TRUE PRICE ASSESSMENT METHOD FOR AGRI-FOOD PRODUCTS

True price assessment method for agri-food products

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[4] For more information on the *PPS True and Fair Price for Sustainable Products*, please refer to https://www.wur.nl/nl/project/Echte-en-eerlijke-prijs-voor-duurzame-producten.htm

This **True price assessment method for agri-food products** was developed and tested in several case studies by True Price and Wageningen Economic Research within the Public Private Partnership True and Fair Price for Sustainable Products (PPS Echte en Eerlijke Prijs voor Duurzame Producten).

This document contains the key steps to assess the true price of agri-food products and value chains and provides modelling guidance and requirements for scoping, data, and reporting.

It is complemented by other documents that together present the method for true pricing of agri-food products, and potentially other products as well.

Section 0.4.3 *Documents of the true price method* presents an overview of all the method components.

The full methodology is available here.

Content

0. Introduction

0.1. Why true pricing?

The agri-food sector delivers a very large value to society. Unfortunately, production and consumption of food is also associated with negative impacts - called externalities - on people and the environment – think of carbon emissions, water pollution and potentially unsafe labour conditions. A part of these negative impacts is regulated by legal means, but often additional actions are required over and above the statutory requirement to produce socially responsible and sustainable products (Muilwijk et al., 2019). Additional measures are needed mainly due to the complexity of agri-food value chains, which are often spread across multiple countries with varying systems of government control.

Quantitative measurements of externalities based on sustainability indicators may support companies to produce as sustainably as possible (e.g., by selecting and monitoring improvements in a fact-based way), it may support consumers to make better choices, and it may support governments to make effective policy.

The “true price” quantifies external and sometimes invisible costs of production and consumption. These costs are not reflected in the market prices. A part of true pricing, the process of finding the true price, is the quantification of externalities and their expression in one monetary unit. Typically, externalities are expressed in technical units. For instance, greenhouse gas emissions are expressed in kilograms of CO_2-equivalents. The process to translate technical units into monetary units is called monetisation. The true price shows what the price of a product would be if the cost of all externalities would be considered. In general, true pricing has two main goals:

1. to enable market actors (consumers, companies, investors and governments) to take knowledge-based sustainable decisions, and
2. to give focus and direction to government policy.

Different background reports on true pricing have been published that further specify the reasons why true pricing should be used. The report “*Op weg naar de echte prijs, echte waarde en echte winst van voedsel*” by True Price and Wageningen Economic Research provides background on the benefits of true pricing in the food sector for businesses, government and consumers and highlights the need for advancement in true pricing techniques (de Groot Ruiz et al., 2018). The vision paper “*A roadmap for true pricing*” by True Price provides additional information about the background of true pricing and contains more information on the use of the true price by different users (True Price, 2019). The current document and the other components of the true price methodology for agri-food products (see Section 0.4.3 *Documents of the true price method*), by contrast, answer the “how” question of the calculation of true prices.

0.2. What is the true price?

The true price is the sum of the market price (the price at which a product is offered) and the true price gap (the social and environmental costs caused by its production and consumption), as illustrated in Box 1.

For consumers and other purchasers, the true price gap gives a unique sustainability indicator that is comparable with the product price. It provides transparency by showing the negative social and environmental impacts and incentivises consumers and other purchasers to choose the most sustainable product (the product with the lowest true price gap). In addition, the true price can assist companies and governments in defining improvement opportunities. The true price identifies and ranks negative impacts, which helps in prioritizing efforts for improvement. Furthermore, it allows to compare the benefits of interventions, in terms of reduced social and environmental costs, with their implementation costs.

Positive effects of agrifood products are also important, and true pricing can help to measure and communicate them. In the used **Valuation framework,** positive effects are to be accounted for in a separate metric, such as the 'true value'.[5] Some positive impacts can however be captured directly by the true price as a metric. For example, reduction of social and environmental costs of a product over time will be captured by a true price comparison over time. The same holds for reductions compared to a benchmark. Positive externalities can furthermore be included in the true price if they offset negative externalities *for the same indicator* (e.g., greenhouse gas emissions and carbon sequestration, water pollution and water purification, negative and positive effects on workers' health, etc.) *for the same affected group of people or environmental compartment* of the product under study. In other words, each impact of the true price can never have a value that is subtracted from the true price gap as a whole.

In the document **Valuation Framework for True Price Assessment of Agri-food Products**, a rights-based approach for the valuation of quantified impacts for the purpose of true pricing based on the Principles for True Pricing is presented (Galgani, Woltjer, de Adelhart Toorop, & de Groot Ruiz, 2021b; True Price Foundation, 2020). The Valuation Framework for True Price Assessment of Agri-food Products can be referred to for further information on the definitions and normative foundations of the true price method for agri-food products.

[5] See the Valuation Framework for True Price Assessment of Agri-food Products for addressing positive impacts within the context of true pricing (Galgani, Woltjer, de Adelhart Toorop, & de Groot Ruiz, 2021b).

The true price (a simplified example with three impacts)

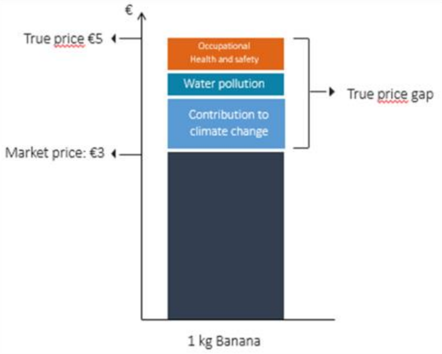
Imagine, the supermarket price of bananas is €3.00 per kilogram. This is the market price.

Assume that for the production of 1 kg of banana, 10 kg's of CO_2-eq. has been emitted and 0.05 kg of N has been emitted to water. For every 30,000 kg fruits produced, one occupational accident occurs. For sake of simplicity, assume these greenhouse gas emissions, water pollution and occupational accidents capture all social and environmental impacts of production.

Assume that we also know that the carbon emissions can be reversed through carbon capture and storage for € 0.10 per kilogram. The restoration cost of Nitrogen to water is €10 per kg, and the sum of medical costs and the loss of well-being is € 15,000 per accident.

Now, the true price of the product is calculated as follows.

Market price (1 kg of fruit)			€3.00
Footprint indicator	Value	Monetisation	
Greenhouse gas emissions	10 kg CO_2-eq	0.10 €/ kg CO_2-eq	€1.00
Nitrogen emissions to water	0.05 kg N	10 €/kg N	€0.50
Occupational accidents	1/30,000 accidents	15,000 €/accident	€0.50
Total true price gap (1 kg of fruit)			€2.00
Total true price (1 kg of fruit)			€5.00



Box 1: A simplified example of the true price

0.3. Why a true price assessment method?

The concept of the true price has been developed over the last decade by True Price and Wageningen Economic Research. However, a systematic methodology to assess true prices is currently not available (de Groot Ruiz et al., 2018). One of the goals of the Public-Private Partnership “Echte en Eerlijke Prijs” (2019-2022) is to develop a method for true price calculation that facilitates widespread adoption and comparability of true prices. This methodology must be supported by all relevant parties (e.g., actors in the agri-food sector,) and made publicly available. Accordingly, this document has been developed within the Public-Private Partnership “Echte en Eerlijke Prijs” to address this gap.

The assessment of a true price gap consists of the quantification and valuation of social and environmental impacts of production and consumption expressed per unit of a product. Therefore, the calculation of the true price of an agri-food product requires knowledge of the full product chain and the possible externalities. A structured approach on how to measure and value externalities is needed but was lacking until now. This methodology document aims to provide analysts with a stepwise approach to calculate true prices, and to provide guidance on how to make the required choices in each of these steps.

0.3.1. Intended audience

This document is meant as a handbook for all analysts and researchers that want to calculate the true price of an agri-food product. It provides step-by-step guidance to do so.

Many of the steps described in this document are an interpretation of existing Life Cycle Assessment (LCA) methodologies and good practices. However, people without prior LCA knowledge will be able to carry out a true price assessment following the steps specified in this document. LCA experts and practitioners will also be able to follow and apply this method. They will recognize much of the content of this document. Correspondences and differences between terminology and method used here and LCA standards and practice are indicated in the text.

0.3.2. Relation to Life Cycle Assessment

Life Cycle Assessment (LCA) is an established scientific field that deals with the quantification of impacts at the product level, mainly for environmental impacts, but to some extent also for social ones (Social LCA, or S-LCA). A true price assessment builds on LCA to quantify (a part of) the impacts included in the true price, following an established approach. Data from Life Cycle Inventories (LCI) and Life Cycle Impact Assessments (LCIA) serve as a valuable source of secondary data for a true price assessment.

The impact-specific modules of this true price method specify the method to calculate each true price impact (e.g. climate change, water use, underearning, etc.). They have two components: quantification and valuation. The quantification section provides more information on the modelling approach, impact indicators and their units, and it largely builds on LCA impact assessment methods and data. In general, LCI data or LCIA results can be used for quantification, as long as the following requirements are met:

- The LCA indicators match the true price indicators (definition and units) of the relevant impacts
- The LCIA method used to quantify the different indicators has the same modelling approach as the true price impacts.
- The lifecycle phases included in the LCA source are consistent with the scope of the rest of the true price assessment

In case these are not met, LCA results cannot be used directly, because they cannot be combined with true price monetisation factors. In some cases, the impact-specific modules can help to transform available LCA data to fit with the true price methodology (see Section 0.4.3 *Documents of the true price method* for a complete list of available impact-specific modules).

For more information on true price indicators, their relation to LCA indicators, and how they are combined with true price monetisation factors see also Stage C: Measure and value.

0.4. Reading guide

The chapters of this report correspond to the nine steps of the assessment method. This first chapter is numbered as Chapter 0, so that the numbering of the nine following chapters matches those of the steps. This method contains mandatory requirements as well as recommendations. Section 0.4.2 specifies how to distinguish these in the text.

Finally, this document does not stand alone: Section 0.4.3 shows how the document can and should be used in combination with complementary documentation, and Section 0.4.4 highlights the key references this document builds on.

0.4.1. Steps of a True Price Assessment

A true price assessment consists of four stages and nine logical steps (Figure 1).[6] The subsequent steps aim to ensure a complete assessment of the true price, but the output of some steps might require some of the earlier steps to be reconsidered. A true price assessment is an iterative process, for which this document aims to provide guidance (Figure 2).

Stage A: Frame
- Step 1: Define goal and audience

Stage B: Scope
- Step 2: Define the product
- Step 3: Define product lifecycle
- Step 4: Determine impacts in scope

Stage C: Measure and value
- Step 5: Measure the impacts
- Step 6: Value the impacts
- Step 7: Integrate the impacts

Stage D: Report
- Step 8: Interpret and test the results
- Step 9: Report

Each step ends with a section that specifies the output of the step. For many elements of the output, examples are provided that can be used in Step 9: Report.

Relation to LCA phases

Stage A and part of Stage B correspond to the "Goal and scope definition" phase of an LCA, part of stage B and stage C corresponds to the "Inventory analysis" and "Impact assessment" LCA phases and Stage D corresponds to the "Interpretation" phase, following ISO 14040 (ISO, 2006a).

0.4.2. Requirements, recommendations, and options

The rest of the document gives guidance and recommendations for each of the stages and steps in a true price assessment. Specific terminology, following the PEF recommendations, is used to express requirements, recommendations, and options for the users to follow. The formulation used to express *requirements* is "shall", which indicates what is required in a true price assessment. With "should", the *recommendations*, which are less strict than requirements, are indicated. *Options* that the practitioner may choose to include or not are indicated with "may".

[6] The process is adapted from the Natural Capital Protocol and The Social & Human Capital Protocol (Natural Capital Coalition, 2016; Social & Human Capital Coalition, 2019).

