VOC or NMVOC[6]
Sulphur oxides	SO_2, SO, SO_3, SO_x
Ammonia	NH_3

On-site measurement is the best approach to estimating your non-GHG air emissions. However, it could be complex and impractical when considering the entire value chain for your natural capital accounting. Random sampling for measuring your emissions throughout the year can be used to estimate your annual non-GHG air emissions.

When on-site measurement is not available, you can calculate your non-GHG air emissions indirectly. For example, to calculate the non-GHG air emissions in your own operations from fossil fuel energy consumption and/or transport, you can use information on the quantity and type of fuel used and the type of combustion process/engine. Additionally, you can use secondary data sources to estimate your emissions.

Potential secondary data sources are:

- Air quality indexes (if information on indicators is published) [41], [42]
- EEIO modeling such as Exiobase [43]
- LCA models and databases such as the ReCiPe [44] model and Ecoinvent [45]; these include information on characterization factors
- WHO global air quality guidelines [46]

The definition of VOCs and non-methane VOCs (NMVOC) might be subject to variations in different countries and regions. As a preparer, you will need to refer to the local definitions, which provide you with the regulatory limits and the emission measurement definitions.

Particulate Matter (PM) emissions are not only produced from the burning of biomass or fossil fuels. Other types of dust created by agriculture or industry can also be sources of PM. PM is classified according to particle size: PM10 refers to particles with a diameter of 10 micrometers or less, PM2.5 refers to fine particulate matter with a diameter of 2.5 micrometers or less. PM10 is expressed exclusive of PM2.5 to avoid double counting. If your measurements don't differentiate between PM10 and PM2.5 you can estimate the ratios using statistical data from the EEA [47], World's Air Pollution: Real-time Air Quality Index [48], or WHO Air Pollution Data Portal [49].

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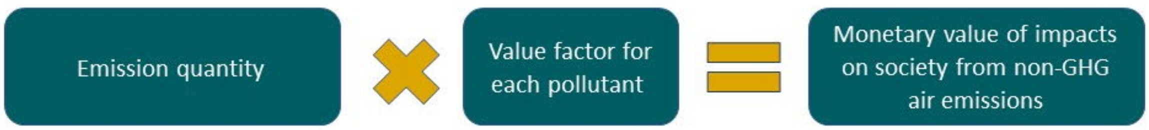
[6] Non-methane VOCs, as methane is considered within the GHG emissions impact driver.

Example: Company A calculated its non-GHG air emissions through its entire value chain, using a mix of primary and secondary data to calculate the monetary value of non-GHG air emission impacts on society following these steps:

Step one: Measure the quantity of non-GHG air emissions using a combination of primary and secondary data.

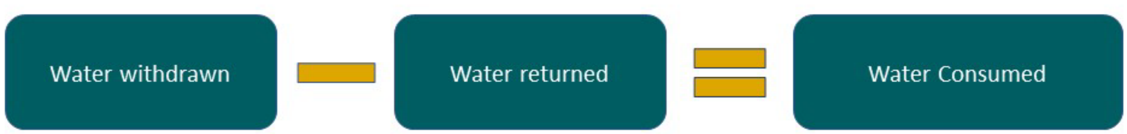
Step two: Value (and then sum) your non-GHG air emissions for each air pollutant across the value chain (calculate your impacts in monetary values).



Recommendation: It is important to understand that the non-GHG air emission indicators do not cover the entire list of non-GHG air emissions but represent the most significant primary and secondary pollutants in terms of societal costs for most sectors and regulatory limits. If you have identified additional indicators that are not included in the table above but are material to your business, we recommend expanding beyond the provided table to include those additional material indicators coupled with your explanation of their addition and vice versa in the case of any omissions from the provided table.

4.2.3. Water consumption

You will need to quantify the amount of water withdrawn and not returned to the water cycle (i.e., water used in the production of a good or service that becomes unavailable, or water that is contaminated and cannot be returned to a water source).[7]



To calculate your water consumption, we recommend creating a water balance by measuring the water withdrawal (input) and then subtracting the water released/returned to the water source (output). The difference will illustrate the amount of water consumed (input – output = consumed water). Your water balance should include the types of withdrawal per source (e.g., groundwater, river, municipal water supply), especially if the water is released back to a different watershed.

[7] You may want to differentiate between "blue" and "green" water here [106]. Note that "grey" water is considered in section 4.2.4. on water pollution.

Please note that if the contaminated water (wastewater) is treated and reintroduced to the water cycle, it is not considered consumed water.

In the absence of direct measurement (primary data) of your water consumption, usually along your value chain, the following secondary data sources can be used to estimate your water consumption:

- Aqueduct [50]
- AQUASTAT by FAO [51]
- AWARE (Available Water Remaining) [52]
- CropWat [53] and CLIMWAT [54] by FAO, (focus on agricultural water consumption)
- EEIO modeling such as Exiobase [43]
- India water tool [55]
- LCA models and databases such as the ReCiPe [44] model and Ecoinvent [45]
- Water Footprint Network [56]
- WWF Risk Filter Suite [57]

Recommendation: Since it is important to consider regional water scarcity levels, we recommend coupling the results of valued impacts from water consumption with a qualitative analysis describing local water scarcity levels.

Example: Company A calculated the water consumption of a product following these steps:

Step one: Calculate the amount of water consumed.

Consumed water = Input water (withdrawn) – output water (returned)

Step two: Value the monetary impacts on society (please refer to the NCMA methodology document regarding valuation techniques and impact pathways).

4.2.4. Water pollution

You will need to measure the amount of each pollutant in water returned to the water cycle, even if the water has undergone a wastewater treatment process. For best practice, we recommend that you specify the water source to which contaminated water is released.

For primary data:

- If the water is treated and discharged off-site, you will find information on the quantity of water and pollutants at the facility/company providing wastewater treatment.
- If your company is regulated, you will find information on your company's water pollution within your management/information systems.

In case primary data are not available (e.g., for your value chain), the following secondary data sources can be helpful:

- EEIO modeling such as Exiobase [43]
- EPA chemical databases [58]
- LCA models and databases such as the ReCiPe [44] model and Ecoinvent [45] (e.g., for freshwater eutrophication, freshwater ecotoxicity, marine ecotoxicity)
- Regulatory thresholds (in this case, you can assume that your water pollution levels are equivalent to regulatory thresholds)
- USEtox database [59] (e.g., for ecotoxicity)
- WHO chemical databases [60]

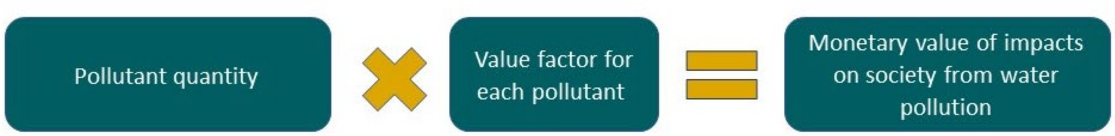
The release of chemicals to water bodies leads to increased:

- (Eco)Toxicity: discharged chemicals lead to increased aquatic-ecotoxicity levels affecting flora, fauna, and human health. The chemicals resulting in increased water pollution levels include methanol, manganese compounds, and ammonia.
- Eutrophication: nitrate compounds account for the majority of chemicals released to water. Increased nitrogen levels lead to algal bloom which results in depleted oxygen levels that impact aquatic ecosystems, water availability, and human health [61].

