CHEMICAL SECTOR GUIDANCE ON APPLYING THE NATURAL CAPITAL MANAGEMENT ACCOUNTING METHODOLOGY

NCMA Chemical sector guidance

July 2023

About this document

This document was developed through the EU LIFE program by the Transparent Project.

The document is a work in progress. Detailed feedback from a number of experts has already 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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ABOUT

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

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

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

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LIST OF ACRONYMS

CC – Capitals Coalition

CO_2 – carbon dioxide

EEIO – environmentally extended input-output model

EPA – Environmental Protection Agency

EP&L – environmental profit and loss account

ENCORE – Exploring Natural Capital Opportunities, Risks, and Exposure

GHG – greenhouse gas

ICOS – Integrated Carbon Observation System

IFAC – International Federation of Accountants

IO – input-output model

ISO – International Organization for Standardization

LCA – life cycle assessment

LCI – life cycle inventory

LCIA – life cycle impact assessment

MEA – Millennium Ecosystem Assessment

NCMA – Natural Capital Management Accounting

NOx – nitrogen oxides

PET – polyethylene terephthalate

P&L – profit and loss

SASB – Sustainability Accounting Standards Board

SEEA – System of Environmental-Economic Accounting

UNEP – United Nations Environment Program

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

VBA – Value Balancing Alliance

WBCSD – World Business Council for Sustainable Development

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 sector guidance document provides an overview and additional resources in support of the steps needed for the application of natural capital management accounting that are specific to the chemical sector. Additional documents provide a standardized methodology for natural capital management accounting (the NCMA methodology), and the NCMA general guidance to support implementation of the methodology.

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 [1]. 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 [2].

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.

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

In addition to the NCMA general guidance document, the Transparent Project is developing sector-specific guidance documents based on the experience of piloting companies. Sector-specific guidance is currently available for the following sectors:

- Agri-food
- Apparel
- Chemicals

The NCMA general and sector-specific guidance documents set out the steps and actions to apply the methodology to measure and value business impacts on society.[1]

2.1. About the chemical sector guidance

The chemical sector guidance is intended to complement the NCMA methodology by focusing on its applicability to the chemical sector and illustrating the outcome of the methodology's use when applied in that sector. The guidance provides industry-specific considerations on:

- Objective of measuring and valuing impact
- Scoping and materiality
- Data availability
- Measuring and valuing your impact drivers in monetary values

The guidance provides an example based on the chemical sector to assist in understanding the impact of sector-relevant business activities across the value chain. In applying the methodology, further breakdowns, changes, and specifications are needed to best reflect chemical sector business models.

2.2. About the intended users

Similar to the NCMA methodology, this 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 details on terminology such as "impact," "impact driver," "impact pathway," and "valuation techniques."

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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 regarding publicly sharing the results.

3. OBJECTIVE AND SCOPE

The focus of this section is to provide you with the steps and actions you will need to take to establish a set of corporate Environmental Profit & Loss accounts based on standardized NCMA methods and guidance developed under the Transparent Project. This section helps you to consider the intended use of your results to help you in selecting and applying methods most appropriately. It is also critical at this stage to make explicit the objective, scope, and assumptions that underpin your measurement and valuation of natural capital (see Figure 1).

Figure 1. Questions on the objective and scope of your accounting

What? to consider for natural capital accounting	**Objective** - What is the purpose?
	Scope - What should be the boundaries?
	Materiality - What are the minimum impact drivers that should be considered during the materiality analysis?

To set up your natural capital accounting we recommend the following phases:

- Define objective and scope
- Engage and train
- Measure and value
- Interpret and test the results
- Take action

For more details, see the NCMA general guidance.

3.1. Objective

Whereas the main objective of the NCMA methodology is to develop an EP&L, you may want to apply the NCMA methodology to achieve a specific goal. It is essential to develop and clearly define the objective(s)/goal(s) of your natural capital accounting; for more details and examples, see the NCMA general guidance.