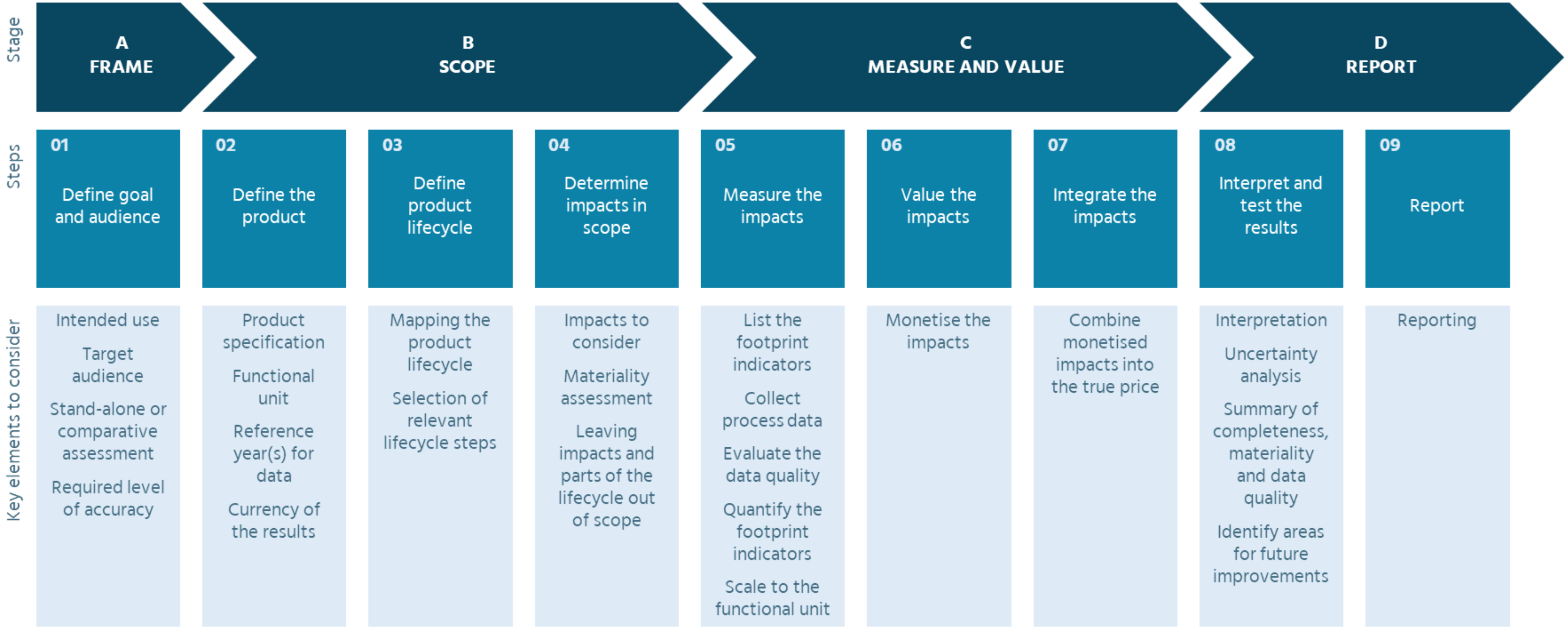


Figure 1: The stages of a true price assessment

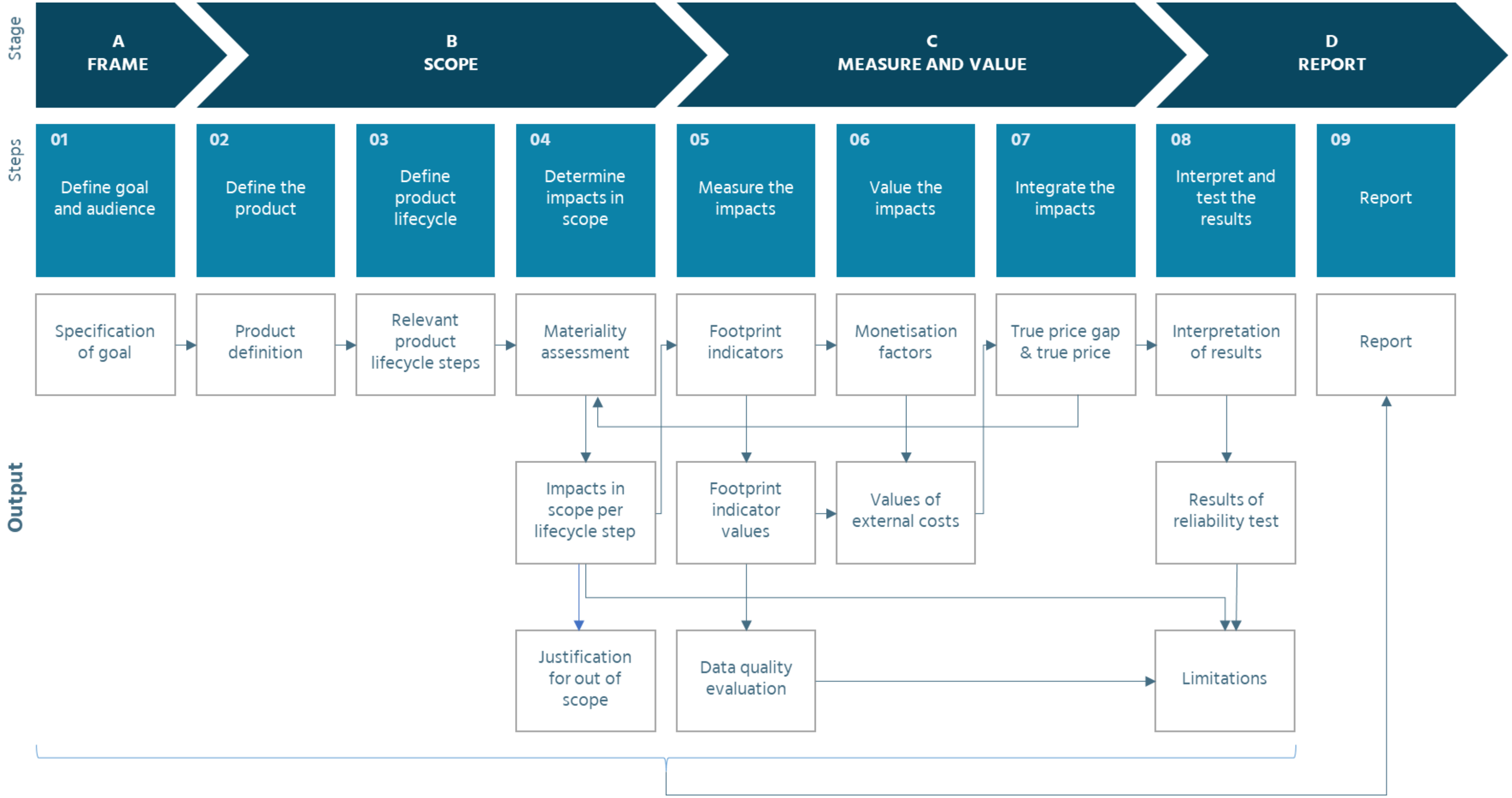


Figure 2: The output of the various steps of the assessment method, and relation between steps.

0.4.3. *Documents of the true price method*

This document, the **True Price Assessment Method for Agri-food Products**, explains the key steps of a true price assessment for agri-food products and their value chains. It provides modelling guidance as well as requirements for scoping, data, and reporting. The Assessment Method is accompanied by other documents that together present a methodology for true pricing of (agri-food) products (Figure 3).

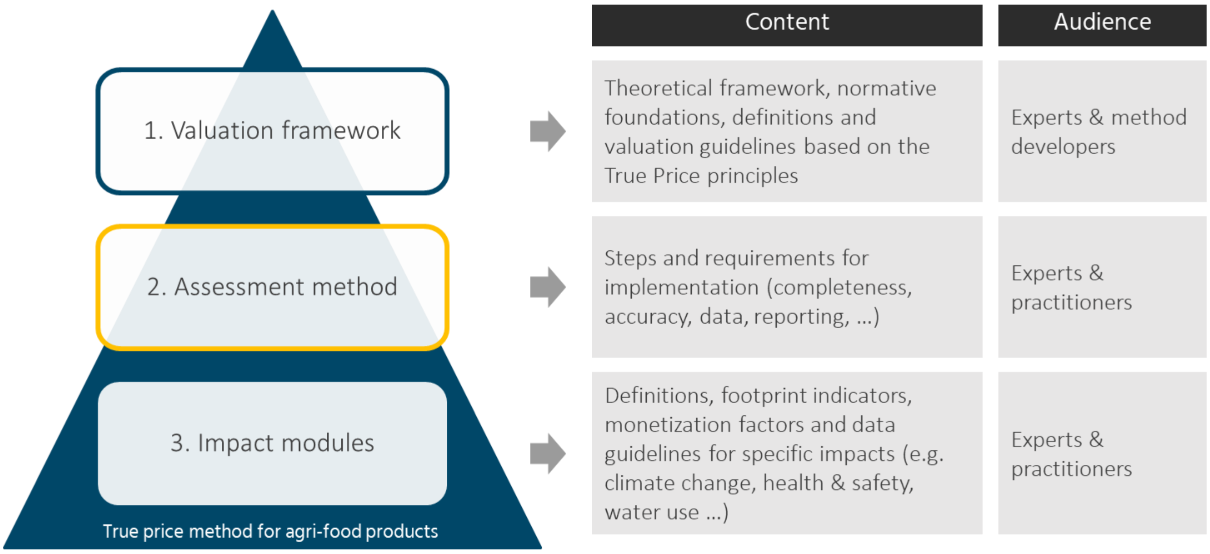


Figure 3: Components of the true price methodology for agri-food products. This document is the assessment method.

The **Valuation framework for true pricing of agri-food products**, contains the theoretical framework, normative foundations and valuation guidelines for true pricing.

The **Impact-specific modules for true price assessment** contain the specific methods, developed within this project, to measure and value six natural and five social and human capital impacts.[7] The natural impact modules (published at the time of writing) are:

- Contribution to climate change (Galgani, Woltjer, de Adelhart Toorop, de Groot Ruiz, et al., 2021a)
- Land use, land use change, biodiversity and ecosystem services (Galgani, Woltjer, de Adelhart Toorop, de Groot Ruiz, et al., 2021b)
- Soil degradation (Galgani, Woltjer, de Adelhart Toorop, Varoucha, et al., 2021c)
- Scarce water use (Galgani, Woltjer, Kanidou, de Adelhart Toorop, et al., 2021d)
- Air, soil and water pollution (Galgani, Woltjer, Kanidou, Varoucha, et al., 2021e)
- Fossil fuel and other non-renewable material depletion (Galgani, Woltjer, de Adelhart Toorop, & de Groot Ruiz, 2021a)

The social and human capital modules that have already been published and are expected to be published within the project:

- Occupational Health and Safety (Galgani et al., 2022)
- Living Income (van Veen & Galgani, 2022)
- Child Labour (Galgani et al., forthcoming)
- Consumer Health (Manouchehrabadi et al., forthcoming)
- Animal Welfare (Vissers & Woltjer, 2022)

[7] See 'Annex 1: List of impacts in true pricing' for a complete list of impacts that can be included in the true price.

The requirements and recommendations provided in this set of documents focus on the true price assessment of agri-food products in general and are not aimed at a product in particular. However, the applicability of these requirements and recommendations has been tested by a number of case studies of specific agri-food products. The results of the case studies are not always publicly available, but an overview of the cases can be found in Annex 3.

Finally, this document does not elaborate on monetisation factors. Monetisation factors are described conceptually in the Valuation Framework and provided for specific impacts in the impact-specific modules.

0.4.4. Key external references

Although there is not yet a generally accepted method to calculate true prices, several elements of guidance exist for parts of the choices to be made and several of the steps to follow. The key references that this document builds upon are presented and discussed below.[8]

- **Natural capital protocol** (Natural Capital Coalition, 2016) and **Social and Human capital protocol** (Social & Human Capital Coalition, 2019). These protocols present guidelines for organizations to integrate natural, social and human capital in their operations, with a specific focus on the private sector. The assessment steps used by this document are largely drawn from these protocols.
- **ISO standards 14040, 14041, 14042, 14043, 14044 on Life Cycle Assessment** (see list of references). This family of ISO standards defines the steps, requirements, and good practices in the field of LCA. The method in the present handbook is in line with the prescriptions of these standards, except where otherwise indicated.
- Product Environmental Footprint (PEF) Recommendations (Zampori & Pant, 2019). This is the LCA methodology framework of the European Commission, containing the rules on how to measure environmental performance of a product. Even though the PEF does not deal with the assessment of social impacts, the true price method described here draws inspiration in several points from the PEF, aiming for consistency with the standard wherever applicable. Annex 1 expands on the correspondence between PEF impact categories and true pricing impacts.
- UNEP Guidelines for Social Life Cycle Assessment of Products (United Nations Environment Programme (UNEP), 2009). These guidelines are the most authoritative reference on social LCA. The guidance provided in this document was useful in the development of the true price assessment method.
- **Principles for True Pricing** (True Price Foundation, 2020). This document presents the normative principles underlying the true price concept and method, including the definitions of true price and true price gap, principles on how to select social and environmental impacts to include in a true price and principles on how to attribute impacts of businesses to the level of individual products.
- **Framework for Impact Statements (FIS)** (de Adelhart Toorop et al., 2019)**.** The FIS provides a framework for organizations to measure and report their societal impact based on the Integrated Profit & Loss method. The five principles used in the measurement phase are taken from this framework.

A full list of sources, including the above stated key references, is provided at the end of this document.

0.5. Towards standardization of true pricing

This **True price assessment method for agri-food products** and its complementary documents are aimed to enable practitioners to get started with true pricing and calculate the external costs of agri-food products.

[8] These documents are not developed within the PPS *True and Fair Prices for Sustainable Products*.

Ultimately, a standard is required to determine in a univocal way how to determine *the true price* of a product, in a manner that allows full comparability of true prices of all products.

This goes beyond the purpose of this document. This document provides the required steps to be followed when performing a true price assessment. These steps provide the necessary framework to support a high-quality and transparent assessment. However, these steps on their own cannot fully prevent insufficiently sound claims on the true price of a product.

Within the scope of this document, guidelines in terms of completeness and data quality are laid out, to guarantee the quality of an assessment:

1. **The assessment should be sufficiently complete** (i.e., without excluding any material or only a few less-material impacts and/or lifecycle phases, see Step 4),
2. **The assessment should be based on data of sufficient quality** (i.e., high data quality for more material impacts and ideally most of the process data is product- or value chain specific, see Section 5.2.3).

The underlying general principle is that **the level of quality should be proportionate to the goals of the assessment**, whether it is used internally or to support public claims, and whether it supports a comparison between products. Section 1.2.1 and 1.2.3 elaborate further on this topic.

A study can however follow this method without meeting these two requirements. For example, an assessment of a single or only a couple of true price impacts, most likely ignores important external costs. Also, results can rely on low quality data for highly materiality impacts or value chain steps. In cases like these, accuracy will be low and it is questionable whether the results can be called *the true price*. In absence of a standard to determine this, such a study can however still be said to follow this method, to apply true pricing, to be a step towards true pricing, to calculate external costs with the true price method, or to result in a true price *proxy* or *truer price*.

0.6. Key definitions

True price	The true price of a product is the sum of the market price and the true price gap of that product. It reflects the price a buyer would have to pay for a product if the cost of remediating its unsustainable externalities would be added on top of its market price.
True price gap	The true price gap of a product is the sum of all remediation costs of all unsustainable externalities caused by the production and consumption of that product.
Unsustainable externality	The consequences of difference between the current production method and a situation where no generally accepted rights for current or future generations would be violated, for parties that did not choose to incur those consequences. An unsustainable externality is not necessarily an externality in the economic sense of the word and the word unsustainable has a very specific interpretation in being the violation of international rights.
Externality	A societal cost or benefit that affects a party who did not choose to incur this cost or benefit. An external cost is a negative externality and an external benefit is a positive externality.
Social impacts of products	Impacts on people and communities caused by production and consumption of a product. In the context of a true price gap assessment, social impacts are

	unsustainable externalities related to breaches of human rights and labour rights.
Environmental impacts of products	Impacts on the environment, and indirectly on people and communities, caused by production and consumption of a product. In the context of a true price gap assessment, environmental impacts are unsustainable externalities related to the breaches of environmental rights and human rights.
Product	Generally defined as any good or service (ISO, 2006b). In this document the focus is specifically on agri-food products.
Supply chain	Network of businesses linked in the production and distribution of a product
Product lifecycle	Consecutive and interlinked stages of the production and consumption of a given products, including supply chain (from raw material acquisition or generation from natural resources to the production of intermediate products and final products), consumption and disposal (including recycling) of any waste product generated during production and consumption (Adapted from ISO 14044:2006 (ISO, 2006b, p. 2)).
Process	A part in the product lifecycle that can be described separately from the others, so that the product lifecycle can be fully described as a set of mutually exclusive processes.
Process data	All data used to measure the selected impacts, including but not limited to use of fertiliser, pesticides, water or energy, productivity, financial data, social performance data or environmental performance data of a specific process in the product lifecycle.
Modelling parameters	Parameters that are required to translate process data into footprint indicators.
Footprint indicators	Variables that quantify the actual social and environmental impacts that are in scope to calculate the true price of a product. Footprint indicators must be calculated in such a manner that they can be monetised and they can be compared meaningfully across different life cycle steps.
Monetisation factor	Estimate of the remediation cost of the impacts measured by the footprint indicators. In some cases, different monetisation factors may be country/region-dependent and be different for the same impact for different parts of the product lifecycle (for example, if some damage cost coefficients are proportional to local income levels and the damage occurs in different countries).
System boundaries	Specification of which processes of the product lifecycle are taken into account (adapted from ISO 14044:2006 (ISO, 2006b, p. 5))
Functional unit	Quantified performance of a product for use as a reference unit (adapted from ISO 14044:2006 (ISO, 2006b, p. 4))
Materiality	The significance of the social or environmental impacts for the product under study
Materiality assessment	Evaluation of which impacts are relevant for which products, supply chains, or parts of a supply chain, based on available knowledge.