Example: Company A calculated the water pollution resulting from their business activities following these steps:

Step one: Quantify the amount of each pollutant (all pollutants that are deemed material from the scope) released to the water source (in kg or lb).

Step two: Value the monetary impacts on society (please refer to the NCMA methodology document regarding valuation techniques and impact pathways).



4.2.5. Land use

Land use materiality significantly depends on the company's sector/sectors. For example, land use is very material for agriculture, forestry, mining, and others while less material for the tertiary sector (service sector) including finance, insurance, digital services, and others.

For primary data:

You will need to measure the area of the land that your business activities occupy/use and specify how the land is used. You can find information on your buildings and sites within company management/information systems. You can request data from your suppliers on the land- use footprint associated with your business activities.

For secondary data:

- EEIO modeling such as Exiobase [43]
- JRC technical report (2016): Land-use related environmental indicators for Life Cycle Assessment [62]
- LANCA ® [63] by Fraunhofer Institute: country- and land-use-specific characterization factors for e.g. erosion resistance, groundwater regeneration [64]; see Annex VI for monetary valuation
- LCA models and databases such as the ReCiPe [44] model and Ecoinvent [45]

In the event that land associated with your company has multiple uses/users, you can allocate the impacts based on the following approaches:

- Economic allocation: here you allocate land use based on your economic share of the overall land output
- Physical allocation: here 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

Additionally, allocation can be based on mass, volume, energy, chemical composition, number of units, etc. We recommend being transparent about the allocation rule you apply.

Example: Company A calculated the land-use impact resulting from their business activities following these steps:

Step one: Quantify the amount of land use associated with business activities in the scope.

Step two: Value the monetary impacts on society (please refer to the NCMA methodology document regarding valuation techniques and impact pathways).

4.2.6. Solid Waste

As gaseous waste is considered in non-GHG air emissions, and fluid waste is considered in water pollution, this portion of the methodology and guidance focuses on the impacts generated by solid waste disposal. You will need to make a distinction between waste generated and waste diverted and account for them separately.

You will need to quantify the amount of hazardous and non-hazardous waste generated through in-scope activities. Since categories of hazardous and non-hazardous waste are defined by local authorities and differ from location to location this can make it difficult to compare business activities that take place in different locations. In your accounting, we recommend you follow a consistent definition of hazardous and non-hazardous waste across all sites and locations, while ensuring compliance with the local regulatory defined limits. If you want to consider plastic waste, please refer to Annex IV of the NCMA methodology.

The type of waste and method of disposal (incineration, landfill, or material recovery) are key factors that dictate how natural capital and society is impacted. The quantitative indicators that we recommend for measuring this impact driver are:

- Mass of waste disposed to landfill (kg)
- Mass of waste incinerated (with/without energy recovery) (kg)
- Mass of waste material recovered (kg)

For primary data, you can find information in the invoices and reports of your contracted waste treatment facilities, usually including information on the type of waste and type of treatments.

For secondary data sources (e.g., for your value chain), you can use:

- LCA models and databases such as the ReCiPe [44] model and Ecoinvent [45]
- EEIO modeling such as Exiobase [43]

In case of lack of data on final waste treatments, we recommend estimating the distribution of your waste into the most likely/suitable waste treatments available in the locations where you operate.

Example: Company A computed the solid waste generated by their business activities by following these steps:

Step one: Quantify the amount of hazardous and non-hazardous waste using primary data obtained from the waste management company.

Step two: Value the monetary impacts on society (please refer to the NCMA methodology document regarding valuation techniques and impact pathways).

5. DEPENDENCIES AND VALUE TO BUSINESS

The scope of this document is to provide guidance on how to use natural capital management accounting to assess the impact on society of a business's activities, based on the piloting experience by companies. Dependencies and value to business are therefore out of scope for this document and left for future development.

6. USING THE RESULTS

After generating your results, you will need to interpret and test them, and eventually act upon them. You may also report them externally.

6.1. Interpret and test the results

To interpret and test results, you should:

(i) Test your key assumptions by carrying out
   - Sensitivity analyses
   - Scenario analyses

(ii) Collate results

(iii) Validate and verify the accounting process and results. Seek (external) assurance or verification, if planning to disclose your accounting publicly

6.1.1. Test key assumptions

Sensitivity analysis

A sensitivity analysis is used to test the robustness of your natural capital accounting, and to test how changes in your input data affect your outputs. This helps you identify how changing your input parameters leads to changes in your results, and what aspects you need to consider more carefully. The underlying goals for sensitivity analysis are model calibration, model validation, and assisting with the decision-making process. [65]

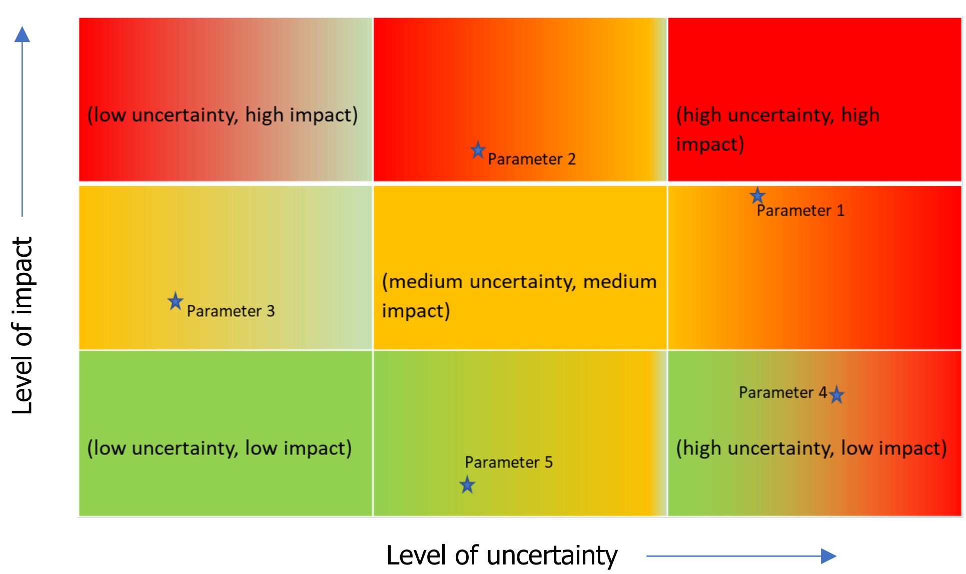
There are different methods of carrying out a sensitivity analysis, many of which require knowledge of statistics. All methods are designed to help you understand the degree of confidence you can have in your results, without overstating their accuracy. To better understand this section, the example below shows how outputs react to different input[8] parameters (example based on [66]).