3.2. Scope

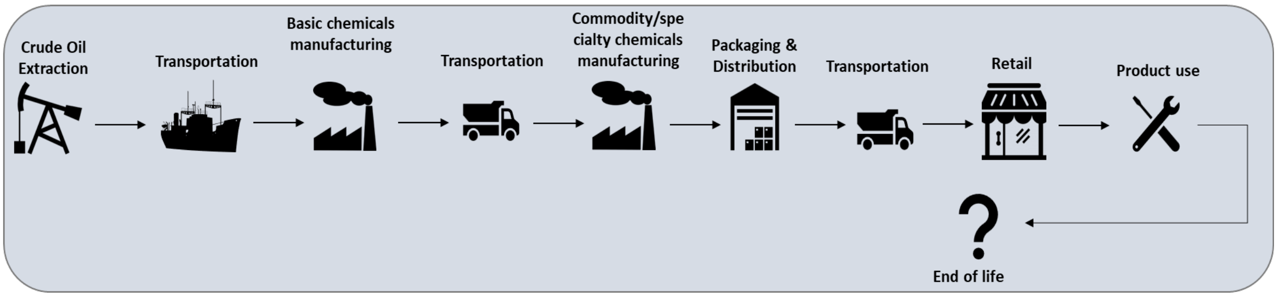
Defining the objective(s) of your natural capital accounting facilitates your process of defining/selecting the scope of application. The focus here is on the value chain and impacts in scope. For all other aspects to be considered, see the NCMA general guidance.

3.2.1. Value-chain boundaries

The chemical sector's global landscape is rapidly changing in terms of development, technologies, and innovation. The chemical industry provides numerous products used as inputs in multiple industries, such as electronics and optical equipment, motor vehicles and trailers, and food and beverages. [3]

A wide variety of products are derived from organic, inorganic, biological, and synthetic sources, such as fossil fuels, basic chemicals, commodity chemicals, speciality chemicals, agrochemicals, pharmaceuticals, etc. This significant range of products adds complexity to value chains due to several factors such as the choice of materials used to create final products, amount of processing needed, supply chain locations, etc. Figure 2 illustrates the chemicals value chain, focusing on crude oil extraction as one of the main product output categories of the chemicals sector.

Figure 2. Chemicals value chain originating from crude oil extraction



Adapted from Life Cycle Assessment in the chemical product chain [4].

Generally, chemical industry product outputs and related feedstock can be classified into three groups:

- *Basic chemicals*: Consist mainly of chemicals sold within the chemical industry and to other industries before becoming products suitable for the general consumer. Basic chemicals are produced in large quantities and are currently still largely based on fossil fuels (hydrocarbons).
- *Commodity chemicals*: Highly standardized products that are homogenous across all manufacturers and are typically produced in large quantities. They are also known as bulk chemicals and include synthetic fibers, plastics, rubber products, composites, and paints [5]. Commodity chemicals have multiple applications and uses.
- *Specialty chemicals:* Manufactured because of their performance or function, these can be single-chemical entities or formulations whose composition sharply influences the performance and processing of the customer's product. They include food additives, cosmetics, construction materials, resins, and pharmaceuticals. A specialty chemical usually has one or two core uses [6].

Defining business activities into supply (and possibly value) chain levels depends strongly on the type of chemical products and whether they are produced to manufacture other products or to be used directly by end users. Due to this distinction the material impacts in the value chain are case specific. For instance, the paints industry will have different material impacts as compared to the detergents industry.

3.2.2. Impact drivers

For first-time preparers, we recommend carrying out your natural capital accounting on all six impact drivers within the scope of the methodology (see NCMA general guidance for more details).

Material impacts should be included as defined by relevant frameworks, standard setters, and initiatives. To identify material environmental impact drivers for the chemicals sector as established by existing initiatives, an analysis was conducted on chemical-sector specific sustainability requirements. The goal of this analysis is to provide you with:

- A basic understanding of the industry's sustainability obligations, sustainability goals, and commitments
- Additional sector-specific impact drivers to consider outside the scope of the Transparent methodology

Your material impacts highly depend on your business model. It is recommended that you look at your business model and activities (as a whole) to identify the most relevant impacts, and then review the various standards and initiatives to close any gaps in identifying your material impacts. Furthermore, we recommend expanding your analysis to documents not considered here and monitoring developing initiatives not included in the analysis of this guidance document, to ensure that the goals of your company and its decision-making processes are aligned with disclosure requirements and sector commitments (for example, the SASB Chemicals sustainability accounting standard [7] and ENCORE [8], see Annex I for more details).