Stage A: Frame

The framing stage consists of one step:

- Step 1: Define goal and audience

This stage prescribes the requirements and recommendations for the choices in defining the frame of the assessment.

This stage, together with the Scope stage, corresponds to the “Goal and scope definition” and “Inventory” steps of LCA (ISO, 2006a).

For this stage, the output is:

- Specification of goal
  A clear specification of the goal of the true price assessment, including the intended use of the study, commissioner of the study, target audience, whether the study is stand-alone or comparative, and the applied review process for process, data and reports (if applicable).

Step 1: Define goal and audience

1.1. Introduction

As the first step, a clear definition of the goal and audience shall be made, as part of framing the assessment. This step determines the requirements for subsequent steps, as it has strong implications on the scope, the calculation methods used and the quality of the data used, but also determines requirements on reporting. For example, an assessment with an external use, will require higher transparency in the reporting phase (see Step 9: Report) and a comparison between two products will require data of higher quality than a stand-alone assessment (see below).

See *A roadmap for true pricing* for a more comprehensive discussion of how true prices can be used by different users (True Price, 2019).

A definition of the assessment goal includes the following aspects, based on the goal definition of the European PEF standard for environmental footprints (European Commission, 2013, p. 118):

- Intended use
- Target audience
- Stand-alone or comparative assessment
- Commissioner of the study
- Review process

Specifying these elements will be useful throughout the assessment to determine the required level of accuracy (Section 1.2.4)

1.2. Key elements

1.2.1. Intended use

The intended use of a true price assessment can take many different forms, but an important aspect is whether the assessment is aimed at internal or external use.

Internal use

Individual companies can use the true price internally to understand, monitor and manage negative impacts on the environment, or to improve purchase decisions. In that way, companies can improve their sustainability performance, for example by identifying the most important negative impacts of their products, comparing their products with a benchmark, comparing suppliers, determining what to invest in, or deciding how to innovate to improve sustainability performance.

External use

External applications are the communication to the public about the impact of their products (especially in the case where the true price gap is significantly lower than that of alternative products or a benchmark). In addition, branch organisations can use the true price to help their members with the above-mentioned goals, and governments can use the true price (often of a larger group of products) to develop regulation (stimulation, taxation and legislation).

1.2.2. Target audience

The target audience is partly determined by its intended use, but the target audience should be further specified. Examples of target audiences are different decision makers within a business, internal or external stakeholders of the organisation, investors, governmental organizations, consumers, or the general public.

1.2.3. Stand-alone or comparative assessment

A true pricing study can be a stand-alone or comparative assessment. The method presented in this document provides guidance for both stand-alone and comparative assessments. It shall be specified whether the goal is to make a comparison between products.

Stand-alone assessment

A stand-alone assessment focuses on a single product. A specific type of stand-alone study is the calculation of the true price of a product for retail, a sector benchmark, representing for example an average product in a product class on the market, or a best-practice scenario.

Results of a stand-alone assessment do not necessarily allow to draw conclusions based on comparison with results of other studies. This should be clearly stated in the intended use section of the report.

Comparative assessments

Often, a true price assessment is designed to compare the true price of two or more products. Those can be, for example, a comparison between a specific product and a benchmark, two or more products of different production technologies, or products with different supply chains. Needless to say, in a comparative assessment, the underlying methodological aspects of each true price calculation must be comparable.

A comparative assessment with the goal to make public claims on the sustainability of a product, product type or specific brand compared to others, requires higher accuracy and transparency (see section 1.2.4).

It is possible to distinguish within- and between-study comparisons.

- **Within-study comparisons.** For a within-study comparison, the true price calculations of the to-be-compared products are performed in one study.
  For a within-study comparison, the underlying scope, data quality and other methodological aspects are directly controlled by the assessor. Any deviation in methodological aspects and level of accuracy between scenarios should be motivated, compatible with the goal of the assessment and transparently documented.

- **Between-study comparisons.** A between-study comparison uses results from separate studies to compare the true price of products to each other. This can be a comparison between multiple existing studies, or the results of an existing study can be combined with an assessment that is still to be performed.
  The aim of true pricing is to have easily comparable true prices for all products. This requires a high level of accuracy and full standardization of how true prices are calculated, which goes beyond the scope of this document (see also Section 0.5*: Towards standardization of true pricing*).
  Until a standard is available that each true price assessment follows, caution should be taken when comparing the results of two or more assessments (a between-study comparison), because the methodological aspects of the various studies do not necessarily match. At least, the aspects determining the accuracy of the different assessments that are relevant for the comparison should be comparable: think of, for example, a selection of impacts and lifecycle steps, data quality, method choices, monetisation factors, and more.
  Mostly, between-study comparisons allow for generic conclusions with a limited scope, such as 'Impact X is the largest contributor to the true price gap in the countries included in both studies', but do not allow for direct comparison of quantitative results, such as 'Impact X is 30% larger for product A (in the new assessment) than for product B (in the pre-existing assessment)'.

1.2.4. Required level of accuracy

Some assessments require a higher level of accuracy than others, because of their intended use. A very accurate true price assessment can be significantly data and resource intensive. However, in some cases it might be sufficient to provide a simplified assessment with a lower level of accuracy.

An assessment to monitor sustainability performance for a producer or group of producers or to assess alternative options to improve the production cycle with a holistic approach requires a (relatively) high level of accuracy.

On the other hand, a true price assessment with the goal to gain a global overview of the impacts of a product or product group, or to identify so called 'hotspots', requires a lower level of accuracy. This type of assessments is often sufficient to steer some types of decisions with more limited resources, for example when a large number of products are assessed in a short time. For this type of assessment, general LCA guidance, such as the ISO 14040 standards can be used as inspiration to determine the required level of accuracy (ISO, 2006a).

Assessments with the goal to make a public claim on the sustainability of a specific brand, product type or production system compared to another one, require a high level of both accuracy and transparency.

Aspects determining the level of accuracy

For reasons of comparability and transparency, the information required to determine the accuracy of a true price assessment shall be communicated, especially when the results are shared externally. The accuracy of a true price assessment is determined by:

- The completeness of the scope, consisting of
  - Product specification (See Step 2: Define the product)
  - Lifecycle steps in scope (See Step 3: Define product lifecycle)
  - Impacts and indicators in scope (See Step 4: Determine impacts in scope)
- The underlying assumptions and calculations to measure and value impacts, such as[9]
  - Impact methods (See Step 5: Measure the impacts)
  - Modelling parameters (See Step 5: Measure the impacts)
  - Allocation approach (See Step 5: Measure the impacts)
  - Monetisation factors (See Step 6: Value the impacts)
- The quality of the data included (See Section 5.2.3: Evaluate the data quality)
- The review process on process, data and reports of the assessment

The outputs of each step of the assessment ensure that the information regarding these three aspects is collected during the study.

The development of a classification of assessments according to their level of accuracy is a topic for future development of this method.

Accuracy of public claims based on comparisons

Using the results of a true price assessment in communication to consumers to claim a better sustainability performance of one product, product type, production process or brand compared to another one is a public claim based on a comparative study. This requires a high level of accuracy and transparency.

[9] This aspect of accuracy is largely determined by the quality of the method to measure and value specific impacts. In most cases, the influence of the practitioner is therefore limited, unless the practitioner has choices to make within the method and/or the method for an additional impact is developed by the practitioner.

High level of accuracy is determined by the aspects explained in the previous section. A third-party expert review of the study is highly recommended. Furthermore, as for all comparisons, methodological choices shall be consistent, the impacts and parts of the value chain that are material for the comparison shall not be excluded from the assessment, and data quality shall be sufficient for supporting the conclusions. Claims based on results from different studies (between-studies comparisons) are only possible if these have strictly followed the same method.

Requirements on transparency for public claims based on comparative studies are specified in Step 9: which deals with how to report the results of a true price assessment.

ISO standard 14044:2006 specifies additional requirements for comparative LCA studies that are intended for public claims (ISO, 2006b, para. 5.3). These include, among others, requirements on a critical review process, as specified in ISO/TS 14071:2014(E) (ISO, 2014). The reader is hereby made aware of potential legal consequences of unsound public claims when not following these standards. Even though the current document sets lower requirements, compliance with these standards is recommended.

Best practice

The Product Environmental Footprint (PEF) recommendations as developed by the European Union can be a useful source of inspiration to determine the requirements for a high-accuracy true price assessment (Zampori & Pant, 2019). Suggestions for best practices to improve the accuracy of a true price assessment, often inspired by PEF, are provided in textboxes, such as this one, throughout the document.

1.3. Output

For this step, the output is:

- **A clear specification** of the goal and intended use of the true price assessment, including:
    - The **intended use** of the study
    - The **target audience**
    - The **commissioner** of the study
    - Whether the study is **stand-alone or comparative**
    - Whether a **review process** is applied.

Table 1 provides an example of the definition of the goal of a true price assessment for the hypothetical tropical fruit case.

Table 1: Illustration of the goal definition for the hypothetical tropical fruit.

Aspect of the goal definition	Example
The intended use	To identify the largest impacts of the production of the tropical fruit. The result will not be communicated externally.
The commissioner of the study	The export organization of tropical fruits
Target audience	The export organization, producer organizations and producers.
Stand-alone or comparative	Stand-alone, the result is not intended to be compared with other products
Review process	Since the result will only be used internally, there is only an internal review process

Stage B: Scope

The scoping stage consists of three steps:

- Step 2: Define the product
- Step 3: Define the product lifecycle
- Step 4: Determine material impacts

This stage prescribes the requirements and recommendations for the choices in defining the scope of the assessment.

This stage, together with the Frame stage, corresponds to the “Goal and scope definition” and “Inventory” steps of LCA (ISO, 2006a).

For this stage, the outputs per step are:

- Step 2: Define the product
    - Product specification
- Step 3: Define the product lifecycle
    - Specification of lifecycle processes
- Step 4: Determine material impacts
    - A first version of a materiality table
    - Impacts in scope
    - Justification of excluded lifecycle steps and impacts

Step 2: Define the product

2.1. Introduction

When assessing the true price of a product, it shall be defined which product is studied and what the related supply chain is. The product definition shall be in line with the defined goal of the study, and shall include the following aspects:

- Product specification
- Functional unit
- Reference year(s) for data
- Currency of results

Choices for the product definition are driven by the goal of the study, but also data availability should be considered and acknowledged. The first step is to specify the product, and the aspects that are related to it. The requirements, recommendations and options are described below.

2.2. Key elements

2.2.1. Product specification

Once a product is chosen, there are several ways of defining it as the object of a true price assessment. The product specification shall define further what type of product is assessed. This shall be repeated for all studied products in case of a comparative study.

The product type, the place in the product lifecycle, the production scale, and the geography shall be part of the product specification.

Product type

The product type should be clearly defined because this helps in clarifying the supply chain and influences all following steps as well. It shall be specified whether the study is about the average, the most common, or a specific product type.

- The **average** (e.g., the average of all potatoes grown in the Netherlands) refers to the average across a mix of products on the market with many different properties: varieties, regions, certification status (biological and conventional), farm size, quality grade, etc.
- The **most common** type (e.g., the most popular variety of potatoes grown in the Netherlands, or potatoes sold by a specific retailer) is typically an average of several producers that all share well-defined characteristics.
- A **specific** product type is one with a specific supply chain, from a specific producer or group of producers, from a specific region, with specific farming practices, a specific certification status or farm size, specific varieties, etc.

The choice for the product type should be consistent with the goal definition and documented. When it is intended to use the study to make a claim on the sustainability performance of a product, a product-specific analysis should be used. When the aim is to provide an overview of the impacts of a product group, a well-defined average should be used.

Place in the product lifecycle

It shall be defined at which place in the lifecycle the product is studied. This can be at the primary production stage (farm gate), an intermediate product in between processing stages, a product at factory gate after processing or a product at retail stage (i.e., a consumer product in the shop, or a dish in a restaurant). Normally, the true price is calculated for products that are being bought and sold, but if relevant for the goal of the assessment, the focus can also be a product in use. . The goal of the study influences the place in the lifecycle at which the product is assessed.

The true price can be assessed for a product at any place in the product lifecycle, but the results of the assessment should be clearly communicated as such.

For example, when the goal is to study unpackaged apples as purchased from the farmer by a distributor, the product should be studied at the primary production stage and the true price shall be communicated as the true price of an apple at the farm gate. Similarly, the true price of cocoa (as an ingredient for chocolate) can be assessed and shall be communicated as the true price of cocoa, not as the true price of chocolate.

A consumer product, such as a plastic packaged apple bought from a supermarket, is at a different place in the lifecycle and hence also requires the consideration of more processes within the system boundaries (such as packaging production and disposal). The lifecycle of a processed product at retail, for example apple mousse, also includes processing, packaging, retail and packaging disposal.

The choice of the place in the product's lifecycle determines the way the lifecycle is defined in Step 3: Define product lifecycle.

Relevant geographical areas for lifecycle processes

It shall be defined which geographical area is most representative for the studied product lifecycle, including the location of production and consumption. The choice should also be consistent with the goal and product type definition. In case of a specific product definition, processes in the corresponding area shall be assessed. For the analysis of an average product type, the average of the most common areas should be studied. This should be defined in such a way that it covers a significant share of the market.

Agricultural products that are part of a rotation scheme

If a product is part of a crop rotation scheme, this shall be considered in the product specification. This dimension of the product definition can influence other steps of the true price assessment later on. Interactions across crops and over years within crop rotations can be important. In crop rotation systems atmospheric nitrogen is fixed in certain crops of the rotation cycle, such as legumes, and is returned to the soil. This leads to a reduction in nitrogen fertilisation needs, not only for their own production but also for the following grain crop. These interactions should as much as possible be captured in the output of the assessment. Benefits, as well as burdens, such as nitrogen surplus leaching, shall be attributed to all products in the rotation scheme. When treating crop rotation products as discrete annual cultivations, i.e. monoculture systems, these interactions are neglected, resulting in a false estimation of the true price of the product under study. Additional information on how to approach products that are specified to be part of a rotation practice can be found in Section 2.2.2 and the related concept of allocation is addressed in section 5.