Example: Modeling can be used to estimate GHG emissions in the life cycle of electric vehicles (EVs), battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), etc. In the case of BEVs and HEVs, carbon intensity of the electric mix used for battery charging is an important parameter. For each additional percent of electricity share provided by wind turbines (with carbon intensity of 25 g CO2-eq./kWh) in place of coal-based electricity (with carbon intensity 790 g CO2-eq./kWh), there is a drastic reduction in emissions of BEVs. Comparatively, other parameters like increasing the engine or drive-train efficiency would decrease kilometric GHG emissions by a little over 4%. Based on the sensitivity analysis results, management can decide where to channel efforts to help achieve significant GHG emission reductions.

There are four main types of sensitivity analyses we recommend to test the results of your natural capital accounting using the NCMA methodology:

1. Impact-specific sensitivity analysis: this is to test the robustness of the model on which your value factor was calculated by testing how the model parameters impact your valuation of impacts. We recommend you create an impact versus uncertainty matrix as shown in Figure 6, where you map all your parameters by assessing their level of impact on the results and the level of uncertainty associated with the estimation/calculation of each parameter.

Figure 6: Example of an impact versus uncertainty matrix



[8] Inputs here refer to data entries in the sensitivity analysis model that would result in an output.

2. Materiality sensitivity analysis: based on the selected valuation approach you will need to assess which material data types and information you will need to obtain to conduct your calculations.
3. Parameter impact: helps you understand how sensitive your results are to changes in an input parameter for your selected valuation approach.
4. Parameter uncertainty: helps you analyze the robustness and uncertainty levels in the estimation of your paraments based on the data collection and aggregation methods.

Scenario analysis

The intention of a scenario analysis is to identify changes that will lead to greater reductions in negative environmental impacts [67]. The bulk of the difficult work in environmental impact accounting consists of exploring alternative futures in ways that provide information of utility to decision makers [68]. The concept of valuation enables you compare outcomes and impacts on society across at least two scenarios: the baseline scenario, and a chosen scenario/s that is being "valued."

The example below, based on a study in the Western Balkan region [69], demonstrates what scenario analysis can look like.

Example: The Western Balkan region is one of the air pollutant hotspots of Europe with particulate matter ($PM_{2.5}$), ozone, and many other pollutants frequently above legislated limits. A scenario analysis was done to analyze differences in air quality impacts on crop yields and human health in response to various policy measures from the years 2020–2050 using the TM5-FASST[9] [70] and ECLIPSE V6b[10] [71] tools.

Current legislation was considered as a baseline scenario, incorporating only national commitments under the Paris Agreement. The other scenario under consideration was maximum technical reduction Sustainable Development scenario with no cost constraints (most ambitious scenario) where climate policy is aligned with SDG 13 (climate action) and the Paris Agreement, keeping temperatures below 2°C. Different indicators were used to measure impacts on crop yields and human health and various data sources were used for projections related to crop yields, human population, etc.

The results of the study showed that in the baseline scenario, the impact of $PM_{2.5}$ on human health, and the impact of ozone on agricultural productivity would be stabilizing or slightly reducing, whereas the impact of ozone on human health would likely increase. On the other hand, the most ambitious policy intervention showed the most positive effects.

[9] The TM5-FASST tool, developed at JRC Ispra (Italy), allows you to evaluate how air pollutant emissions affect large-scale pollutant concentrations and their impact on human health (mortality, years of life lost) and crop yield.

10 Evaluating the Climate and Air Quality Impacts of Short-Lived Pollutants

Recommendation:

Uncertainty of valuation: Value factors that are publicly available are usually presented in globally or regionally consolidated figures (excluding GHG emission value factors such as the social cost of carbon which estimates global climate damages). This would result in having monetary value of impacts with a high level of uncertainty and might not reflect the impacts caused by your business activities in a specific location. Depending on the type and materiality of the decision to be made with the results of the natural capital accounting, we recommend conducting your own studies (impact pathways) analysis to better reflect the conditions of your settings.

Furthermore, using value factors from different sources for the same impact driver might lead to very different monetary value of impacts. Variability may be due to the use of different valuation approaches, impact pathways, or underlying modeling. To drive greater transparency you may present the valued impacts in a range, coupled with an explanation of how the upper and lower limits of the range were calculated.

Similarly, businesses can make decisions using scenario modeling to explore how certain decisions and policies can affect impacts on society:

Types of scenarios that you may wish to consider include [72]

- **Intervention** scenarios or real alternatives being considered (e.g., for comparing alternative development projects or project locations, or comparing alternative materials used within particular products)
- **Exploratory** scenarios, assessing possible unexpected futures (sometimes used in risk assessments)
- **Vision** scenarios, describing explicitly desirable or undesirable futures (also used in risk and strategy assessments). Vision scenarios can be used to inform potential "business as usual" scenarios as well
- A **counterfactual** is a form of scenario that describes a plausible alternative state of the site and its environmental conditions that would result if the company did not operate. More than one counterfactual can be considered, to account for different perspectives (e.g., those of stakeholders or experts)

6.1.2. Collate results

You will need to compile and present your natural capital accounting results in a way that is suitable to your defined objective and selected scope, and that facilitates your decision-making process. It is important that in presenting the results they are set out in such a way to help you understand trends and facilitate comparisons between alternatives and the context of decision making.

This is likely to involve some form of analytical approach or framework, such as:

- Cost-benefits analysis
- Multicriteria analysis
- Environmental profit and loss account

- Integrated profit and loss account
- Total contribution or total contribution margin

When collating results, you should follow the rules explained in the NCMA methodology:

- Present value-chain levels separately, acknowledging different levels of control and ability to influence.
- Present impacts separately for each impact driver.
- Provide details on your materiality assessment and justify any exclusions.
- Provide details on both internal and external data sources, as well as an assessment of their quality.
- Explain key modeling assumptions, external and internal model sources and limitations, as well as the results of your sensitivity analysis. If there is significant measurement uncertainty, be clear about the level of uncertainty (e.g., by showing ranges rather than only absolute point estimates).
- To avoid the risk of greenwashing, there should be no netting of results.
- Clearly state where your approach deviates from the recommendations of the methodology.

Including notes similar to those found in financial statements may help other stakeholders interpret the results of your accounting.

6.1.3. Validate and verify the accounting process and results

Validation and verification may cover the accounting process, the results, or both. Depending on the application, the validation and verification can be conducted by internal colleagues and/or external stakeholders.

For internal colleagues, topic-specific experts can review the plausibility of the results and provide further information.

You may also look for external assurance. When selecting your assurance provider, consider your business application. If you are planning to integrate natural capital information into your standard corporate reports (annual report, non-financial report), there may be requirements on the type of assurance provider and required level of assurance (limited/reasonable).

Verification is an independent process involving expert review to check that your subject matter (natural capital accounting) gives a (satisfactory) true representation of the process and results.

The risk of material misstatement can never be reduced to nil, and therefore there can never be absolute assurance. For a reasonable assurance engagement, the assurance provider needs to reduce the risk of material misstatement to an acceptably low level as the basis for a positive form of expression of the practitioner’s conclusion. For a limited assurance engagement, the assurance provider collects less evidence but enough for a negative form of expressing the conclusion. Given the maturity of limited assurance, it is most prevalent for sustainability information including natural capital accounting.