In preparing this document, a small analysis was conducted based on sustainability reports by various companies in Europe and other parts of the world. The results in Table 1 show the relative importance chemical-sector companies place on various topics.

This table can be used as a starting point to compare and identify your material topics in relation to those from companies with a similar business model (benchmarking), in addition to alignment with other initiatives and frameworks, while maintaining regulatory compliance. Benchmarking should be done with caution, making sure to reflect company-specific conditions.

Table 1. Materiality analysis for the chemical sector

Material topics with level of importance											
Company	GHG emission	Water consumption	Water pollution	Biodiversity	Energy use	Land use	Renewable energy	Waste	Sustainable procurement	Non-GHG air emissions	Circular economy
BASF	High	High	High	Medium	High	*	*	High	Medium	High	High
LyondellBassel	High	Low	High	Low	Medium	Low	*	High	Low	High	High
Linde	High	Medium	*	*	High	*	Medium	Medium	*	Low	Low
Umicore	High	High	High	High	Medium	*	Medium	Medium	Medium	*	Medium
Air Liquide	High	High	High	High	*	*	*	High	High	*	Medium
Johnson Matthey	High	High	*	*	*	*	*	*	Medium	*	Medium
Covestro	High	High	High	Medium	High	*	High	High	High	*	High
Yara International	High	Medium	Medium	Medium	High	*	High	*	Medium	High	Medium
Evonik Industries	High	Medium	Medium	Low	Medium	*	Medium	Medium	*	*	High
Brenntag	High	High	High	*	High	*	High	High	High	*	High
Braskem	High	High	High	Low	High	High	*	High	Medium	High	*
Alpek	High	High	High	*	High	*	*	*	*	*	High
Tata Chemicals	High	High	High	High	High	*	High	High	*	*	High

*Note – The * indicates lack of sufficient information to comment on the level of importance. Though many companies were found to be working on and reporting on these issues in their sustainability reports, it can be difficult to assess how they translated their material topics into practice.*

4. MEASURE AND VALUE

To measure and value the impacts of business activities in the chemicals value chain, this document provides additional guidance for:

- Data collection needs
- Measuring the physical quantities for each impact driver
- Valuing your measured impacts in monetary terms

The following section provides support in applying the NCMA methodology (see Figure 3).

Figure 3. Questions on the measure and value step of your accounting

How ? to make an informed decision	**Data Collection -** How to gather data for impact drivers?
	Measurement - How to measure impact drivers?
	Valuation - How to value impacts in monetary units?

4.1. Principal accounting modules

4.1.1. Measure your impact driver

To measure the physical quantities of the impact drivers considered in scope, you will use primary data, secondary data, or a combination of both. For more details on typical data sources and additional guidance, see the NCMA general guidance.

In addition to the sources listed here, the Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) regulation [9] can be a useful data source for the chemical sector. Annex II provides a list of LCA databases specific to the chemical sector.

If multiple products are produced in a chemical system, you might need to distribute the inputs and the outputs between products, services, and business activities considered in the scope of your natural capital accounting. In addition to the allocation types listed in the general guide, the following might be suitable to the chemical sector (subject to your specific case):

- Mass allocation: the most commonly used allocation method in the chemical industry
- Volumetric allocation: based on the volume of materials used in the production process
- Energy allocation: based on the energy content used in the production process
- Molar content allocation: based on the molar mass of chemicals used in a specific production process [10]

4.1.2. Measure the change 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 guidance, please see the NCMA general guidance.

4.1.3. Value your impacts on society

After measuring your impact drivers, you will calculate the monetary values of your impacts by multiplying the measured 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. For guidance, please see the NCMA general guidance.

4.2. Specific accounting modules by impact driver

This section provides key considerations to take into account when measuring impacts for each impact driver and the related impact pathways when undertaking natural capital accounting using the NCMA methodology.