2.2.2. Functional unit

The functional unit expresses the chosen product as a measurable amount, such that alternative chains and the various steps in the value chain can be compared. The functional unit (FU) is a concept related to lifecycle assessments. It expresses the function of the product quantitatively. For example, one t-shirt made from cotton may be used as a functional unit[10], or one kilogram of apples sold in a retail store.

[10] The functional unit of one t-shirt would require a further specification of the amount of material used. For example, specified in volume or mass.

The FU is used to scale the results of an assessment and to compare products or scenarios on an equal basis. In the scope phase the functional unit of the product being studied shall be specified. Following the ISO 14044 requirements and guidelines for LCA, comparison between products shall be made on basis of the same function, quantified by the same functional unit (ISO, 2006b).

In case of a comparison between food products, the function of food is often expressed as one unit of product as purchased and sold, e.g., one kilogram, one litre, or one pack. In some cases, it may be specified in calories or protein to make different types of food comparable.

The FU should be representative for the intended public of the study and shall be consistent with the defined place in the lifecycle that the product is studied. For example, when a consumer is the intended audience of the study, and the product is defined at the place in the supermarket, a study on potatoes could have 1 kilogram of packaged potatoes at retail as a FU. But when the intended audience is producers and the product is defined to be studied at the farm, 1 ton of (unpacked) potato at farm gate could be used. In some cases, (interim) results on per hectare or per FTE basis, can also be useful. The European Commission's PEF method may provide additional guidance on how to select a relevant functional unit (Zampori & Pant, 2019).

For products that are part of a rotation scheme, the entire rotation sequence should be captured in the assessment, even though this can be challenging. A FU that is applied in this type of study in LCA is area over time, a basket of products or total dry matter production. When individual crops within the rotation are targeted for true pricing, allocation is required (see Section in 3.2.1 on crop rotation and section 5.2.2 on Allocation. True pricing, however, focuses on single products. It is therefore better to use a product-level FU, such as kg of specific product. Other FUs can be used in particular cases, but their use requires special attention.

2.2.3. Reference year(s) for data

The reference year for data is the year to which the data should (ideally) refer to in the study. In many studies the best reference year is the last completed year. In case available data does not cover the reference year, it should be updated to be representative for that year. This aspect is further discussed in a later section about data collection. In case of inter-year comparison, multiple reference years should be defined.

2.2.4. Currency of the results

The currency of results is defined as a combination of currency name and currency year (e.g., Euro 2019, or US dollar 2018). The currency year is required since the same amount of money has a different value in different years, due to inflation. It is recommended to have the same currency year as the reference year for data, as this simplifies the interpretation of the results.

2.3. Output

For this step, the output is:

- **Product specification**
  A specification of the product(s) that are being assessed in the study. The description includes the product type, place in the product lifecycle, geography, functional unit, reference years and the currency of the results.

Step 3: Define product lifecycle

3.1. Introduction

A product's lifecycle includes all consecutive and interlinked stages of its production and consumption, including supply chain (from raw material acquisition or generation from natural resources to the production of intermediate products and final products), consumption and disposal (including recycling) of any waste product generated during its production and consumption (Adapted from ISO 14044:2006 (ISO, 2006b, p. 2)).

In this step, the steps in the lifecycle of the product under study, and the relevant lifecycle steps, the phases of the lifecycle that should be considered in the study (system boundaries) are defined.

The lifecycle shall be defined by listing specific lifecycle processes, including their inputs and outputs. A process can be a supply chain step, a waste management step or an activity related to consuming the product. Defining the boundaries consists of two steps:

- Mapping the product lifecycle, and
- Selection of relevant lifecycle steps

This step is input to the materiality assessment (see section 4.2.2), in which for each lifecycle step it is determined which environmental and social impacts can be considered material.

3.2. Key elements

3.2.1. Mapping the product lifecycle

The first step is to map the lifecycle of the product in a diagram, including inputs and outputs of each process. An example of a diagram for a basic production and consumption chain is shown in Figure 4. Such a diagram needs to be made, adjusted to the lifecycle of the product in scope.

Main elements of a product lifecycle

Generally, the total supply chain of a product should be considered in a true price assessment. A complete supply chain of a product should cover (at least) the following processes:

- Material extraction for and production of all the input, such as, but not limited to fertiliser, pesticides, energy supply and fuel.
- Agricultural production
- Packaging process
- Transport
- Consumer phase
- Treatment of all waste generated in the lifecycle

In certain cases, specific parts of the product lifecycle can be left out of scope, but this is an activity done in the following steps. Here, the goal is to gain a complete overview of the lifecycle of the product. Some elements, specifically relevant for an agrifood product lifecycle, are discussed in more detail below.

Production of capital goods

The production of capital goods, such as buildings and machinery, utilised throughout the lifecycle, contributes to the impact of the product under study. This contribution can be material, especially for products relying on material intensive infrastructure. This can be the case for greenhouse cultivation, vertical farming and all agri-food products where the impact of building material extraction, construction and waste should be included.

Consumer phase

True pricing focuses on products in the context of purchase. Therefore, the consumption or use phase of the product under scope is often less relevant. However, in certain cases it can be material to the goal of the assessment if the associated impact is important. Consumption is relevant for example when looking at the impact of consumer health, for fibres used as insulation material, for plants used for green walls, for packaging waste, for food waste during this phase, and more. The end-of-life phase of a product is not so relevant for food products, as the end of life coincides with consumption phase. The same holds for biofuels. However, there can be an end-of-life phase for other agricultural products, such as for example bio-based construction materials. This does not mean that waste should not be taken into account.

Waste treatment

Food waste occurs throughout a product's value chain, often has a substantial impact and should therefore be part of the analysis. Food waste occurring at different lifecycle phases should be part of the conversion to the functional unit of the analysis. For example, 1 kg of potatoes at retail might require the production of 1.2 kg of potatoes because of losses during harvest, storage, transport, processing, and packaging. This waste ratio should be reflected by the conversion factors that are used to scale the results of different lifecycle phases to the functional unit.

Next to food waste, the additional impact of waste management should also be accounted for in all steps of the product lifecycle. When the analysis is focused on the whole life cycle, the treatment of packaging waste connected to the production and consumption phases should be included, if packaging is part of the product specification.

Production of additional products or co-products

Furthermore, activities throughout the lifecycle of the product might also contribute to the production of additional products, or co-products (for example, activities producing milk also produces meat). The impacts related to the shared activities should be *allocated* to both the assessed product and the co-products. For such an *allocation*, information on, for example, the price or volume of the co-products in relation to the assessed product is required. The same holds for inter-cropping and multi-functional systems such as combined crop-livestock systems, row cropping, agroforestry and more. In assessing such system, the complexity increases. Waste streams that have an economic value, because of allocation, do not bring a burden in terms of waste treatment, and they can also be allocated some of the impact. These are often referred to as by-products, and can be treated as co-products (see Section 5.2.2 for more details on allocation).

Crop rotation

Finally, when crop rotation is applied in the production of agricultural products with the purpose of improving the management of the cultivation area and reducing the impact of production on the soil quality and fertiliser use, it should be included in the assessment. Accounting for the impact of crop rotation is not an easy task. A consensus on how this can be included has not yet been reached in the LCA community, while the focus of true pricing on individual products restricts the application of suggestions, such as the use of FU and economic allocation, as described in section 2.2.2 and 5.2.2. However, whenever crop rotations are expected to influence the sustainability of individual products in the rotation, it is strongly recommended to develop an approach to include it in the analysis. Assessing the rotation cycle as a whole, with all products that are part of it, in combination with economic allocation to the crop under study is recommended by this assessment method.

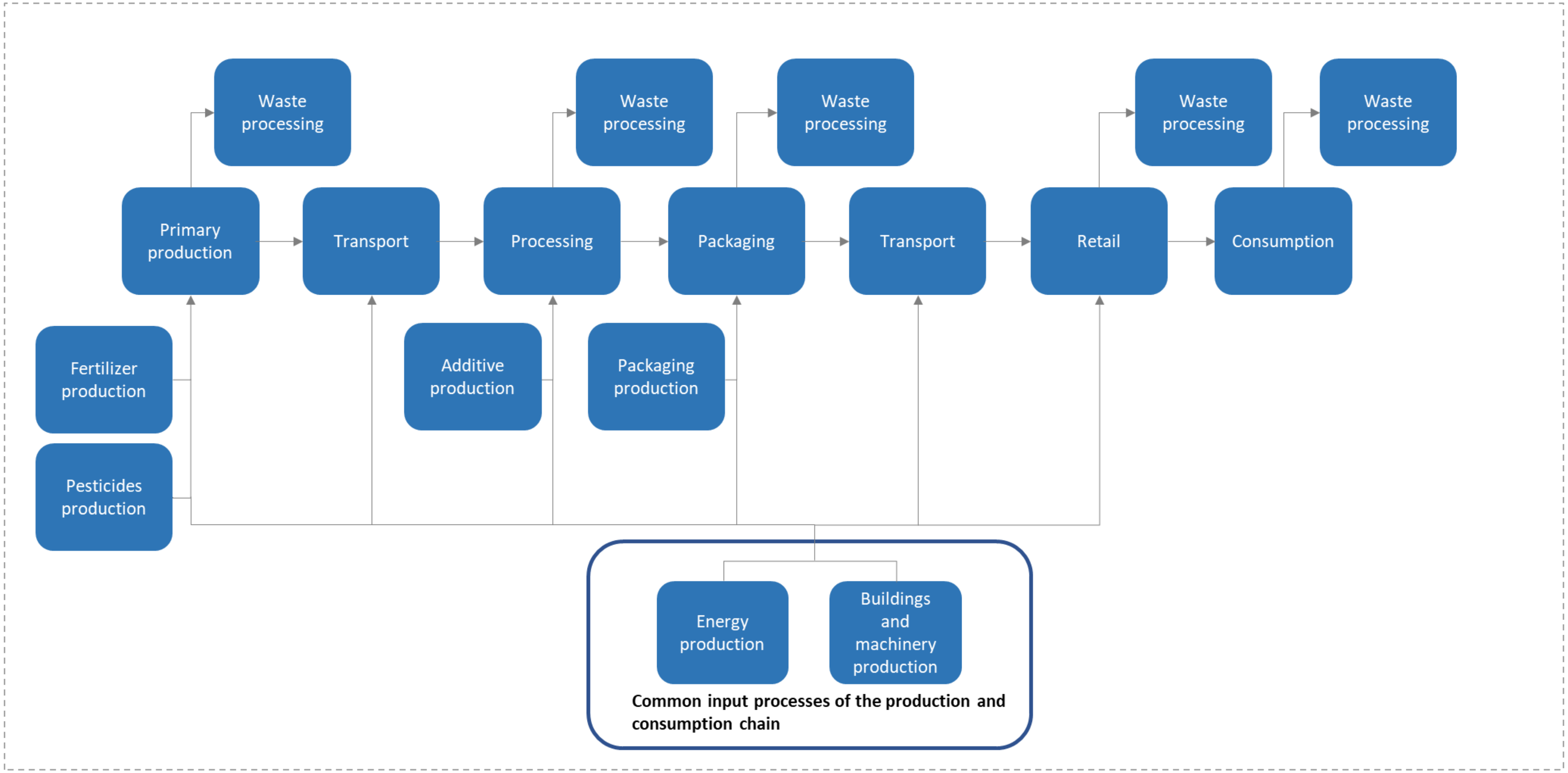


Figure 4: Example of a diagram of the production and consumption chain. This chain should be specified according to the product under study. Each box represents a process and each arrow the output of a process which is input to another process.

3.2.2. Selection of relevant lifecycle steps

This step consists of selecting which aspects in the lifecycle of a product are relevant to the assessment. This step does *not* result in the final choice of lifecycle steps in scope for the assessment, but rather in a preliminary list of lifecycle steps for which materiality and impacts in scope of the assessment can later be determined.

In general, each aspect of the product's lifecycle should be included: all components and ingredients, all inputs and outputs and all lifecycle steps or processes. This said, there are aspects of the lifecycle that can lead to a preliminary selection:

- **Components and ingredients.** All components of a product shall be considered in the calculation of a true price assessment. However, for complex products, or products with many different components or ingredients, one may consider decreasing the level of detail, when this is consistent with the goal of the assessment and when it can be argued that it does not significantly influence the results.
  Reducing the level of detail may be done by e.g., leaving out small components or simplifying the assessment by combining different components of a similar material. For example, to decrease the level of detail, a true price study for mayonnaise can include oil and eggs but exclude the preservative ingredients that make up only a small amount of the total product. The exclusion of components and ingredients shall follow the goal definition and the materiality of the components and ingredients should be considered.
- **Inputs and outputs.** Supply chain processes can have a multitude of inputs and outputs. Examples of process inputs are electricity, water, and fertilizers, but also land. Products, co-products, by-products, emissions to air, water and soil and waste streams are examples of process outputs. In some cases, certain inputs or outputs may be excluded from the study. This consideration shall be based on the goal of the assessment, as well as on materiality of the inputs and outputs.
- **Lifecycle steps or processes.** In accordance with the ISO 14040 standards for LCA (ISO, 2006a), a total lifecycle includes consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources (e.g., fertilizer production, growing of tomatoes), to processing stages (e.g., production of chocolate), consumption to final disposal (e.g., disposal of packaging). In some cases, it may be chosen to leave out lifecycle steps in the true price assessment. This shall be consistent with the goal definition.
  For example, the goal of a true price assessment may be to select among various suppliers of one product. In that case it is not necessary to consider the consumption and end-of-life phases (unless these phases are influenced by the choice of supplier). However, when the goal is to gain a global overview of the impacts of a product in a true price assessment, all aspects of the chain shall be included. The choice to leave out processes or phases shall be based on the goal of the assessment as well as on the materiality.

At this stage it is possible to simplify the lifecycle by grouping different steps. It is also possible to exclude aspects that are considered irrelevant for the final result. This can be either because the goal of the study is to compare alternative scenarios in which these parts of the lifecycle are identical, or because their impact is expected to be orders of magnitude smaller than the rest of the lifecycle.

Under no circumstances, can any aspect of the lifecycle be excluded if 1) the excluded aspect is one of the most important parts of the supply chain, 2) sources are known that indicate the significance of the excluded aspect to the total impact of the product, and 3) exclusion of the aspect affects the results in light of the goal of the assessment.