6.2. Take action

After finalizing your natural capital accounting results, the information obtained can be used to support decision making and monitor against your strategy.

6.2.1. Apply and act on results

Depending on your business application, your actions in response to your accounting are likely to differ. For example, you can use the results to inform decision makers about the natural capital impacts of sourcing decisions, building new sites, or improving manufacturing processes. In some cases, the methodology can also be useful to monitor impacts, without directly reacting to a specific natural capital management report.

If planning to set targets (e.g., to act within planetary boundaries), you should review your modeling choices in order to reflect specific management choices.

6.2.2. Communicate results

Your natural capital accounting results provide insights into your business's performance by demonstrating the impacts of business activities on society. It thus provides a comprehensive understanding for business steering and accountability to stakeholders. Depending on your results, you may want to communicate internally and/or externally. In communicating results, the appropriate level of detail should be chosen depending on the purpose of your communication. You should also consider an appropriate frequency of communication, depending on your business application. For example, if tracking progress towards a target, you may want to communicate interim results monthly or quarterly as part of your management reporting, whereas you may want to report externally only on an annual basis.

The use of impact data for decision making and monitoring is an evolving field and businesses and capital providers are developing approaches to incorporate these data to establish a comprehensive assessment of business activities. It is important that performance indicators are contextualized so that performance can be assessed against targets. Recognition of planetary boundaries is a critical step in evaluating absolute and relative performance.

We highly recommend including information on key modeling assumptions and data sources used, as well as limitations. For example, make clear which impact pathways are included in the natural capital results, and which impacts require further consideration. Since some stakeholders might prefer quantitative measures such as tons of CO_2 emitted, or liters of water consumed, we recommend providing information on the impact drivers alongside the computed impacts.

When presenting your results, you may want to display them in an EP&L (Environmental profit and loss account) or, if you expand the scope of your accounting to human and social capital, in an IP&L (Integrated profit and loss account). This allows you to have an overview of your triple-bottom-line impacts (environmental, social & human, and financial), facilitating sustainable decision making and strategy setting through the increased transparency and visibility of your impacts.

We also recommend you consider developing a sustainability dashboard that includes the value of your impacts in monetary terms. Using a dashboard provides you with an interactive view of your value chain sustainability performance information. A dashboard assists your company in addressing the complexities of sustainable value-chain management by demonstrating your performance with charts and reports, allowing you to make informed strategic decisions. For a list of case studies by corporates, please see the overview by the Capitals Coalition [73], and the pilot studies by the Value Balancing Alliance [74].

ANNEX I. POTENTIAL RESULTS TEMPLATES

Below, we include templates that can be used to display your results. Moreover, Figure 9 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 [73], and the pilot studies by the Value Balancing Alliance [74].

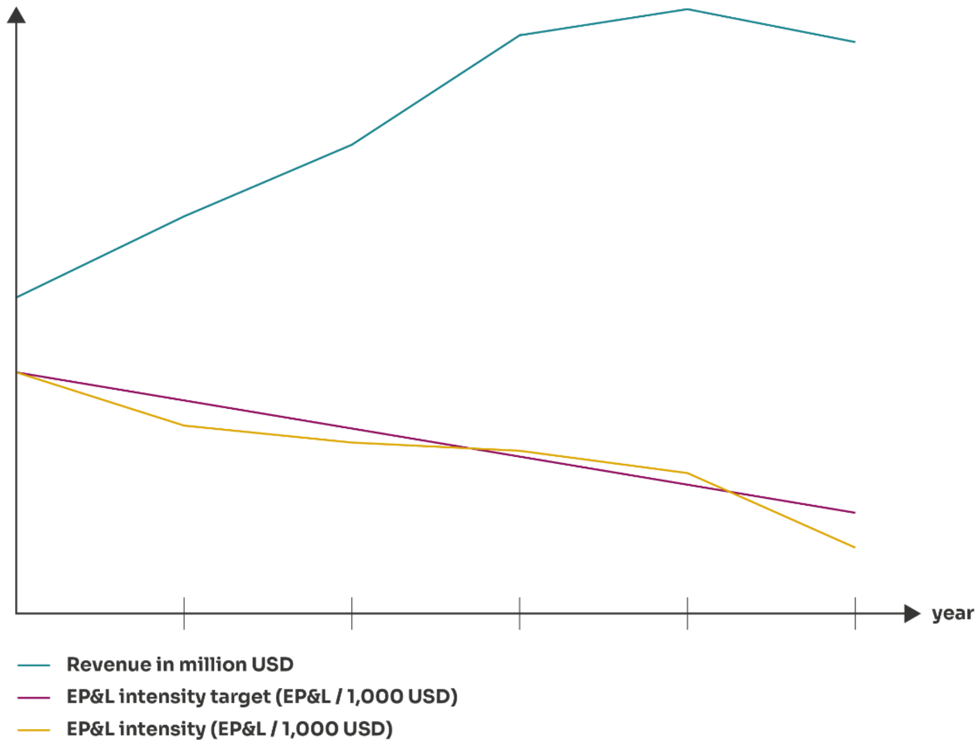
Table 7: Environmental Profit & Loss template

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

Table 8: 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			
Environ-mental	GHG emissions Non-GHG air emissions Water consumption Water pollution Land use Solid waste			

Figure 7: Sample EP&L intensity graph



ANNEX II. INTRODUCTION TO USING EEIO

Environmentally Extended input-output (EEIO) analysis is a simple and robust approach to evaluate the relationship between economic activities and environmental (natural capital) impacts. EEIO analysis can be used to evaluate the upstream and downstream natural capital impacts embodied in goods and services traded between countries. This annex illustrates an example of the application of EEIO analysis to measure and value the upstream impacts of business activities.

EEIO analysis is used to quantify the economic drivers of natural capital impacts, such as GHG emissions, or non-GHG air emissions. EEIO analysis mainly aims to:

- Calculate the indirect natural capital impacts caused by the purchase and consumption of a good or service.
- Calculate the indirect natural capital impacts caused by goods and services traded between countries.

EEIO analysis can reflect physical or monetary flows between industries. For the application of the NCMA methodology, we focus on monetary flows to achieve monetarily valued natural capital impacts. We use a Leontief model to illustrate the use of EEIO analysis.[11]

A Leontief model is a model reflecting national- or regional-level economics. It is based on having n number of industries/sectors producing n number of different products, such that the outputs equal the inputs (i.e., consumption = production).

There are two types of models used:

- Open model: some of the produced output is consumed internally by industries and the rest is used by external bodies (final demand)
- Closed model: all the produced output is only consumed internally by the industries

The example below describes an open model where the demand for goods and services is divided between the production sectors and external bodies (such as consumers). The choice of an open model is due to this being the most common approach used in Multiregional input-output analysis, which spans different countries and sectors.

Using EEIO analysis for estimating the upstream impacts of a company's activities entails collecting data on all purchased goods (i.e., including goods and services consumed as inputs for other production processes).