4.2.1. Greenhouse gas (GHG) emissions

Consuming about 50% of the energy input as feedstock or raw material, the chemical sector is the largest industrial energy consumer in direct CO_2 emissions [11]. Direct CO_2 emissions from primary chemical production in 2020 were estimated at 920 $MtCO_2$ or approximately 18% of industrial CO_2 emissions.

Specific activities which are important to consider for the measurement of GHG emissions are:

- Raw materials extraction and feedstock
- Manufacturing processes
- Energy and fuels input
- Flue gases and fugitive emissions

4.2.2. Non-GHG air emissions

The main source of non-GHG air emissions emitted by the chemical sector is the burning of oil, coal, and gas to power the transformation of chemicals. The emitted air pollutants in addition to CO_2, are NO_2, NO_x, mercury, and SO_2 [12]. Industrial non-GHG air emissions impact human health (both health of workers and of the local population) causing increased mortality, morbidity, and respiratory diseases [13].

Specific activities which are important to consider for the measurement of non-GHG air emissions are:

- Manufacturing processes
- Energy and fuels input
- Flue gases and fugitive emissions
- Use and end-of-life treatments

For agri-chemicals, you will also need to consider on-site emissions from the application of nitrogen-based fertilizers.

Ammonia is the most produced air pollutant in the chemicals industry, as it represents the basis for all synthetic nitrogen fertilizers which are used in around 50% of global food production.

4.2.3. Water consumption

The water consumption impact driver depends on the final products being produced and the technologies used. Although the chemical industry is a significant water user, it is leading innovation in reducing its water footprint [14].

Specific activities which are important to consider for the measurement of water consumption are:

- Water-intensive manufacturing processes
- Cooling and heating processes
- Raw materials extraction
- Product use phase [15]

4.2.4. Water pollution

Chemicals manufacturing and processing leads to the generation of wastewater released into water bodies. Usually, pollutant release thresholds are regulated and require permits, nevertheless this does not prevent natural capital impacts being caused by the pollutants.

Specific activities which are important to consider for the measurement of water pollution are:

- Manufacturing processes
- Use phase and end-of-life treatment

4.2.5. Land use

Land use in the chemical industry is mostly connected to the raw materials used and their extraction processes, and also to waste generation within the industry.

Specific activities which are important to consider for the measurement of land use are:

- Raw material extraction
- Own operations land-use footprint
- Soil degradation

Chemical industry land use affects ecosystem services and human health. As an example, the use of chemicals alters soil function and degrades it, leading to a loss of ecosystem services, biomass, and species. This eventually leads to increasing impacts on human health due to increased susceptibility to diseases.

4.2.6. Solid waste

In the EU, the chemical sector is responsible for between 8 and 16 million metric of tons of solid waste per year, which can be split into hazardous and non-hazardous waste. Hazardous waste accounted for about one-third of total waste in 2017 and 2018 [16].

Chemical industry waste disposal takes one of the following forms:

- Underground injection wells
- Landfills
- Surface impoundments
- Other treatments (incineration with or without energy recovery, materials recovery) [17]

Specific activities which are important to consider for the measurement of solid waste are:

- On-site waste disposal
- Raw materials extraction (e.g., waste rock in mines)
- End-of-life treatment
- Packaging

5. DEPENDENCIES AND VALUE TO BUSINESS

The scope of this guidance 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 take appropriate action. You may also report them externally. This step is highly case-specific, yet does not differ between sectors. Therefore, please refer to the general guidance for more information.

7. CALCULATION EXAMPLE

In the following, a simplified example of a producer of PET bottles in the chemical sector is described to illustrate the steps necessary to perform natural capital management accounting. For ease of understanding, we consider a chemical company whose product portfolio is a single 1-liter PET bottle type. This is a strongly simplified example and does not reflect the large product portfolio of most companies. In the case of a large product portfolio, a large share of the corporate impact can be calculated as the sum of environmental impacts for the produced products (see section 6.1.2. of the general guidance for more information about aggregating impacts).

The chemical company uses 21 g of PET bottle resin for the production of a single 1-liter PET bottle.[2] Per year, the company produces 1 million tonnes of PET bottles of which 70% of the plastic is recycled. The production of PET bottles occurs in multiple stages with PET resin production being the first step.