Feasibility issues related to data or resources availability *shall not* constitute a reason to leave sections of the supply chain out of the assessment at this stage. If parts of the value chain are considered material but have limited data availability, their inclusion or exclusion can be assessed in the Step 4: Determine impacts in scope.

In any case, the choice to leave out or simplify parts of the lifecycle shall always be described clearly, and the motivation and assumptions upon which the choices are based shall be documented.

Best practice

The contribution of the excluded aspect to the total mass, value, and/or labour in the whole supply chain can be used for a decision based on quantitative information. For the social impacts, every supply chain step should be considered separately. For the environmental impacts, the decision may be based on existing LCAs.

For example, the Product Environmental Footprint recommendations define a cut-off to exclude minor lifecycle processes, even if they fall within the product specification (defined in section 2.2.1). This cut-off allows for processes to be 'excluded up to 3.0%, based on material and energy flows and the level of environmental significance (single overall score). The processes subject to cut-off shall be made explicit and justified in the PEF report, in particular with reference to the environmental significance of the cut-off applied' (Zampori & Pant, 2019).

3.3. Output

For this step, the output is:

- **Specification of lifecycle processes**
  A specification of which lifecycle processes are relevant to the assessment. This includes the name of a lifecycle step or process, its specification, the measurement units of its output and the quantity of output required per functional unit of finished product.

- **Lifecycle diagram**

- **Selection of relevant lifecycle processes.** Motivation to exclude a specific process at this stage already, or to aggregate several lifecycle steps into one.

Table 2 provides an example on how to report the specification of lifecycle processes.

Table 2: Illustration of how lifecycle processes in scope can be reported.

Process	Specification (e.g., inputs and geographical location)	Output unit	Reason for exclusion (if applicable)
...	...	...	...
...	...	...	...

Step 4: Determine impacts in scope

4.1. Introduction

Environmental impacts are generally related to resource use, land use, and emissions. Social impacts reflect negative effects of economic processes on workers, local communities, the global community, and consumers. In this step it shall be determined which societal impacts are included in the true price assessment, and for which steps in the value chain, specifically, these impacts are material. More detailed guidance for specific impact is provided in **impact-specific method modules** (see Section 0.4.3).

Definition of a material impact

The Global Reporting Initiative defines material topics as 'those topics that represent the organisation's most significant impacts on the economy, environment, and people, including impacts on their human rights' (GRI, 2021). Following GRI's definition and the Principles for True Pricing, an impact is material when it constitutes a 'negative effect in violation of internationally accepted obligations of businesses in relation to human rights, labour rights, or environmental rights (and other relevant rights)' (True Price Foundation, 2020). Additionally, since a true price assessment is also a form of ranking of impacts, an impact can be considered material when it is expected to have a significant contribution to the true price gap. This, however, can only be determined based on the results of previous true price studies (or other true cost assessments), and only for the impacts that these studies cover. Examples of how to determine material impacts are provided in Section 4.2.2.

4.2. Key elements

4.2.1. Impacts to consider

A standard list of social and environmental impacts to consider, together with a more detailed discussion on the normative choices to consider certain impacts, is provided in *Annex 1: List of impacts in true pricing*. This list shall serve as a starting point for the total number of impacts to consider. The final choice of impacts considered should cover all relevant issues related to the product lifecycle, following the normative foundation in the *Valuation Framework* and based on the results of the materiality assessment. Depending on the goal definition, practitioners may narrow down or expand the list of impacts to consider, but they should keep in mind this influences whether the result of a true price assessment can be called a true price (see section 0.5).

4.2.2. Materiality assessment

The true price is determined by the contribution of each lifecycle step, required to produce and consume the functional unit of the product, to each of the impacts in scope. A materiality assessment shall be performed to help determining the impacts in scope for the current true price study.

A *materiality assessment* is an evaluation of which impacts are relevant per phase of a product's lifecycle. Any activity in any lifecycle phase that *causes*, *contributes to*, or *is directly linked* to one of the true price impacts is a reason to consider an impact material for the specific lifecycle phase (GRI, 2021).

For each lifecycle step, each impact shall be assigned one of the following four levels of materiality:

- **Material (+)**
  An impact is identified as material when any source of information indicates the impact constitutes a negative effect (as defined in the section *Definition of a material impact*). Once an impact has been identified as material, a further distinction shall be made between material impacts (+) and material impacts that are likely to be top contributors to the true price gap (++). This distinction is based on the expected severity of an impact, following guidelines in (GRI, 2021). The severity of

an impact is assessed through its scale (i.e., how grave the impact is), its scope (i.e., how widespread the impact is. For example, the number of individuals affected, or the extent of the environmental damage), and its irremediable character (i.e., how hard it is to counteract or make good the resulting harm). The severity of an impact is assessed relative to the severity of the other material impacts and can therefore be used to rank material impacts according to their significance.

- **Material and likely to be top contributor (++)**
  Material impacts can be further identified as likely to be top contributors to the true price gap. The identification as a top contributor is based on the relative severity of the impact with respect to the other impacts under consideration. Qualitative information, previous true price assessments for the same or similar products, other weighted or normalised results from LCA can provide an indication of relative materiality of impacts (EC Joint Research Centre, 2017).
- **Non-material (-)**
  The identification of an impact as non-material is preferably based on quantitative information but may be based on qualitative information or expert opinion. In any case, no negative effect (as defined in the section *Definition of a material impact*) is expected and no source is found that indicates the specific impact to be material for any of the lifecycle phases.

Best practice

An impact may be identified as non-material if no known assessments of social or environmental impacts, sector- or product-specific guidance, qualitative or quantitative indicates that the specific impact is significant for one of the lifecycle phases of the product. For environmental impacts the Environmental Product Declaration method and Product Environmental Footprint recommendations and studies should be consulted.

Furthermore, a plausible motivation should be given that shows that the combination of all excluded lifecycle phases for one impact is not expected to contribute significantly to the total impact. For example, the Product Environmental Footprint recommendations defines a good quality level for completeness at 80-90% coverage for each impact (Zampori & Pant, 2019).

- **Unknown materiality (+/-)**
  When no source of information identifies an impact as material (+ or ++) or not material (-), the materiality of the impact is temporarily identified as unknown. Further research is required to identify the impact as material or not material. This can happen during or after the assessment.

Materiality is related directly to the monetised value of the various impacts in the true price gap of the studied product. It depends on a combination of quantity (i.e., the size of the impact measured by the footprint indicator) and value (i.e., its monetisation factor). Furthermore, when performing a comparative assessment, materiality is also given by the extent to which the impacts are expected to change between the compared products.

The materiality of impacts should be identified based on different sources of information (GRI, 2021):

- **(Secondary) data sources**
  If (secondary) data are already known/available to the practitioner, these shall be used to identify material impacts. True price studies, other true cost accounting studies, weighted and normalised results from LCA can provide an indication of relative materiality of impacts (EC Joint Research Centre, 2017). Qualitative data also informs materiality. Secondary data that are used in further steps of the true price assessment shall be used to update the materiality assessment if these data provide additional information.
- **Stakeholder engagement**

Stakeholders can be engaged to identify the impacts that are material to them. Engagement is preferably done directly, or otherwise through credible stakeholder representatives or proxy organisations (such as NGO's or trade unions).

- **Expert consultation**
  Experts on the product and relevant topics should be consulted to identify material impacts when insufficient information is available.

Ultimately, a materiality assessment will, to some extent, require informed and documented value judgement from the practitioner, considering the sources of information listed above.

Ideally, at least all material impacts (+ and ++) should be included in the true price assessment for their relevant lifecycle phases. Their relative significance can be used to prioritize impacts in the following steps. If at a later stage, impacts that are considered material are taken out of scope for feasibility reasons, this should be reflected upon in the interpretation and limitations of the study, and wherever possible a qualitative assessment should be done.

The results of the materiality assessment can be provided in a structured overview following the template in Table 3. The assessment of an impact's materiality can change when the results of the assessment are known, or more information becomes available. Therefore, the materiality assessment shall be updated when new information requires to do so.

4.2.3. Leaving impacts and parts of the lifecycle out of scope

To simplify an assessment, it is possible to leave impacts out of scope, fully or for certain parts of the lifecycle. The choice to leave impacts out of scope (for specific parts of the lifecycle) should ideally only apply to less or non-material elements, and it shall always be described clearly, documenting the sources and assumptions upon which the choices are based.

Feasibility issues related to data availability do not constitute a reason to leave impacts or parts of the lifecycle out of scope. As much as possible, if impacts for specific phases of the product's lifecycle are identified as material but have limited data availability, they shall be assessed using the best available proxies. This is especially important for impacts that are likely to be severe contributors to the results.

If impacts are excluded without a justification based on a materiality assessment, this should be clearly specified as a limitation of the study.

For a comparative assessment, a study supporting a public claim, and in other cases where the goal of the assessment requires it, a high level of accuracy is required. Completeness of the impacts and lifecycle steps in scope is an important determinant of assessment accuracy (See Section 1.2.3: *Stand-alone or comparative assessment*). If material impacts and parts of the lifecycle are out of scope, this will limit comparability between the results of the assessments with results of other studies. To ensure the assessment will be able to meet its goal, an iterative process to improve the scope of the assessment might be required throughout the assessment. Section 8.2.4 Identify areas for future improvements *provides guidance* on identifying areas for improvement.

4.3. Output

For this step, the outputs are:

- **Materiality table**
  A first version of a materiality table (following the template in Table 3) that indicates a first indication of the level of materiality for each impact for each lifecycle phase.

- **Impacts in scope**
  A list of impacts in scope (for each lifecycle step, if applicable), based on the materiality assessment. Potentially ranked according to the impacts' materiality.

- **Justification of excluded lifecycle steps and impacts**
  Justification (including relevant sources and assumptions) for each impact or lifecycle step that is left out of scope.

Table 3: Example materiality table. All impacts should be included. Lifecycle phases to include in the materiality assessment are determined those in previous steps.

	Lifecycle step						**Comments**
Environmental capital impacts	Sourcing of raw materials	Farming	…	Transport	…	Consumption	
Contribution to climate change	(++, +, - or +/-)	(++, +, - or +/-)	…				
Air pollution	(++, +, - or +/-)	…					
Water pollution	…						
…							
Social and human capital impacts							
Child labour	(++, +, - or +/-)	(++, +, - or +/-)	…				
Forced labour	(++, +, - or +/-)	…					
Gender discrimination	…						
…							

++ Material impact, likely to be top contributor

\+ Material impact

\- Non-material impact

+/- Impact of unknown materiality

Stage C: Measure and value

This stage consists of three steps:

- Step 5: Measure the impacts
- Step 6: Value the impacts
- Step 7: Integrate the impacts

In this stage of the true price assessment the impacts in scope are measured and valued.

In LCA terms, stage C corresponds to the “Inventory analysis” and “Impact assessment” phases (ISO, 2006a, 2006b). Step 5: *Measure the impacts* roughly corresponds to data collection, building of a lifecycle inventory and carrying out characterization. *Step 6: Value the impacts* can be considered a form of weighting, which results in impacts converted to monetary units through economic modelling. *Step 7: Integrate the impacts* consists of the aggregation of the various monetized impacts.

For this stage, the outputs per step are:

- Step 5: Measure the impacts
    - List of footprint indicators
    - Process data
    - Data sources and data quality evaluation
    - Value of footprint indicators
    - Allocation method, if applicable
- Step 6: Value the impacts
    - Monetisation factors
    - Value of external costs
- Step 7: Integrate the impacts
    - True price gap
    - True price

Step 5: Measure the impacts

5.1. Introduction

This step is a central step in the true price assessment, as each impact in scope will be measured and quantified per functional unit. This section provides guidance on how to quantify the impacts that are considered in the study.

True pricing is done on the basis of more than 20 social and environmental impacts (see section 4.2.1). The quantification method and data needs differ per impact. **Impact-specific modules**, which include impact pathways, calculation framework, typical data requirements, monetisation factors and guidance in data collection, are provided separately. This document guides the general process, which consists of four sub-steps:

1. Determine the footprint indicators
2. Collect process data
3. Quantify the footprint indicators
4. Scale to the functional unit

In *Step 5: Measure the impacts* five principles, inspired by Impact Institute's Framework for Impact Statements (de Adelhart Toorop et al., 2019), shall be followed:

1. Objectivity
2. Conservativeness
   Assumptions, calculations, imputations, or estimates should be made conservatively. In general, best estimates are selected during the assessment process. However, in case there are multiple equally reasonable or likely approaches to deal with some modelling choices, the approach will be chosen that has the least risk of underestimating negative impact or overestimate positive impacts.
3. Uncertainty and transparency
4. Consistency
5. Allocation
   Impacts that are caused by a process that has multiple outputs should be allocated across the various outputs (see section 0 for further details).

5.2. Key elements

5.2.1. List the footprint indicators

The impacts within the scope of a true price assessment are calculated based on well-established pathways of cause and effect. For each impact, standard pathways and calculation frameworks are provided in the **Impact-specific Natural, Social and Human Capital modules** of this *True pricing method for agri-food products* (See *Section 0.4.3*). In some assessments, calculation frameworks can be slightly modified to fit specific data availability.

Each impact is quantified by one or more indicators, each with a specified reference unit. The quantified social or environmental impact in the equivalent unit is called a *footprint indicator*. Footprint indicators measure the actual social and environmental impacts in scope. For example, the footprint of the impact 'contribution to climate change' is 'greenhouse gas emissions', expressed in the reference unit 'kilograms CO_2 equivalent'. The footprint indicators are monetarily valued in the next step by multiplying each with a monetisation factor, and then integrated. They correspond to the impact category mid-point or end-point indicator results of LCA. An example of a calculation framework expressed as a calculation tree for CO2 is shown in Figure 5.

Hypothetical example of calculation framework

The figure below provides a simplified calculation framework for the contribution to climate change of a hypothetical filled in with hypothetical values for the process data, modelling parameters and monetisation factor.