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[11] Although the mathematics of EEIO analysis is not complex, the explanation included here may nevertheless be difficult to understand without a mathematical background.

The main data to be collected must include:

- Vendor country: The country where a purchase was produced or provided.
- Product classification: A description of the purchased item, containing sufficient detail to assign purchases to their related economic sectors.
- Value: The purchased volume in monetary units, ideally in the currency used in the IO table (USD or EUR). Currency conversion might be needed in the data preparation process.
- Year: The year in which the purchase was booked.

To calculate the environmental impacts using an EEIO model, a satellite account is needed. The satellite account is an extension of the System of National Accounts (SNA) which includes environmental data such as CO_2 emissions.

To demonstrate the use of EEIO models and how data from SNAs can be used for measuring your upstream impacts when applying the NCMA methodology, an illustrative example is described. The example shows how to calculate natural capital upstream impacts (GHG emissions) in monetary values using Multiregional input-output modeling (MRIO) based on a Leontief model analysis.

The Leontief IO model[12] is used in the example to measure the environmental impacts of the business and afterwards these impacts can be valued in monetary values using value factors. The Leontief analysis describes both the direct economic effects generated by the company and the indirect effects arising due to the input (intermediates) the company demands from other companies/ sectors.

In the following section, the Leontief model for a simplified two-sectors and two-economy model is briefly explained. Following that, a simplified, step-by-step case is shown to demonstrate the application.

1. Leontief model:

To calculate upstream impacts using a Leontief model, the following equations are applied:

The total production of a sector can be described by the production of intermediates that are purchased by other sectors for production and the demand of final consumers. This balance between the total input and output can be described by the following equations:

$$x_{11} + x_{12} + y_1 = x_1 \qquad \text{(A1.a)}$$

$$x_{21} + x_{22} + y_2 = x_2 \qquad \text{(A1.b)}$$

where

x_i : the total output, or production, of sector i,

x_{ij} : the flow of input (intermediates) from sector i to sector j

y_i : the total final demand for sector i's product.

[12] The Leontief model IO analysis is suitable to measure the upstream impacts of business activities, through the examination of the interdependencies between production and goods within a selected sector.

Denoting the input coefficient, a_{ij}, the equations above can be rewritten as follows:

Leontief equation:

$a_{11} * x_1 + a_{12} * x_2 + y_1 = x_1$ (A1.b)

$a_{21} * x_1 + a_{22} * x_2 + y_2 = x_2$ (A2.b)

$y_1 = x_1 - a_{11} * x_1 - a_{12} * x_2$ (A1.c)

$y_2 = - a_{21} * x_1 + x_2 - a_{22} * x_2$ (A2.c)

$y_1 = (1 - a_{11}) * x_1 - a_{12} * x_2$ (A1.d)

$y_2 = - a_{21} * x_1 - (1 - a_{22}) * x_2$ (A2.d)

In matrix terms:

$A * x + y = x$ (A5)

$y = x - A * x$ (A6)

$y = (I - A) * x$ (A7)

$y * (I - A)^{-1} = x$ (A8)

These formulas, in particular (A7) and (A8), will help you to understand the principal idea of the Leontief inverse in the example below.

2. Step-by-step example

Please note the example provides a simplified view for valuing upstream impacts. Applying EEIO analysis to estimate your upstream impacts requires expert knowledge and you will very likely need external support for this.

Consider a scenario which includes two economic sectors, chemicals and agriculture. The two sectors purchase and sell goods to each other and to a population that purchases the final products sold by the two sectors. This is illustrated in an EEIO table (Table 9).

Table 9: Input-output table for the agriculture and chemicals sectors including total input (intermediated), final demand, and final output

		Transaction matrix T				**Final demand matrix Y**		**Final output matrix**
Country	**Country**	Country 1	Country 1	Country 2	Country 2	Country 1	Country 2	Output(sum)
	Sector	Agriculture	Chemicals	Agriculture	Chemicals			
Country 1	**Agriculture**	600	150	100	150	300	300	1600
Country 1	**Chemicals**	400	400	40	90	300	200	1430
Country 2	**Agriculture**	100	50	500	150	200	150	1150
Country 2	**Chemicals**	0	100	600	500	100	50	1350
Total		**1100**	**700**	**1240**	**890**	**900**	**700**	**5530**

The table shows yearly monetary transactions in the economy. The transaction matrix T shows transactions of the sectors with each other. The first column shows that the agricultural sector in country 1 purchases $600 from the agriculture sector and $400 of goods and services from the chemicals sector in country 1. Country 1 imports goods and services worth $100 from the agriculture sector in country 2 and does not require any inputs from the chemical sector in country 2.

Rows in contrast show which outputs a sector produced and who demands the produced products. For instance, in the example above, the agricultural sector in country 1 produces products worth $600 for the agricultural sector in country 1, products worth $150 are demanded by the chemical sector in country 1, and country 2 demands products worth $100 for the production of agriculture, and products worth $150 for the production of chemicals. Moreover, the final demand matrix Y shows that final consumers demand products worth $300 in country 1 and country 2, each. Overall, the output of the agricultural sector of country 1 amounts to 1600$ (the sum of all products demanded).

Step one: Calculate the total output X

As a first calculation step, the total output produced by a sector must be computed.

$T + Y = X$

Where T : intermediate consumption

Y : final demand

X : total output

Step two: Quantify the natural capital impacts of sectors (e.g., tonnes of GHG emissions)

If the EEIO table you use does not contain the information you want to quantify, you will need to collect information on the environmental impact you are interested in. For example, you need to collect data on the GHG emissions by each sector in each country. This data is called a satellite account. For our example, we assume the following dataset:

	Country 1 Agriculture	Country 1 Chemicals	Country 2 Agriculture	Country 2 Chemicals
GHG emission (tonnes)	200	150	700	350

Based on the table, the agriculture sector emits 200 tonnes of carbon in country 1, and 700 tonnes of carbon in country 2. The chemicals sector emits 150 tonnes of carbon in country 1 and 350 tonnes of carbon in country 2.

Step three: Calculate the direct intensity vector s

The direct intensity vector s should include information on the emissions generated to produce *one unit* of output. To calculate s, the GHG emissions (satellite account vector[13]) are divided by the transposed[14] output vector x^T.

Compute transpose of the output vector x^T

	Country 1 Agriculture	Country 1 Chemicals	Country 2 Agriculture	Country 2 Chemicals
Output	1600	1430	1150	1350

The direct intensity vector s is now expressed in tons of CO_2/$

$s = GHG / x^T$

	Country 1 Agriculture	Country 1 Chemicals	Country 2 Agriculture	Country 2 Chemicals
GHG emission (tonnes CO_2/$)	0.125	0.104895	0.608696	0.259259

The direct intensity vector describes the tonnes emitted for one unit of output produced. For example, the agricultural sector in country 1 on average emits 0.125 tonnes of CO_2 to produce one USD worth of output.