Some exclusions made in the example for simplification reasons:

- The study doesn't trace the damages as far back as petrochemicals production (i.e., crude oil extraction).
- The impacts from construction and materials used for equipment, buildings, and other auxiliary facilities are not included.
- The impacts from bottle caps and labels, etc. are also beyond the scope of this illustration.

7.1. Step one: Objective and scope

The company's objective is to monitor their impacts along their value chain to identify hot spots and prioritize actions in reducing their environmental impacts. Therefore, the company aims to assess their corporate footprint.

In this example, the environmental impacts of one PET bottle as a functional unit have been calculated. Afterwards, the results will be scaled up linearly to calculate damages for assumed production capacity which can be roughly assumed as the environmental impact of the entire company.

7.2. Step two: Measure and value

In the next step, the company needs to collect information on both the impact drivers, as well as suitable value factors.

Ideally, the company would start collecting primary data on its impact drivers along the entire value chain, which include the following:

1) Upstream

- Raw material production
- Transportation

[2] Based on an LCA study for Indian PET bottles [18], 21 g of PET bottle resin can be used as a functional unit because it is considered sufficient to package 1 liter of drinking water.

2) Own operations

- Processes to produce PET resin (different polymerization processes)
- Molding processes (injection and blow molding)
- Anti-contamination processes
- Packaging
- Transportation

3) Downstream

- Transportation
- Filling and sealing of bottles
- Bottle collection, segregation, and packing
- Disposal

4) Recycling

Since the chemical company has no primary data available, they decide to refer to an LCA study to quantify the impact drivers by value-chain level [18] (Table 2). Since the study does not include all necessary information, the following assumptions were made to quantify the impact drivers:

- For non-GHG air emissions, acidification potential (i.e., kg SO_2 eq.) was used
- For water pollution, the eutrophication potential (i.e., kg phosphate eq.) was used

Table 2: Reference table for distribution of impacts across the value chain, based on LCA study on PET bottles (p.20 of [18])

Environmental indicators	**Upstream**	**Own operations**		**Downstream**	**70% recycle with credit**
		Production step 1	Production step 2		
GHG emissions: Global Warming Potential (GWP 100 years) [kg CO_2-eq.]	45.9%	4.7%	43.7%	5.3%	31.9%
Non-GHG air emissions: Acidification Potential (AP) [kg SO_2-eq.]	31.2%	1.2%	63.2%	4.4%	6.8%
Water pollution: Eutrophication Potential (EP) [kg phosphate-eq.]	38.6%	3.5%	50.6%	7.3%	11.5%

Note: Production steps refer to (1) production of PET resin and (2) preform production including steps such as bottle blowing.

GHG emissions

The Global Warming Potential (GWP) is quantified at 92 g CO_2 eq. / 21 g PET bottle [18]. Based on the reference table (Table 4), 45.9% comes from upstream activities, 48.4% comes from own operations, 5.3% comes from downstream, and 31.9% can be credited from recycling.

Therefore, the quantified emissions for upstream (cradle-to-gate) are (analogously for the other value chain levels):[3]

45.9% * [0.092 kg CO_2 eq. / 0.021 kg] * 10^9 kg

= 2.01 * 10^9 kg CO_2 eq.

Non-GHG air emissions

The acidification potential is quantified at 0.998 g SO_2 eq. / 21 g PET bottle [18]. Out of this, 31.2% comes from upstream activities, 64.4% comes from own operations, 4.4% comes from downstream, and 6.8% can be credited from recycling.

Therefore, the quantified non-GHG air emissions for upstream (cradle-to-gate) are (analogously for the other value chain levels):

31.2% * [(0.998 g SO_2 eq./1000) / (0.021 kg)] * 10^9 kg

= 1.48 * 10^7 kg SO_2 eq.

Water consumption

A single 21 g water bottle requires approximately 17.41 liters of water [19]. Out of this, 61% comes from upstream supply chain, 33% comes from own operations, and 6% comes from downstream [19]. (Recycling was not calculated because of lack of data in this case.)