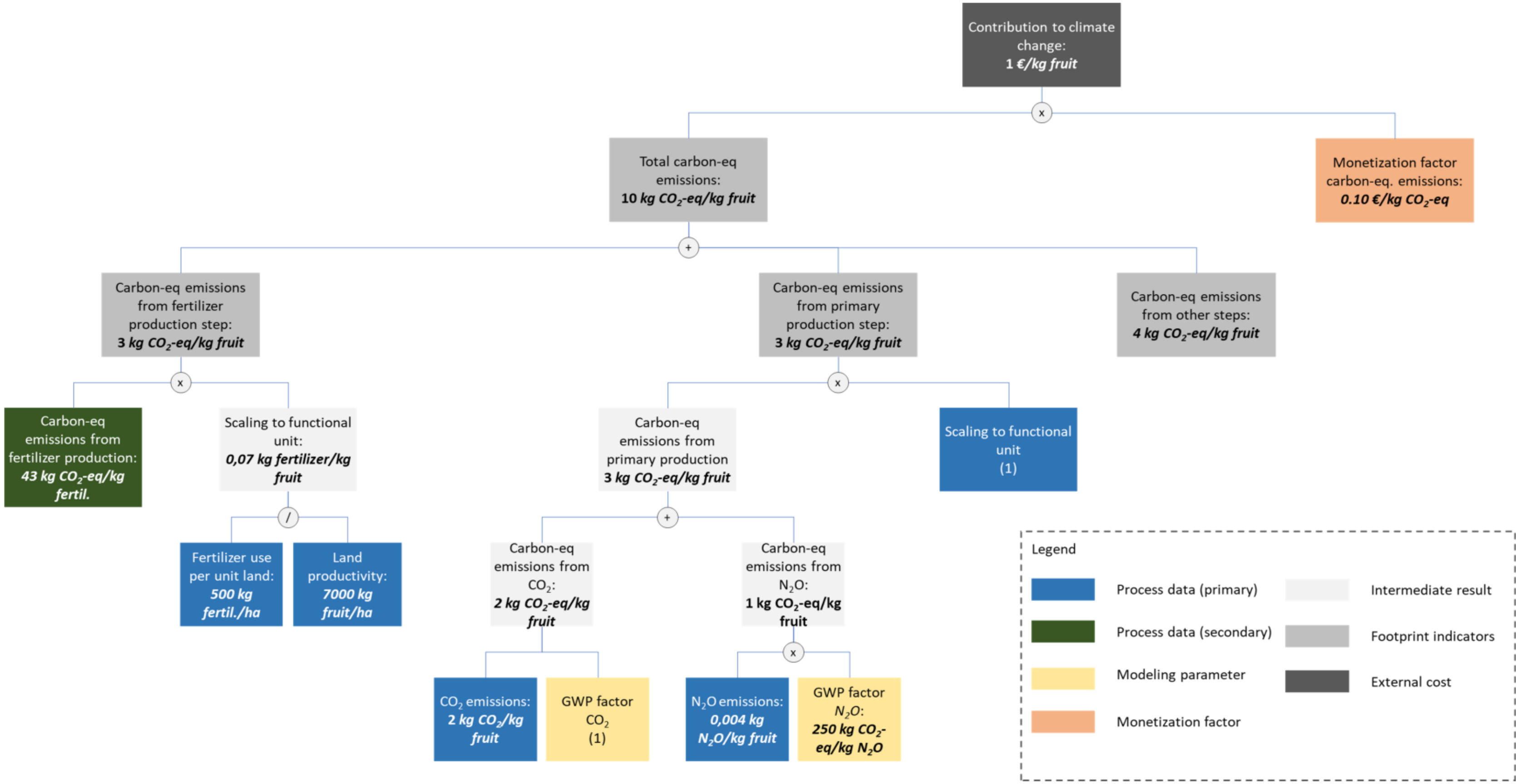


Figure 5: Example of a calculation framework in the form of a calculation tree. The example should not be interpreted as an obligatory format but as an illustration that suits the hypothetical data availability in the example. In this case, carbon dioxide (CO_2)-equivalent emissions from fertilizer production are directly available from existing sources, while emissions in the primary production step are measured separately for two greenhouse gases, (CO_2) and nitrous oxide (N_2O). Global warming potential (GWP) factors (referred to as modelling parameters) express the contribution to climate change of a specific greenhouse gas relative to CO_2. These GWP factors are used to combine different greenhouse gases of the primary production into one equivalent unit (kg CO_2-equivalents) while for the fertilizer production process the total emissions expressed in CO_2 equivalents are used as process data directly.

At the end of this sub-step, it should be clear which footprint indicators are required to measure each impact in scope. Guidance to determine which footprint indicators to use for the impacts in scope is provided in **Impact-specific modules**. Process data should be collected specifically for the project under study. Guidance on the collection of process data is provided in Section 5.2.2.

5.2.2. Collect process data

Reliable data sources are needed to determine the size of impacts (i.e., to quantify the footprint indicators). Footprint indicators are normally calculated using a combination of modelling parameters and process data.

- **Modelling parameters**. The modelling parameters translate process data into footprint indicators. The characterisation factors of environmental LCA, such as the 'Global warming potential' of various greenhouse gases, are an example. Other examples are risk factors, soil model parameters, local regulatory requirements or any other variable that is not specific to a production process that is required to quantify the footprint indicators. In many cases, modelling parameters are location dependent. Impact specific guidance on these parameters is provided by the impact-specific modules. For environmental impacts, these also specify which LCA impact assessment method should be applied.
- **Process data**. Process data includes the data that needs to be collected to describe the processes in the product lifecycle, including use of agricultural inputs, productivity data, crop rotation data, financial performance data, social performance data or environmental performance data of the specific production (or consumption) processes in scope. This includes primary data that can be measured directly (such as the emissions in the example) and secondary data that is found in literature. This also includes supporting data points such as land and labour productivity (respectively the production per hectare per year and per FTE per year). In environmental LCA terms this represents data on inputs (materials, energy, or products) and outputs (emissions as well as products, co-products, and waste flows) of unit processes. More guidance on the requirements for the quality of general data can be found in section 5.2.3.

Data collection applies mainly to process data, as modelling parameters (and the monetization factors required in the next step) are specified in the **Impact-specific modules** (See section 0.4.3).

There are three steps involved when collecting process data: Firstly, assess the data needs according to the calculation framework. Secondly, collect the required data Lastly, evaluate the data quality based on the stated requirements.

Assess data needs

The list of footprint indicators determines which process data and modelling parameters need to be collected. The relevant **Impact-specific Natural, Social and Human Capital method modules** of this methodology specify the data needs per impact. The quantification and data needs sections in those documents provide details on the calculation framework and the required data.

In this sub-step, you determine for each footprint indicator which data you need to collect and which data is provided in the **Impact-specific modules**.

Additionally, process data should be collected also for allocation (if relevant) and for conversion to the functional unit and waste in the value chain.

Allocation

If allocation is required, additional data to determine allocation factors need to be collected.

Allocation is needed when the product under study is produced in processes that inherently give rise to multiple products. Examples include the production of beef and milk from a milk cow that is slaughtered at the end of her life, or the cogeneration of heat and electricity in a Combined Heat and Power system in a greenhouse (that in turn uses the heat to grow fruits or vegetables but delivers some of the electricity to the grid). Crop rotation or multi-cropping, where a given piece of land is used to grow several crops over the years are other examples.

In these situations, the analysis of the true price gap under study typically requires assessing the total social and environmental impacts of the process and *allocating* part of it to each of the end products (including the product under study). Different approaches to allocation exist and for a true price assessment we follow the PEF recommendations to use economic allocation (Zampori & Pant, 2019).

The basic principle of economic allocation is that "having determined the various functional flows of a multi-functional process, all other flows need to be allocated to these functional flows according to their shares in the total proceeds" (Guinée et al., 2004), where proceeds stands for financial revenues.

In certain cases, the output waste of a different process can be used as input for the product under study (for example, when animal manure from other farms is used as fertilizer). When this waste has zero economic value, based on the principle of economic allocation, the impact of upstream activities of the waste product, doesn't contribute to the true price. On the other hand, if it is purchased at a price, it is considered an input product and its upstream impact should be calculated, allocated and it contributes to the true price.

Conversely, waste generated in the lifecycle of the product under study might be used to produce other products (used as a by-product). If these by-products are sold, then they have an economic value and part of the impact can be allocated to them. For example, if a farm is selling organic waste to others as feedstock for energy production, then part of the farming impact is allocated to these waste flows. The same holds for farms selling organic waste or manure as fertiliser, or a food processing facility selling by-products as animal feed.

For more information on economic allocation, see (Ardente & Cellura, 2012; Guinée et al., 2004).

Other allocation methods as well as substitution can in some cases be used, if LCA studies using these are the only available data points to the researcher, but this should be transparently documented, as it limits the comparability of the results with other studies, unless allocation has low influence on the results.

Best practice

It is recommended to include the allocation method among the parameters included in the uncertainty analysis step.

For more information on allocation, refer to Annex 4.

Data on conversion to functional unit and waste in the value chain

Finally, data needs to be collected for scaling results of each lifecycle step to the functional unit of the study.

For each process in the value chain, footprint indicators will first be quantified per unit of their own output (e.g., kg N fertilizer, for the value chain step of fertilizer production). This should later be scaled to the amount that is needed for one functional unit (e.g., kg potato, if the assessment is about potatoes, or kg of potato chips, if the assessment is about that) with help of a conversion factor for each step of the lifecycle. The conversion factor represents the units of output of each process required for one functional unit (e.g., kg N fertilizer/kg potato, or kg of potato/kg of potato chips, etc.). This can be determined with help of the lifecycle overview that is created in *Step 3: Define product lifecycle* of the method.

Data on product waste at all steps in the value chain should be part of the calculation of these conversion factors. For example, 1 kg of potatoes at retail might require the production of 1.2 kg of potatoes because of losses during harvest, storage, transport, processing, and packaging. This ratio should be part of the conversion factors to scale to the functional unit, so that waste is taken into account in the results. To do so, this kind of data points need to be collected too.

Collect data

For collecting process data, the best available data should be used to quantify each footprint indicator. For the calculation of true prices, this can be either primary or secondary data. Primary data is *data gathered directly from measurements at process level*, which describes the situation of the specific product system under study. Secondary data is *data that is available in databases or published studies or may be calculated using other sources*.

In general, the data that is used should be consistent with the goal and scope of the assessment. For example, when a public claim is made for a specific product, primary data about the most material processes and impacts of that supply chain are required to support the claim. However, if secondary data is more representative or appropriate, these may also be used for the most material processes. These requirements are in line with the Product Environmental Footprint recommendations and ISO 14044 (ISO, 2006b).

In some cases, there is neither primary nor secondary data available that are sufficiently representative for the subject of study. Any such data gaps shall be filled using the best available generic or extrapolated data (Zampori & Pant, 2019). For the most material processes and impacts, it is highly recommended to collect new primary data. In any case, the choices made to fill data gaps shall be applied consistently across all the data gaps, in line with the goal of the assessment, and should be clearly and transparently documented.

5.2.3. Evaluate the data quality

The data quality shall be sufficient to enable meeting the goal of the assessment. This helps to identify which data is needed during the data collection process, e.g., which geographical location is representative for the data and from which year the data should be. Data quality is determined by several aspects (based on the Product Environmental Footprint recommendations and ISO 14044 (ISO, 2006b)):

- **Time representativeness**
  The data reflect specific conditions of product under study in terms of time.
- **Geographical representativeness**
  The data reflect specific conditions of product under study in terms of geographical area.
- **Technological representativeness**
  The data reflect specific conditions of product under study in terms of technology, type of organization and product.
- **Completeness**
  The data sources cover sufficiently each impact category.
- **Methodological appropriateness and consistency**
  The study method is applied uniformly to the various components of the analysis. This should be in line with the goal and scope of the assessment.
- **Data uncertainty**
  The variability of the data values for each data expressed (e.g., variance) is sufficiently low. This is related to the process data, not to the modelling parameters. Based on qualitative expert judgement or relative standard deviation as a % if a Monte Carlo simulation is used.

Four quality levels for process data are defined, based on representativeness in terms of time, geography, and technology. Table 4 provides descriptions of the data quality levels and examples of data of the corresponding quality.

Table 4: Description of data quality levels. Level 4 is the highest quality score, level 1 is the lowest quality score.

Level	Type of process data	Description	Example data	Examples sources
4	Value chain data	Primary data or other data gathered directly at process level, which describes the specific value chain under study.	Average values for specific value chain under study (i.e., geographically, technologically and time representative).	Company provided data Primary data collection Tailored LCA data (requires expertise, time and resources)
3	Secondary specific product data	Secondary data that describes the same production method and the same geography as the product under study, but not necessarily the same value chain.	Product average: technologically, geographically and time representative	Same as level 2, but where scope is fully representative
2	Generic product data	Secondary data that describes the product under study, but not entirely representative of the considered production method and geography.	Product average: either technologically or geographically representative	Secondary sources where scope is partly representative • LCA (such as LCA database, LCA studies, PEF benchmarks) • Sector studies and thematic studies (e.g., wages in the banana sector) • National or international thematic databases
1	Generic data	High level estimate that can be describing the sector, the food group or similar products	Sector-country average OR Product average, nor technologically nor geographically representative nor time representative	High level sector studies Sector statistics Environmentally extended Input-Output High level global databases LCA sources where scope is not representative

A description of the data quality is required to help understand the accuracy of the study. The data quality description should include the following:

- **A qualitative assessment of the data quality based using scores.** The quality of each datapoint (process data required for each footprint indicator) shall be assessed according to the four data quality levels described in Table 4.
- **Considerations and limitations on the choice of data sources**. The choice for data sources used in the study should be motivated, e.g., why one source was chosen over the other, or why the choice was made to use secondary data rather than to collect primary data. Other elements of data quality such as completeness, methodological consistency and appropriateness and data uncertainty can also be discussed here.

An example of how to report the data sources and the related data quality levels is provided in the section 0.

In some cases, like a comparative assessment or a study supporting a public claim, a high level of accuracy is required. Data quality is an important determinant of assessment accuracy (See Section 1.2.3: *Stand-alone or comparative assessment*). Material life cycle steps and impacts (those with high results in the assessment or following the materiality assessment in Section 4.2.2) require data of sufficient quality. To ensure the assessment will be able to meet its goal, an iterative process to improve both the scope of the assessment and the quality of the data might be required throughout the assessment. Section 8.2.4 *Identify areas for future improvements* provides guidance on identifying areas for improvement.

Best practice

When a true price assessment is going to be compared to other true price assessments, the assessment of data quality is more extensive and the requirements on data quality are stricter. The data quality evaluation in this study has been designed to balance what is helpful and what is practical. The Product Environmental Footprint recommendations provide a more extensive data quality assessment and requirements that can serve as a benchmark to assess data quality when highly accurate results are required (Zampori & Pant, 2019).

5.2.4. Quantify footprint indicators

In this sub-step the magnitude of the impacts is determined, using the data points that were found in the previous sub-step and the calculation framework to quantify footprint indicators.

The result of the quantification step is a set of footprint indicators for each impact, calculated for each of the lifecycle processes in the system boundaries[11]. Each footprint indicator is expressed in the unit specified by the **Impact-specific module** and scaled to one unit of output of that process (for example, if the impact is climate change and the process is Nitrogen fertilizer production, the unit of the quantified footprint indicators could be kg CO_2-eq/kg N fertilizer).