Step four: Calculate technical coefficient matrix A

Capturing the embodied emissions[15] in the intermediate inputs sold from sector to sector and eventually becoming final products purchased by final consumers, this step provides an overview and an approach to track the movement of embodied impacts (CO_2 emissions in this example) between countries and sectors.

The technical coefficient matrix A provides the amount of input a sector needs to receive from other sectors to create a dollar of output (also measured in dollars).

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[13] A vector is a matrix of one row or one column.

[14] The transpose of a vector can be computed by switching rows and columns. It is denoted x^T.

[15] Embodied carbon refers to GHG emissions arising from manufacturing, transportation, installation, and maintenance.

The technical coefficient matrix can be calculated by dividing all inputs from a sector by the output of the sector:

A= T/X

		Country 1 Agriculture	Country 1 Chemicals	Country 2 Agriculture	Country 2 Chemicals
Country 1	Agriculture	0.375	0.104895	0.086957	0.111111
Country 1	Chemicals	0.25	0.27972	0.034783	0.066667
Country 2	Agriculture	0.0625	0.034965	0.434783	0.111111
Country 2	Chemicals	0	0.06993	0.521739	0.37037

For example, to produce one unit worth of output, the agriculture sector in country 1 requires inputs worth \$0.375 from the agriculture sector in country 1, \$0.25 from the chemical sector of country 1, and \$0.0625 from the agriculture sector in country 2. No inputs are needed from the chemical sector in country 2.

Assume a consumer purchases a bottle of oil worth of \$1 from a company that is part of the chemicals sectors in country 1. To produce this bottle of oil, inputs from the agricultural sector (oil) and the chemical sector (bottle) are needed. To calculate the total upstream emissions associated with the bottle of oil, you need to respectively move through the different sales layers (supplier tiers) between the upstream sectors to find the total dollar output required from each sector, while accounting for the intermediate purchases (inputs) between the sectors to create the bottle of oil.[16]

From the input-output table, the second column shows that the production of the \$1 bottle of oil in country 1 requires inputs from both sectors and both countries. In particular, to produce \$1 of output in the agricultural sector in country 1, we need inputs worth \$0.105 from the agricultural sector in country 1, \$0.28 from the chemical sector in country 1, \$0.035 from the agricultural sector in country 2, and \$0.070 from the chemical sector in country 2.

To understand the modeling of the overall upstream value chain intuitively, we consider an even more simplified case. Restricting the required inputs to the inputs of country 1 for now, we can describe the inputs to generate \$1 worth of output of a bottle of oil as follows:

For country 1: To create the bottle of oil worth \$1, we must purchase an input of \$0.104895 from the agriculture and \$0.27972 from the chemicals industry. This can be described as in Figure 8 below.

[16] A bottle of oil was selected for this example since it represents a product that starts in the agricultural sector and then moves to the chemicals sector.

Figure 8: Chemicals sector output for the first two production layers in country 1

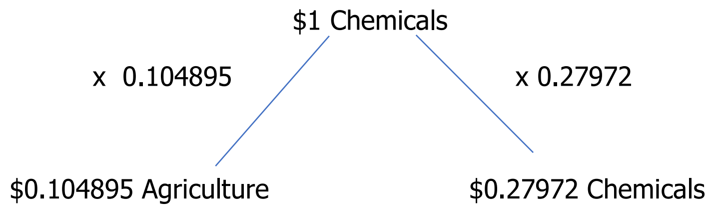
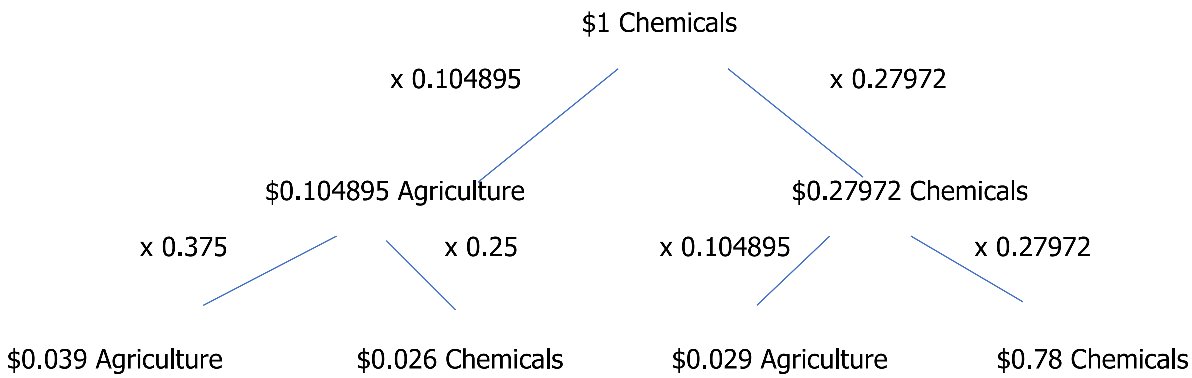


Figure 9: Chemicals sector output for the third production layer in country 1



This logic continues to the third production layer and can be described as in Figure 9 (again only considering country 1).

This process continues in principle to include all countries and until the contribution of subsequent layers further diminishes. This makes it tedious and infeasible in the case of large EEIO, as the branching grows with the number of sectors, countries, and production layers. This issue is solved using a Leontief analysis. This includes the following steps:

a) Calculating the Leontief matrix
The Leontief matrix equals the identity matrix[17] minus the technical coefficients matrix:

$$I - A$$

Where I: identity matrix

[17] The identity matrix is a square matrix with ones on the main diagonal and zeros everywhere else.

		Country 1 Agriculture	Country 1 Chemicals	Country 2 Agriculture	Country 2 Chemicals
Country 1	Agriculture	1	0	0	0
Country 1	Chemicals	0	1	0	0
Country 2	Agriculture	0	0	1	0
Country 2	Chemicals	0	0	0	1

The Leontief Matrix is: $I - A$

		Country 1 Agriculture	Country 1 Chemicals	Country 2 Agriculture	Country 2 Chemicals
Country 1	Agriculture	0.625	-0.1049	-0.08696	-0.11111
Country 1	Chemicals	-0.25	0.72028	-0.03478	-0.06667
Country 2	Agriculture	-0.0625	-0.03497	0.565217	-0.11111
Country 2	Chemicals	0	-0.06993	-0.52174	0.62963

b) Calculate the Leontief inverse matrix,[18]

$$(I - A)^{-1}$$

		Country 1 Agriculture	Country 1 Chemicals	Country 2 Agriculture	Country 2 Chemicals
Country 1	Agriculture	1.814647	0.34839	0.752911	0.489987
Country 1	Chemicals	0.675179	1.550334	0.550456	0.380441
Country 2	Agriculture	0.30721	0.201024	2.268004	0.475735
Country 2	Chemicals	0.329557	0.338766	1.940506	2.024704

[18] Please note that the calculation of the inverse is not straightforward and will probably require specialized software, especially for large EEIO tables with multiple regions and sectors.