Therefore, the quantified water consumption for cradle-to-gate is (analogously for the other value chain levels):

61% * [(17.41 l water/1000)m^3 / 0.021 kg] * 10^9 kg

= 5.06 * 10^8 m^3

Water pollution

A single 21 g PET water bottle has quantified pollutants of 0.057 g phosphate eq. [18]. Out of this, 38.6% comes from upstream supply chain, 54.1% comes from own operations, 7.3% from downstream, and 11.5% can be credited from recycling.

Therefore, the quantified water pollution for upstream (cradle-to-gate) is (analogously for the other value chain levels):

38.6% * [(0.057 g phosphate eq./1000) / 0.021 kg] * 10^9 kg

= 1.05 * 10^6 kg phosphate eq.

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[3] Alternatively, the company could quantify and value the impacts by value chain level for one PET bottle and then scale it up to the produced quantity of PET bottles.

Land use

Due to a lack of available information on land use in the underlying studies used as a basis for the assessment, the presented example does not include estimations for impact from land use.

Solid waste

The majority of impacts from solid waste for a chemical company producing PET bottles materialize downstream (end-of-life). Thus, for reasons of simplification, the example focuses on indirect effects of solid waste downstream. For indirect effects of solid waste, GHG and non-GHG air emissions are quantified. For direct effects (i.e., disamenity and leachate impacts), information on the amount of waste split into hazardous/non-hazardous and waste treatment is needed. Since the company lacks this information in this study, it is omitted and marked clearly in the results.

The company assumes that all plastic waste is sent to landfill.

- GHG emissions: 0.3% of GHG emissions come from plastic waste in landfill [18]. Therefore, quantified emissions are:

  0.3% * (0.092 kg CO_2 eq. / 0.021 kg) * 10^9 kg

  = 1.31 * 10^7 kg CO_2 eq.

- Non-GHG air emissions: 0.1% of non-GHG air emissions come from plastic waste in landfill [18]. Therefore, non-GHG air emissions are:

  0.1% * [(0.998g SO_2 eq./1000) / 0.021 kg] * 10^9 kg

  = 4.75 * 10^4 kg SO_2 eq.

- Water pollution impact: A 21 g PET water bottle has a quantified impact of 0.057 g phosphate eq. The contribution of plastic waste to landfill is 1% of the total contribution. Therefore, impact quantification can be done as:

  1% * [(0.057 g phosphate eq./1000) / 0.021 kg] * 10^9 kg

  =2.71 *10^4 kg phosphate eq.

To perform the monetary valuation, the chemical company multiplies the computed quantified impact drivers with the respective value factors. See Table 3 for value factors used in this example.

Table 3: Monetary valuation of environmental impacts quantified in PET bottle producer example

Impact drivers	Value factor	Unit	Reference year	In 2022 values (inflation adjusted[4])	Source
GHG emissions	0.185	\$/kg CO_2	2020	0.212	[20]
Non-GHG air emissions	6.70	\$/kg SO_2	2020	7.67	[21]
Water consumption	1.490	\$/m^3	2020	1.706	[21]
Water pollution	290	\$/kg phosphate	2020	332	[21]
Land use*	2390	EUR/ha	2020	2633.78	[21]
Solid waste*	0.185 for GHG emissions	\$/kg CO_2	2020	0.212	[20]
	6.70 for non-GHG air emissions	\$/kg SO_2	2020	7.67	[21]
	290 for water pollution	\$/kg phosphate	2020	332	[21]

** Land use and direct impacts of solid waste due to leachate and disamenity are out of scope for this example.*

[4] Inflation adjustments for Europe based on Destatis [40], and for the US based on the Bureau of Labor statistics [41].

7.3. Step three: Using the results

To use the results, the company decided to display their results in an Environmental P&L. The results reported in USD are shown in Table 4.

Table 4: Example Environmental P&L for PET bottle producer example

Impact driver	**Value chain monetary valued impacts in USD (million)**				**Total per impact driver in USD (million) [Upstream + own operations + downstream]**
	Upstream	**Own operations**	**Downstream**	**Recycling**	
GHG emissions	426.30	449.52	49.22	296.28	925.05
Non-GHG air emissions	113.73	234.74	16.04	24.79	336.51
Water consumption	862.76	466.74	84.86	---	1414.36
Water pollution	347.84	487.52	65.87	103.63	901.14
Land use*	---	---	---	---	---
Solid waste*	GHG	---	2.79	---	12.16
	Non-GHG air emissions	---	0.36	---	
	Water pollution	---	9.01	---	

** Land use and direct impacts of solid waste due to leachate and disamenity are out of scope for this example.*

ANNEX I. ADDITIONAL SOURCES FOR MATERIALITY ANALYSIS

SASB, Chemicals: Sustainability accounting standard

SASB standards are designed to identify a minimum set of sustainability issues most likely to impact the operating performance or financial condition of the typical company in an industry, regardless of location.