In many cases, monetisation factors are country or location dependent as they represent local remediation costs. An impact might have an effect in multiple geographical locations while being quantified in the same unit. For example, water pollution, measured in kg N-eq, might occur at different locations throughout a product's lifecycle phases. In this case, the corresponding footprint indicators should not be aggregated for

[11] In a conventional LCA approach, first the data is related to the functional unit and then impact (e.g., footprint) indicators are quantified (ISO, 2006b). Here the opposite sequence is proposed in order to allow for the presentation of results in a way that is recognizable by the various actors in a supply chain: footprint indicators per unit of output of each process. Both approaches yield the same result.

the whole life cycle at this stage, but monetarily valued for each relevant location separately and then aggregated.

5.2.5. Scale to the functional unit

Scaling the results of each lifecycle process to the functional unit of the study is a necessary step in order to aggregate them into the true price gap.

The results of each lifecycle process consist of a set of quantified footprint indicators (footprints). To scale them to the functional unit, the following formula is applied to all footprint indicators for all processes in scope for the assessment:

$$\text{Footprint per FU} = \text{Footprint per unit process output} \times \text{conversion factor}$$

The conversion factor represents the amount of output of the considered process needed for each FU (e.g., if the process studied is potato cultivation and the FU is 1 kg of French fries, how many kg of potatoes are needed for 1 kg of French fries, considering wasted produce, processing losses, storage losses, etc.). More information on this is given in *Data on conversion to functional unit and waste in the value chain*, in section 5.2.2.

The result of this step is a set of footprint indicators, including all impacts and specified for each lifecycle process, which are all expressed relative to the same unit, the functional unit of the study.

This step is a normal part of carrying out an LCA, and therefore it does not always need to be done explicitly when working with LCA data already expressed in the right functional unit or with LCA software.

5.3. Output

For this step, the outputs are:

- **Process data**
  Data that is used to quantify the footprint indicators, including allocation and conversion factors for scaling to the functional unit. Confidential data may be reported in a confidential part of the report, and only be shared under confidentiality with reviewers (if applicable). If applicable, also the required adjustments of the original values should be reported.

- **Data sources and data quality evaluation**
  The data sources and data quality evaluation can be reported together (Table 5). As such, an overview of data sources and the associated data quality level is provided. Data quality levels are described in Section 5.2.3. The considerations to choose one data source over the other should be included. The sources can be consulted to validate the used process data or if additional datapoints are required.

Table 5: Example of table to report data sources and data quality.

Data point	Source	Data quality score	Considerations
…	…	…	…
…	…	…	…

- **List and value of footprint indicators**
  The quantified value of the footprint indicator (non-monetized), scaled to the functional unit. These values are to be reported for all impacts under study (Table 6).

Table 6: Example of how to list footprint indicators required to calculate the true price.

Impact	Footprint indicator	Unit	Value
Land use	Land occupation	MSA.ha.yr/FU	…
Land use change	Land conversion	MSA.ha/FU	…
Contribution to climate change	GHG emissions	kg CO_2 eq/FU	…
…	…	…	…
	…	…	…

- **Allocation factors, if applicable**
  The approach used to partition the inputs or outputs of the processes and product in scope between the product under study and one or more other products (ISO, 2006a, p. 4). The table below gives an example of how this information can be reported.

Table 7: Illustration of how the allocation method can be reported.

Step in value chain	Co-product	Allocation factor
Cultivation	Pineapple	X %
Cultivation	Mango	1-X %
…	…	…

A statement on how the above-mentioned allocation factors are determined, including data sources and assumptions, should be included.

- **Deviations from methodology, if applicable**
  Any deviation from the methodology described in this document and the **impact-specific modules** up to this stage shall be clearly described and justified**,** including expected implications for the results, their interpretation, and how the intended goal of the assessment is met. Deviations include changes in quantification methods, data and modelling parameters (such as lifecycle impact assessment data), allocation approach, inclusion of waste in the value chain, and any other relevant change.

Step 6: Value the impacts

6.1. Introduction

In *Step 6: Value the impacts*, each impact is expressed as an external cost with the use of a monetisation factor. External costs and monetisation factors are defined as follows:

- **External costs (social and environmental costs)** are the elements that form the true price gap. They result from the multiplication of footprint indicators and monetisation factors, so they are basically monetised indicators. In LCA terms these are the weighted indicator results. The sum of all the products of footprint indicators of environmental impacts with their monetisation factors represents the total environmental costs. The same applies to social impacts and social costs.
- **Monetisation factors** translate the impacts expressed as footprint indicators to reflect the impacts' costs to society. In some cases, different monetisation factors may be country-dependent and be different for the same impact for different parts of the product lifecycle (for example, if some damage cost coefficients are proportional to local income levels and the damage occurs in different countries). In LCA terms, monetisation factors are weights.

6.2. Key elements

6.2.1. Monetise the impacts

A monetisation factor is applied to the footprint indicator in order to value the relevant impact, as follows:

$$\text{External cost} = \text{footprint indicator} \times \text{monetisation factor}$$

The sum of all external costs for all indicators and value chain steps is the total external cost of that impact:

$$\text{External cost} = \Sigma\ (\text{footprint indicator} \times \text{monetisation factor})$$

The result of this step is a set of external costs expressed in the same unit for all impacts that are considered in the study. This includes social costs (monetised social impacts) and environmental costs (monetised environmental impacts). All external costs are expressed in the same unit, i.e., currency per functional unit.

A major contribution of the method for True pricing of agri-food products developed with this project "True and Fair Price" is the development of a set of monetisation factors, one for each footprint indicator. Monetisation factors are specified in the separate **Impact-specific modules.** Monetisation factors represent the remediation cost of a negative social and environmental impact, based on a combination of restoration cost, prevention cost, compensation cost and retribution cost, following the **Valuation Framework for True Price Assessment of Agri-food Products**. The **Impact-specific modules** and the **Valuation Framework** are separate documents. The **Valuation Framework** provides the overarching guidelines for the development of monetisation factors of all social and environmental impacts to be considered in a true price study, in line with the Principles for True Pricing (True Price Foundation, 2020).

To summarize the calculation pathway, Figure 5 shows the calculation framework with the hypothetical values to illustrate how the final impact can be calculated and valued.

6.3. Output

For this step, the outputs are:

- **Monetisation factors**
  Overview of the monetisation factors per impact used in the study, which reflect the costs to society related to the impacts measured by footprint indicators.

- **Value of external costs**
  The result per impact of the monetized footprint indicators.

An example of how to report on the monetisation factors and the value of external costs is included in the next step (Table 8).

Step 7: Integrate the impacts

7.1. Introduction

In *Step 5: Measure the impacts* and *Step 6: Value the impacts* the magnitude of different external impacts is measured and valued for all processes in the lifecycle of the studied product. In *Step 7: Integrate the impacts*, the different social and environmental costs are summed up, resulting in the true price gap of the product including all parts of the life cycle that are included in the system boundaries.[12]

7.2. Key elements

7.2.1. Combine monetised impacts into the true price

In some cases, it is also useful not to integrate the results across supply chain steps, but only across impacts. This is the case whenever an assessment or comparison of the true price gap at specific steps of the life cycle is (also) of interest. In this case, the various social and environmental impacts are summed up for specific life cycle steps.

In the integration step, it is important to ensure that the impacts are all expressed in a monetary unit before combining them into the final true price.

$$\text{True price gap} = \sum (\text{External cost})$$

The sum of the true price gap of a product and the market price, the price at which this product is on average bought and sold, represents the true price.

$$\text{True price} = \text{market price} + \text{true price gap}$$

Be aware that the true price excludes all positive externalities because these positive effects do not need to be reduced, while the true price does include for example payments needed to give minimum wages and decent living wages, earning opportunities towards levels consistent with international agreements.

[12] The fact that the goal of the assessment is to derive one main monetary indicator as result, the true price gap, is a key difference between true pricing and the LCA approach.

7.3. Output

For this step, the outputs are:

- **True price gap**
  A specification of the true price gap, the sum of all external costs associated to the product.

- **True price**
  A specification of the true price, the sum of the market price and the true price gap.

Table 8 provides an example of how to report on the external costs per impact, the true price gap and the true price.

Table 8: Example of how to specify the true price gap and the true price.

Impact	**Value of footprint indicator**		**Monetisation factor**	**Value of external costs**
Contribution to climate change	10 kg	×	0.10 €/kg	€1.00
Water pollution	10 L	×	0.01 €/L	€0.10
Occupational accidents	1/30,000	×	15,000 €/accident	€0.50
Total true price gap (1 kg of fruit)				€1.60
Market price (1 kg of fruit)				€3.00
Total true price (1 kg of fruit)				€4.60

Stage D: Report

This stage consists of two steps:

- Step 8: Interpret and test the results
- Step 9: Report

In this stage the results of *Stage C: Measure and value* are interpreted, tested, and reported.

For this stage, the outputs per step are:

- Step 8: Interpret and test the results
    - Interpretation of results
    - Results of uncertainty analysis
    - Limitations of the assessment
    - Elements for further research (if applicable)
- Step 9: Report
    - True Price assessment report

Step 8: Interpret and test the results

8.1. Introduction

Interpretation is the process of drawing conclusions from the results, while testing refers to an evaluation of the quality of the results. The two activities are to be carried out in an iterative loop, as the conclusions drawn during interpretation should be tested, and insights on strengths and weaknesses of the results from the testing phase inform interpretation. This section provides guidelines to follow when interpreting and testing the results of a true price assessment.

The results should be interpreted in the context of the true price concept. The result provides insight in the environmental and social impacts and the costs related to the remediation of these impacts.

8.2. Key elements

8.2.1. Interpretation

The goal of interpretation is to understand what the results of the assessment are, how they can be explained, what useful messages can be drawn from them, and what the limitations are. Creating visualizations of the results that help to answer the key questions posed in *Step 1: Define the goal and audience* is also part of this process. Interpretation may be carried out in collaboration with supply chain partners or experts in the field. Below is a list of questions that the interpretation phase should address:

- What are the main results, in relation to the goal of the study?
- Do the main results make sense, and how can they be explained?
- What are the largest impacts? Which ones are small? Does this make sense and how can it be explained?
- If scenarios are compared, what are the key differences and similarities? How can they be explained?
- What are the most surprising outcomes of the analysis, and how can they be explained?
- What are the main limitations of the results?

8.2.2. Uncertainty analysis

The goal of uncertainty analysis is to evaluate the reliability of the results and, if needed, improve it. This includes both an evaluation of the uncertainty of the results stemming from the calculations and the assumptions, as well as how the principles of objectivity, conservativeness, consistency, transparency, and allocation mentioned in Step 5: are applied. To do so, a critical evaluation of all the components of the assessment should be carried out. In any case, the authors strongly recommend including at least a qualitative discussion on what are expected to be (the main) sources of uncertainty and their influence on the findings of the assessment.

The uncertainty of a true price gap has three levels:

1. **Uncertainty on process data and methods** (stochastic): perfect data describing the social and environmental performance of each process in the product lifecycle is not available. There is uncertainty in the methods to determine footprint indicators, due to the choice of specific environmental and socio-economic models, the lack of data to determine all model parameters, and the selection of footprint indicators to assess. Furthermore, there is uncertainty in the monetisation method, due to the choices made gaps in modelling the remediation cost of negative societal impacts or to a lack of data on this aspect.
2. **Uncertainty of scope** (choice related), since different methodological choices (e.g., system boundaries, choice of impacts, and assumptions related to time, technological, geography etc.) have to be made to come to a true price.

3. **Uncertainty of modelling and assumptions** (can be stochastic and choice related), which can be related to assumptions and choices on, for example, modelling principles or the use of calculation methods.

What to test: components to be evaluated to get a better grip on the uncertainty of the results should include the following:

- Scoping choices and assumptions, both in relation to the definition of the system boundaries and the impacts.
- Process data quality and assumptions used to fill data gaps, for process data, modelling parameters and monetisation factors alike.
- Assumptions applied during the calculation, including but not limited to allocation, modelling of footprint indicators and conversion to functional unit.
- Results and their relation to existing studies and knowledge on the same topic
- Limitations and degree of certainty or uncertainty of the results
- Other components that influence the results

How to test: the evaluation can include a literature review, a quantitative uncertainty analysis and/or an expert review.

- A literature review is a comparison of the findings with those of studies with a similar focus. It is especially useful to uncover unexpected results and possible errors in the assessment. The review can encompass for example other external cost accounting studies, other quantitative studies such as environmental and social lifecycle assessments or issue-specific studies (e.g., a study on health circumstances in a specific sector of a specific country).
- A quantitative uncertainty analysis is an estimation of the statistical significance of the results. As described above, it is possible to distinguish three types of uncertainty in a true price assessment: process data (stochastic), scope (choice related), modelling (can be both choice-related and stochastic). The outcome of a *quantitative* uncertainty analysis is an uncertainty range of the results, which may be absolute or relative. This can be estimated developing results for several scenarios using different data and assumptions (e.g., best case – middle – worst case or economic allocation – mass allocation, etc.) or using statistical analysis tools such as Monte-Carlo simulation.
- An expert review consists in having someone not belonging to the assessment team provide comments on the true pricing study. Internal or external experts (experts from within or outside the organisation carrying out the assessment) may be involved. Experts may be asked to review only the findings of the assessment, or the full chain of steps from scoping to data collection, measuring and valuation, or something in between, including breakdowns of results and intermediate results.

The result is a specification of the biggest expected sources of uncertainty, their expected size (if estimated), the approach chosen to deal with them, the influence on the conclusions of the study, and the recommended improvements for future updates of the study.

8.2.3. Summary of completeness, materiality and data quality

Completeness of scope, data quality and how most material impacts in the life cycle are addressed are three crucial determinants of the level of accuracy of a true price assessment. A true price assessment needs to be transparent on these aspects. This also helps to highlight limitations and areas for future improvement. To do so, an overview should be given of what is included (and to what level of data quality) and what is not included (and whether it is material, and the reason for not including). The following guidelines shall be met.

a. A summary of elements in scope for the study (impacts, life cycle steps) and their data quality level should be included, also in relation to their materiality.
    - If an impact is included only for part of the lifecycle, this should be specified.
    - Materiality scores for elements in scope should be updated based on the results of the assessment.
b. All elements that were left out of the study due to scoping decisions should be specified, including their expected materiality.
c. Finally, also impacts of the true price that were excluded from the beginning simply because of a lack of available methods should be listed.