Step six: Calculate overall upstream emissions for one unit of output

To estimate the emissions of each sector associated with all upstream impacts, the Leontief inverse matrix is multiplied with the direct intensity vector s.

$$S = s * (I - A)^{-1}$$

	Country 1 Agriculture	Country 1 Chemicals	Country 2 Agriculture	Country 2 Chemicals
GHG emission	0.570092	0.416362	2.035472	0.915656

This calculation step results in a matrix stating that for each dollar of output to final demand from the agriculture sector in country 1, 0.570092 tonnes of CO_2 upstream emissions are created. The same logic applies for the rest of the columns.

Step seven: Calculate total upstream emissions associated with final demand

Total upstream emissions resulting each year from all sales to final consumers (final demand) made by a sector can be calculated by multiplying the total upstream emission for each dollar of output with the final demand y. To calculate company-specific impacts, you can use your procurement spent for y (i.e., the company-specific demand for products by a sector) as the final demand.[19]

$$E = S \cdot y$$

Where:

E : upstream emissions vector

y : final demand vector

In our example here, we use the final demand of the sector as y. Thus, the final demand vector y can be computed by calculating the total demand of both countries.

Final demand matrix y				
		Country 1 Final demand	Country 2 Final demand	Y Vector (sum)
Country 1	Agriculture	300	300	600
Country 1	Chemicals	300	200	500
Country 2	Agriculture	200	150	350
Country 2	Chemicals	100	50	150
Total		900	700	1600

[19] Please note that element-wise multiplication is necessary here, denoted as "·".

Then the upstream emissions matrix E is now expressed in tonnes CO_2

		Vector
Country 1	Agriculture	342.0553
Country 1	Chemicals	208.1811
Country 2	Agriculture	712.4153
Country 2	Chemicals	137.3483
Total		1400

Step eight: Monetary valuation of CO_2 (GHG) emissions impacts to society

Using a social cost of carbon of $185 per ton [75] the GHG emissions valued in monetary terms are:

		GHG (CO_2) emission ($)
Country 1	Agriculture	63280.22
Country 1	Chemicals	38513.50
Country 2	Agriculture	131796.80
Country 2	Chemicals	25409.44
Total upstream		259000

The social costs of GHG emissions to society by the agricultural sector in country 1 are estimated at about $63280 for its upstream impacts, the same logic applies to the following rows.

The same calculation logic continues for the rest of the impact drivers using different satellite accounts.

ANNEX III. AVAILABLE EEIO TABLES

Please note that the list is indicative, and not exhaustive.

Model	Developer	Temporal coverage	Country coverage	Covered impact drivers	Paid/free	Update frequency	Link
EORA	KGM & Associates (originally University of Sydney)	1990-2021	190 countries	GHG emissions, non-GHG air emissions, water use, land use	Paid	Yes	https://worldmrio.com/
EXIOBASE	NTNU, TNO, SERI, Universiteit Leiden, Vienna University of Economics and Business, 2.-0 LCA Consultants	1995-2016	44 countries	GHG emissions, water consumption, land use	Free	Yes	https://environmentalfootprints.org/exiobase3/
FIGARO	Eurostat and the Joint Research Centre of the European Commission	2010-2019	27 EU countries, UK, USA, 17 main EU partners	GHG emissions, other impact drivers are under development	free	Regular	https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20210526-1
Global MRIO-Lab	University of Sydney		Entire world	Scope-dependent	Paid/free	Regular	https://ielab.info/analyse/ielab-global
GTAP	Center for Global Trade Analysis in Purdue University's Departme	2004, 2007,	121 countries	GHG emissions, non-GHG air emissions, land use	Paid/free	Irregular	https://www.gtap.agecon.purdue.edu/databases/v10/index.aspx

Model	Developer	Temporal coverage	Country coverage	Covered impact drivers	Paid/free	Update frequency	Link
	nt of Agricultural Economics	2011, 2014					
OECD ICIO	OECD	2010-2013	66 countries	GHG emissions, non-GHG air emissions	Free	Yes	http://oe.cd/icio
USEEIO	US Environmental Protection Agency	2007-2012	USA	GHG emissions, non-GHG air emissions, land use, water use, eutrophication, ozone depletion, pesticide use	Free	Regular	https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-technical-content
WIOD	University of Groningen	2000-2014	27 EU countries, Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Norway, Russia, South Korea, Switzerland, Taiwan, Turkey, UK, and USA	GHG emissions, energy use	Free	Irregular	https://www.rug.nl/ggdc/valuechain/wiod/

ANNEX IV. AVAILABLE LCA DATABASES

Please note that the list is indicative, and not exhaustive.

Database	Developer	Country coverage	Compatible software	Paid/free	Link
Agri-footprint	Blonk sustainability	Global	SimaPro	Paid	https://blonksustainability.nl/tools/agri-footprint
Ecoinvent	The ecoinvent Association	Global	SimaPro, GaBi, OpenLCA, Umberto	Paid/free	https://ecoinvent.org/
Eco-profiles	Plastics Europe	EU, Norway, Switzerland, Turkey, UK	GaBi	Free	https://plasticseurope.org/sustainability/circularity/life-cycle-thinking/eco-profiles-set/
EU-LCI	European Commission	EU	SimaPpro	Free	https://single-market-economy.ec.europa.eu/sectors/construction/eu-lci-subgroup/eu-lci-values_en
GaBi	Sphera	Global	GaBi	Paid	https://sphera.com/
Life Cycle Initiative	Hosted by UN Environment Programme	Global	Multiple online tools	Free	https://www.lifecycleinitiative.org/about/about-lci/
ProBas	German Federal Environment Agency	Germany + Global	OpenLCA	Paid/free	https://nexus.openlca.org/database/ProBas
USLCI	The National Renewable Energy Laboratory (NREL)	US	SimaPro, GaBi, OpenLCA	Free	https://www.nrel.gov/lci/

ANNEX V. METHODS TO MEASURE CHANGES IN THE STATE OF NATURAL CAPITAL

Annex V provides a list of methods to use for estimating the change in natural capital for either midpoint impacts (impacts on the environment) or endpoint impacts (impacts on human health, resources, and ecosystems). Methods included are free, reliable, and can be applied at a global scale (geographic coverage includes numerous countries).