The SASB standard describes the reporting requirements for the chemicals industry using the predominant business model and industry segments. It includes the disclosure topics, accounting metrics, technical protocols, and activity metrics required for use in communications to investors regarding sustainability issues impacting the company's ability to achieve long-term value creation.

The natural capital topics prioritized by the SASB standard sustainability disclosure topics and accounting metrics are:

- Management of chemicals in products
- Environmental impacts in the supply chain
- Raw materials sourcing

Table A5: Matching the SASB chemicals accounting metrics and Transparent impact drivers

SASB chemicals accounting metrics	Match with Transparent impact drivers
Greenhouse Gas Emissions	GHG emissions
Air Quality	Non-GHG air emissions
Energy Management	GHG emissions + non-GHG air emissions (for estimations)
Water Management	Water consumption + water pollution (for estimations)
Hazardous Waste Management	Solid waste
Chemicals Management [7]	All

Disclosure on SASB topics requires companies to provide quantitative impacts supported by an analysis and discussion of the impact. By applying the NCMA methodology, companies can move beyond quantitative impacts to monetary values of impacts to support better-informed decision making in their management strategy.

It is suggested to go through the SASB materiality finder, such that you can have an overview of the identified material sustainability topics identified by publicly-listed companies within the sector. [22]

ENCORE, Natural Capital Finance Alliance

Alongside the SASB standards, ENCORE (Exploring Natural Capital Opportunities, Risks, and Exposure)[5] provides a comprehensive overview of industry material topics and a ranking of their materiality (high, medium, low).

ENCORE is a tool to help users better understand and visualize the impact of natural capital change on the economy. By focusing on the goods and services that nature provides to enable economic production, it guides users in understanding how businesses across all sectors of the economy potentially depend and impact on nature, and how these potential dependencies and impacts might represent a business risk, using Extended Environmental Input-Output models.

For the chemicals sector, the prioritized impacts using ENCORE can be translated into monetary valued impacts using the Transparent methodology as demonstrated in Table A2.

Table A6: Matching ENCORE and Transparent impact drivers

ENCORE impact drivers	Materiality rating	Transparent impact drivers
Water use	High	Water consumption
Terrestrial ecosystem use	High	Land use
GHG emissions	High	GHG emissions
Non-GHG air pollutants	High	Non-GHG air emissions
Water pollutants	High	Water pollution
Solid waste	High	Solid waste
Soil pollutants [8]	High	Land use

Additional standards, initiatives, and frameworks that can support the review

These include but are not limited to:

- Science-based Targets Guidance: "Barriers, Challenges, and Opportunities for Chemical Companies to Set Science-based Targets," the guidance focuses on climate change reduction and provides the steps and considerations for a user to set reduction targets [23].
- The European Commission's "Chemicals Strategy for sustainability" [24].

[5] ENCORE was developed by the Natural Capital Finance Alliance in partnership with UNEP-WCMC and was financed by the Swiss State Secretariat for Economic Affairs (SECO) and the MAVA Foundation.

ANNEX II. LCA SOFTWARE IN THE CHEMICAL SECTOR

Annex II provides an overview of the software tools providing life cycle inventory for chemical substances. Life cycle inventory involves the creation of an inventory of the product system's inputs and outputs [4].

Tool	Developer	Description	Paid/free	Link
Carbon minds	Carbon minds	LCA database for chemicals and plastics, compatible with most LCA software	Paid	here
Chemical Life Cycle Collaborative (CLiCC)	University of California, Santa Barbara	Provides estimates of chemical life cycle impacts, human health risks, and hazard information	Free	here
Ecosolvent	Swiss Federal Institute of Technology Zürich	Used for the quantification of the environmental impact of waste-solvent treatment	Free	here
Environmental Assessment Tool for Organic Syntheses (EATOS)	Universität Oldenburg Swiss Federal Institute of Technology Zürich	Drives assessments that aim to improve chemical synthetic sequence	Free	here
Finechem	Swiss Federal Institute of Technology Zürich	Used to estimate the resource use and environmental impacts of petrochemical production based on the molecular structure	Free	here
Wastewater LCI Initiative	2.0 LCA consultants	Calculates life cycle inventories for urban wastewater discharges	Paid	here

GLOSSARY

Baseline	In the Natural Capital Protocol [25], the starting point or benchmark against which changes in natural capital attributed to your business's 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 [26].
Business application	In the Natural Capital Protocol [25], 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 [27]).
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 [28]. Ecosystems are part of natural capital.
Ecosystem services	The most widely used definition of ecosystem services is from the Millennium Ecosystem Assessment [29]: "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 [30]. 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 [31] [32].
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 [33].
Impact	See "natural capital impact."
Impact driver	In the Natural Capital Protocol [25], 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 [34]. Several life cycle impact assessment (LCIA) databases provide a useful library of published estimates for different products and processes.
Materiality	In the Natural Capital Protocol, an impact or dependency on natural capital is material if consideration of its value, as part of the set of information used for decision making, has the potential to alter that decision [35] [36].
Materiality assessment	In the Natural Capital Protocol [25], 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 [25] , 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 [37] [38](adapted from [37]).
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 [25], the part or parts of the business to be assessed (e.g., the company as a whole, a business unit, or a product, project, process, site, or incident). For simplicity, these are grouped under three general headings as below: • Corporate: assessment of a corporation or group, including all subsidiaries, business units, divisions, different geographies or markets, etc. • Project: assessment of a planned undertaking or initiative for a specific purpose, and including all related sites, activities, processes, and incidents. • Product: assessment of particular goods and/or services, including the materials and services used to produce these products.
Price	The amount of money expected, required, or given in payment for something (normally requiring the presence of a market).
Primary data	Data collected specifically for the assessment being undertaken.
Qualitative valuation	Valuation that describes natural capital impacts or dependencies and may rank them into categories such as high, medium, or low.
Quantitative valuation	Valuation that uses non-monetary units such as numbers (e.g., in a composite index), area, mass, or volume to assess the magnitude of natural capital impacts or dependencies.
Scenario	A storyline describing a possible future. Scenarios explore aspects of, and choices about, the future that are uncertain, such as alternative project options, business as usual, and alternative visions.
Scoping	In the Natural Capital Protocol [25], the process of determining the objective, boundaries, and material focus of a natural capital assessment.
Secondary data	Data that were originally collected and published for another purpose or a different assessment.
Spatial boundary	The geographic area covered by an assessment, for example, a site, watershed, landscape, country, or global level. The spatial boundary may vary for different impacts and dependencies and will also depend on the organizational focus, value-chain boundary, value perspective, and other factors.
Stakeholder	Any individual, organization, sector, or community with an interest or "stake" in the outcome of a decision or process.
Temporal boundary	The time horizon of an assessment. This could be a current "snapshot", a 1-year period, a 3-year period, a 25-year period, or longer.
Validation	Internal or external process to check the quality of an assessment, including technical credibility, the appropriateness of key assumptions, and the strength of your results. This process may be more or less formal and often relies on self-assessment.
Valuation	In the Natural Capital Protocol [25], 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 [25], 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 [25] identifies three generic parts of the value chain: upstream, direct operations, and downstream. An assessment of the full lifecycle of a product would encompass all three parts. • Upstream (cradle-to-gate): covers the activities of suppliers, including purchased energy. • Direct operations (gate-to-gate): covers activities over which the business has direct operational control, including majority-owned subsidiaries. • Downstream (gate-to-grave): covers activities linked to the purchase, use, reuse, recovery, recycling, and final disposal of the business's products and services.
Verification	Independent process involving expert assessment to check that the documentation of the assessment is complete and accurate and gives a true representation of the process and results. "Verification" is used interchangeably with terms such as "audit" or "assurance."

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