Data source	Description	Indicators and their link to the NCMA impact drivers (in parentheses)
IPCC 2014 AR5 IPCC 2018 SR 15 IPCC 2022 AR6	The Intergovernmental Panel on Climate Change reports and special reports provide the methodology to measure GHG emission impacts.	Global warming potentials for a 100-year time horizon and other time frames (GHG emissions)
ReCiPe	ReCiPe is a method for impact assessment (LCIA) in an LCA. Life cycle impact assessment (LCIA) translates emissions and resource extractions into a limited number of environmental impact scores by means of so-called characterization factors.	- Particulate matter (non-GHG air emissions) - Trop. ozone formation (non-GHG air emissions) - Ionizing radiation (not addressed) - Stratos. ozone depletion – human health (non-GHG air emissions) - Human toxicity - cancer and non-cancer (non-GHG air emissions/water pollution) - Global warming (GHG emissions) - Water use (water consumption) - Freshwater ecotoxicity (water pollution) - Freshwater eutrophication (water pollution)

Data source	Description	Indicators and their link to the NCMA impact drivers (in parentheses)
		- Trop. ozone formation – ecosystems (not addressed) - Terrestrial ecotoxicity (not addressed) - Terrestrial acidification (not addressed) - Land use/transformation (land use) - Marine ecotoxicity (water pollution) - Marine eutrophication (water pollution) - Mineral resources (not addressed) - Fossil resources (not addressed)
USEtox 2.0	USEtox is a model based on scientific consensus providing midpoint and endpoint[20] characterization factors for human toxicological and freshwater ecotoxicological impacts of chemical emissions in life cycle assessment, developed under the auspices of the United Nations Environment Program (UNEP) and the Society for Environmental Toxicology and Chemistry (SETAC) Life Cycle Initiative. USEtox represents best application practice as an interface between ever advancing science and a need for stability, efficiency, transparency, and reliability.	The two indicators provided by USEtox 2.0 are: - Water ecotoxicity (water pollution): expressed in Comparative Toxic Units or CTUe, which can be translated into an indicator of potentially disappeared fraction of species per m^2 and per year (or PDF*m^2*year) - Human toxicity (non-GHG air emissions/water pollution): carcinogen and non-carcinogen effects) expressed in Comparative Toxic Units, or CTUh, which can be translated into DALYs
LANCA	This application enables the calculation of characterized indicators that describe the effects of processes on the performance of various environmental systems. The LANCA® calculations are based on geo-ecological classification systems and make use of site-specific input data. For more details, see Annex VI.	The ecosystem functions of erosion resistance, mechanical filtration, physicochemical filtration, formation of new groundwater, and biotic production potential can be taken into account by this method within a Life Cycle Assessment (land use)

[20] Mid-point impacts could be marine eutrophication, and end-point impacts could be respiratory disease, damage to buildings, and reduced agricultural yields.

ANNEX VI. VALUATION OF LAND USE BASED ON LANCA METHOD

The LANCA® method allows you to assess changes in the state of natural capital (soil) resulting from different impact drivers. However, the LANCA® method does not provide value factors to complete the valuation process. Consequently, when using the LANCA® method, additional estimations are needed to assess the monetary value of changes in natural capital. Annex VI shows the indicators and units of change in state of soil resulting from the application of the LANCA® method, and indicates additional sources of valuation methods and factors that can be used to complete the valuation process and assess the monetary value of impacts resulting from land use.

Indicator of change in state of soil resulting from the application of the LANCA® method	Unit of indicators of change in state of soil resulting from the application of the LANCA® method	Methods and factors to assess the monetary value of changes in state of soil resulting from the application of the LANCA® method
Erosion resistance	kg soil/m^2 land-year	[76] provides a method to estimate the cost of soil erosion resulting from soil lost (USD/kg soil). As LANCA® provides estimates of soil loss (kg soil/m^2 land-year), this method helps to estimate the value of soil erosion.
Mechanical filtration	m^3 water/m^2 land-year	[77] provides an average replacement cost of treating water with alternative methods to the natural process of water filtration.
Physicochemical filtration	Mol/m^2 land-year	[77] provides an average replacement cost of treating water with alternative methods to the natural process of physiochemical filtration.
Groundwater regeneration	m^3 water regeneration/m^2 land-year	[78] provides information of mitigation cost to reduce water scarcity ($/$m^3$).
Biotic production	kg biotic production/m^2 land-year	FAO provides the average value of biotic production per ha at national level that can be used to assess the value of changes in biotic production (see [79]).

ANNEX VII. OVERVIEW OF VALUE FACTOR DATABASES AND METHODOLOGY DEVELOPERS

Data source	Organization	Geographical coverage	Level of data disaggregation	Applicability	Data accessibility
Environmental Prices Handbook 2017 [80]	CE Delft	Europe	At EU28 level	For impact drivers taking place in Europe. For other context, value transfer functions should be applied.	Free
Methodological Convention 3.0 for the Assessment of Environmental Cost, Cost Rates [81]	German Federal Environment Agency	Germany	At country level (Germany)	For impact drivers taking place in Germany. For other context, value transfer functions should be applied.	Free
Impact Weighted Accounts framework [82]	Harvard Business School	Global	At country level	Context-specific	Free
True Price 2021 [83] Also published in the Impact-Weighted Accounts framework by the Impact-Weighted Account Project, Harvard Business School	True Price	Global	At global level	The level of aggregation is so high that it does not allow capturing local context specificity. This should be kept in mind for decision making, i.e., using them only for high-level screening.	Free
Ecosytem Services Valuation Database [84]	ESVD	Global	At biomes/ecosystem or at country level	For impacts and dependencies on land use	Free
Strong et al. (2020) [78]	World Resources Institute	Global	At country level	Water consumption mitigation costs	Free

Data source	Organization	Geographical coverage	Level of data disaggregation	Applicability	Data accessibility
Social Impact Measurement Model (SIMM): focuses on socioeconomic impacts [85]	Deloitte	Global	At country level	For impact drivers taking place in any country worldwide	Free methodology papers, paid value factors
GIST [86]	GIST	Global	At country level	For impact drivers taking place in any country worldwide	Paid
True Value: Impact Assessment and Valuation 2020 [87]	KPMG	Global	At country level		Free methodology papers, paid value factors
Valuing corporate environmental impact 2015 [88]	PwC	Global	At country level		Free methodology papers, paid value factors
S&P [89]	S&P Global Sustainable1	Global	At country level		Paid
Value Balancing Alliance 2021 [74]	Value Balancing Alliance	Global	At country level		Free methodology papers, paid value factors

ANNEX VIII. THE SOCIAL COST OF CARBON

The social cost of carbon (SCC) is an estimate, in monetary terms, of the economic damage 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 price differs between developers depending on the selected valuation approach and underlying modeling assumptions. Below we provide a list of prices (additional to those listed in Annex VI) that can be used in estimating GHG emission impacts in monetary values:

- Resources for the Future (RFF): "Comprehensive evidence implies a higher social cost of CO2" [90]
- Interagency Working Group on Social Cost of Greenhouse Gases, United States Government: "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990" [91]
- Project Drawdown: "Solutions cost per metric ton" [92]
- CDP: "Putting a price on carbon, The state of internal carbon pricing by corporates globally" [93]

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., 1.5° goal (IPCC 2018 [122], NGFS 2022 climate scenarios [124], [129]).

GLOSSARY

Baseline	In the Natural Capital Protocol [4], 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 [94].
Business application	In the Natural Capital Protocol [4], 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 [95]).
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 [96]. Ecosystems are part of natural capital.
Ecosystem services	The most widely used definition of ecosystem services is from the Millennium Ecosystem Assessment [97]: "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 [98]. 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 [26] [28] [99]**.**
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 [100].
Impact	See "natural capital impact."
Impact driver	In the Natural Capital Protocol [4], 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 [15]. 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 [4], 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 [101] [102].
Materiality assessment	In the Natural Capital Protocol [4], 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 [4], 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 [103] [104].
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 [4], 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: • 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 [4], 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 planet. 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 [4], 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 [4], 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 [4] 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 an 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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