An example of how such an overview can look is given in Table 9a and Table 9b.

Table 9a: Example of a table showing the level of completeness, materiality and data quality of the analysis for a hypothetical assessment. **Materiality here can mean contribution to the total results or, for elements out of scope, expected materiality.*

Impact	Completeness	Life cycle step	Mater-iality*	Data quality	Data explanation
Contribution to climate change		Transport	++	●●●○	LCA database
		Cultivation	+	●○○○	LCA of proxy products.
		Processing, packaging, storage	+	○○○○	Not assessed
Air pollution		Transport	++	●●●○	LCA database
		Cultivation	+	●○○○	LCA of proxy products.
		Processing, packaging, storage	+	○○○○	Not assessed
Fossil fuel depletion		Transport	++	●●●○	LCA database
		Cultivation	+	●○○○	LCA of proxy products
		Processing, packaging, storage	+	○○○○	Not assessed
Land use		Cultivation	++	●○○○	LCA of proxy products
		Transport, processing, packaging, storage	-	○○○○	Not assessed
Soil degradation		Cultivation	++	●○○○	Generic regional data
		Transport, processing, packaging, storage	-	○○○○	Not assessed
		Transport, processing, packaging, storage	-	○○○○	Not assessed
Scarce water use		Cultivation	+	●○○○	LCA of proxy product
		Transport, processing, packaging, storage	-	○○○○	Not assessed
Other non-renewable material depletion		Cultivation	-	●○○○	LCA of proxy product.
		Transport, processing, packaging, storage	-	○○○○	Not assessed
Water pollution		Cultivation	+/-	●○○○	LCA of proxy product
		Transport, processing, packaging, storage	-	○○○○	Not assessed
Occupational health and safety		Cultivation	+	○○○○	Not assessed
		Transport, processing, packaging, storage	-	○○○○	Not assessed
Living income		Cultivation	+/-	○○○○	Not assessed
		Transport, processing, packaging, storage	-	○○○○	Not assessed
Child labour		Cultivation	+/-	○○○○	Not assessed
		Transport, processing, packaging, storage	-	○○○○	Not assessed
Negative effects of consumer health & safety		Cultivation, transport, processing, packaging, storage	-	○○○○	Not assessed

Not assessed Low Medium High Very high

Table 9b: Example of a table showing the elements out of scope for the analysis because no method was available

Other impacts out of scope	Expected materiality
Gender discrimination	+
Underpayment in the value chain	+
Lack of social security	+/-
Excessive and underpaid overtime	+/-
Occurrence of harassment	+/-
Lack of freedom of association	+/-
Forced labour	+/-
Negative effects of community health and safety	+/-
Breach of indigenous rights	+/-
Breach of land rights	+/-
Occurrence of corruption	+/-
Tax evasion	+/-
Deliberate misinformation/lack of transparency	+/-
Breaches of privacy	-
Overuse of other renewable resources	-

8.2.4. Identify areas for future improvements

The outcome of the previous step helps to identify gaps in the assessment and priorities for improvement in future iterations of this assessment. Future iterations can be aimed to:

- Improve data quality for specific impacts and/or lifecycle phases
- Include material impacts (for specific lifecycle phases) that are not included in the current assessment
- Determine materiality of elements for which materiality is unknown.
- Include material elements currently out of scope due to a lack of method. A new method could be developed, but also a qualitative assessment could provide valuable insights alongside a true price assessment.

The most important areas to improve in future studies are the following:

- Impacts with **high materiality and low data quality**
- impacts with **high materiality that are out of scope**
- impacts with **currently unknown materiality**

8.3. Output

For this step, the outputs are:

- **Interpretation of results**

  Discussion of the results and findings of the study. This should be related to the intended goal of the study. The interpretation should be formulated in such a manner that it can be understood by non-experts by providing an intuitive explanation of the causality behind the results.

- **Results of uncertainty analysis**

  A specification of the approach to evaluate uncertainty (literature, quantitative analysis and/or expert review) and the results of the test.

  - Outcome of literature review

    Statement on the main findings of the literature review.

  - Outcomes of review process

    Statement on the outcomes of the review process.

  - Quantitative uncertainty analysis

    Systematic procedure to quantify the uncertainty introduced in the results of the analysis due to the cumulative effects of model imprecision, input uncertainty and data variability (ISO, 2006a, p. 5).

- **Summary of completeness, materiality and data quality**

  For transparency on the level of accuracy of the study, and following for example the templates in Tables 9a and 9b.

- **Limitations**

  Discussion of the limitations of the study in terms of scope, data availability, and conclusions that can and/or cannot be drawn based on the study. This includes a specification of material assumptions, uncertainties, and limitations in the data and analysis resulting from input, calculations, and estimates.

- **Elements for further research (if part of the scope)**

  Discussion of potential areas for future research, related to the product under study and the associated true price analysis.

Step 9: Report

9.1. Introduction

The last step, *Step 9: Report*, includes the reporting of the true price assessment. This should be transparent and complete, making clear what the results are and what are the underlying data, assumptions, methods, calculation steps and limitations. The focus of the report should be consistent with the intended goal and audience of the study, and general requirements on transparency must be taken into account.

9.2. Key elements

9.2.1. Reporting

The report can follow many structures or templates. It presents the logic followed in all the stages of the assessment and includes the output of various steps. A suggested table of contents for a true price assessment is provided in *Annex 6: Report template example*.

While all steps in the assessment method shall be followed, reporting on all the steps is not always mandatory. This section provides guidelines for specific types of reporting and other forms of communication.

Public reports, reports supporting public communication or reports supporting comparative claims require a higher level of transparency on the method that was followed, the data used and the most influential choices that were made by the practitioner. Furthermore, if there has been a review process, its outcomes shall be described explicitly. Assessments that are aimed for internal use have less strict requirements on reporting, but it is always recommended to report on all steps to obtain the results, including references to the sources of the data, and key limitations. Each study should give an explicit interpretation of the results and discuss inherent limitations of the study. Next to that, the goal and audience of the assessment guide the selection of the elements to include in the report.

Table 10 provides an overview of requirements for reporting on the output of specific steps, for three specific categories of reports:

1. **Report including explicit comparative claims that are public**. In this case, transparency requirements are the most stringent. An explicit comparative claim is a comparison between a product or product brand and another product, a benchmark or another brand, drawing conclusions on their relative sustainability performance.
2. **Other public report or report supporting public communication.** Any report that is open to the public or whose results support public communication falls in this category, if it doesn't include explicit comparative claims. Requirements are specified to ensure that the results, the methodology and their limitations are transparently documented.
3. **Other internal report.** Any report that is not meant to be open to the public or support public communication has lower requirements on transparency. In this case, the assessor is best suited to determine what the content should be, based on the needs of the commissioner, confidentiality and the target audience. Suggestions are given.

Requirements are also specified for two other types of communication. Both types require a report (see above) to document the assessment and support the claims made in the communication. Therefore, these two additional types of communication cannot stand alone.

4. **Public report summary**. Summaries of reports have a much broader audience than reports, and it is therefore important that they convey the key elements of an assessment. These requirements can also be used to guide summaries that are not public.

5. **Other public communication**. Any public communication about the results of an assessment should include some key elements of the study. If that is not possible, for example due to lack of space in a retail setting, these shall be included in easily accessible, brief documentation. This is not a substitute of a report, which should be referenced.

Table 10: Required elements for different forms of reporting

	Report including explicit comparative claims that are public	Other report that is public or supporting public communication	Other internal report	Public report summary	Other public communicatio n
Step 1: Define the goal and audience					
Intended use and target audience, commissioner	Mandatory	Mandatory	Recommended	Recommended	Recommended
Step 2: Define the product					
Product specification, functional unit	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Reference year, currency year	Mandatory	Mandatory	Recommended	Optional	Optional
Step 3: Define the boundaries					
Diagram of lifecycle processes	Mandatory	Mandatory	Recommended	Optional	Optional
Specification of processes in scope	Mandatory	Mandatory	Recommended	Mandatory	Mandatory
Step 4: Determine impacts in scope					
Materiality assessment	Mandatory	Mandatory	Recommended	Recommended	Optional
Impacts in scope	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Excluded lifecycle steps and impacts	Mandatory	Mandatory	Recommended	Mandatory	Recommended
Justification of excluded lifecycle steps and impacts	Mandatory	Mandatory	Optional	Recommended	Optional
Step 5: Measure the impacts					
List and value of footprint indicators	Mandatory	Mandatory	Recommended	Optional	Optional
Value of process data	Recommended	Recommended	Recommended	Optional	Optional
Data sources	Mandatory	Mandatory	Mandatory	Mandatory	Recommended
Data quality evaluation	Mandatory	Mandatory	Recommended	Recommended	Recommended
Deviations from methodology	Mandatory	Mandatory	Recommended	Mandatory	Recommended
Step 6: Value the impacts					
Monetisation factors	Mandatory	Mandatory	Recommended	Optional	Optional
Step 7: Integrate the impacts					
True price gap	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
True price gap breakdown by impact and lifecycle step	Mandatory	Mandatory	Recommended	Recommended	Recommended
True price gap breakdown by indicator	Mandatory	Recommended	Optional	Optional	Optional
True price	Recommended	Recommended	Optional	Optional	Optional
Step 8: Interpret and test results					
Interpretation of results	Mandatory	Mandatory	Mandatory	Mandatory	Recommended
Outcomes of review process	Mandatory	Recommended	Optional	Optional	Optional
Uncertainty analysis	Mandatory	Recommended	Recommended	Recommended	Optional
Completeness/materiality/data quality summary	Mandatory	Recommended	Recommended	Recommended	Optional
Limitations of the study and of its conclusions	Mandatory	Mandatory	Mandatory	Mandatory	Mandatory
Step 9: Report					
Reference to the report				Mandatory	Mandatory

Mandatory Recommended Optional

9.3. Output

For this step, the output is:

- True Price assessment report as specified above.

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Annex 1: List of impacts in true pricing

The starting point for defining the impacts to consider in the true price gap is a responsibility of businesses related to basic rights of people. The **Valuation Framework for True Price Assessment of Agri-food Products** provides a more detailed discussion and the definition of impacts and their normative foundation (Galgani, Woltjer, de Adelhart Toorop, & de Groot Ruiz, 2021b).

This annex provides a list of impacts for the assessment of true prices that is identical to the list of impacts in the valuation framework. The list is applicable to any product, sector, or country. This allows true prices in the agri-food sectors to be assessed in a comparable way with true prices in other sectors. The list contains the impacts to consider at the time of writing but is subject to change given future development of the field of true pricing. Therefore, the reader should use the most recent list of impacts available.

For more details, including information on the specific definition, rationale, footprint indicators, data needs and monetisation factors of each impact, the reader is referred to the separately published **impact-specific Natural, Human and Social Capital method modules** (see section 0.4.3 in the main report).

Table 11: List of impacts relevant for true pricing.

Environmental impacts	**Social impacts**
Contribution to climate change	Child labour
Air pollution	Forced labour
Water pollution	Gender discrimination
Soil pollution	Underpayment in the value chain
Land use	Lack of social security
Land transformation	Excessive and underpaid overtime
Fossil fuel depletion	Living income
(Other) non-renewable material depletion	Occurrence of harassment
Scarce water use	Lack of freedom of association
Soil degradation	Negative effects on workers' health and safety
Overuse of other renewable resources	Negative effects of community health and safety[13]
	Animal welfare
	Breach of indigenous rights
	Breach of land rights
	Occurrence of corruption
	Tax evasion
	Deliberate misinformation/lack of transparency
	Negative effects of consumer health & safety
	Breaches of privacy

[13] This impact includes the negative effects resulting from zoonoses and increased antimicrobial resistance. Increased antimicrobial (antifungal, antiviral, antiprotozoal and antibiotic) resistance occurs due to the use of antimicrobial agents (including medicines such as antibiotics) in food production.

Annex 2: Relation between Natural Capital impacts in true pricing and impact categories in PEF

This annex provides a short comparison between the proposed environmental impacts that should be included in a true price assessment and impact categories included in the European Union's Product Environmental Footprint framework (PEF). The true pricing method uses ReCiPe as a core model and aims to be compatible with the PEF framework. Furthermore, the true pricing method focuses on the step of monetisation, which is not covered by PEF. In some instances, the true price method can deviate to use more recent research, to cover a broader scope of environmental impacts, to make the model compatible to monetisation or to improve internal consistency of the method. Harmonization between the true price method and PEF is desirable and should be further pursued.

Below, observations concerning the link between the two methods are provided, followed by impact-by-impact comparisons. The main sources of information that are utilised for these, are the Product Environmental Footprint (PEF) Guide (Zampori & Pant, 2019) and the **Natural Capital impact-specific modules** of the true price method.

1. Application of true price monetisation to PEF impacts

True price monetisation factors can directly be applied to the following six PEF impact categories:

- Climate change
- Ozone depletion
- Particulate Matter/Respiratory inorganics
- Photochemical Ozone Formation
- Resource depletion - water use
- Eutrophication – aquatic

Additionally, monetisation factors can be derived from the true price method if equivalence are known for the following six PEF impact categories:

- Ecotoxicity for aquatic freshwater
- Human Toxicity – cancer effects
- Human Toxicity – non cancer effects
- Acidification
- Resource depletion – mineral, fossil
- Land Transformation (SOM deficit)

Only one PEF impact category cannot be monetised at the moment: Ionizing radiation – human health effects.

2. Correspondence between true pricing impacts and PEF impact categories

Table 12 gives an overview of the correspondence between environmental impacts in these methods.

Table 12: Overview of environmental impacts included in true pricing and corresponding Product Environmental Footprint impact categories.

True pricing environmental impacts	True pricing footprint indicators	Corresponding LCA impact categories from PEF
Contribution to climate change	GHG emissions	Climate change
Air pollution	Toxic emissions to air -Human toxicity	Human toxicity- cancer effects Human toxicity- non-cancer effects
	Toxic emissions to air- Terrestrial ecotoxicity	-
	Toxic emissions to air- Freshwater ecotoxicity	Ecotoxicity for aquatic fresh water
	Toxic emissions to air- Marine ecotoxicity	-
	Particulate matter formation	Particulate matter/ Respiratory Inorganics
	Photochemical oxidant formation	Photochemical ozone formation
	Acidification	Acidification
	Ozone layer depleting emissions	Ozone depletion
	Nitrogen deposition	Eutrophication- terrestrial
Water pollution	Toxic emissions to water -Human toxicity	Human toxicity- cancer effects Human toxicity- non-cancer effects
	Toxic emissions to water- Terrestrial ecotoxicity	-
	Toxic emissions to water - Freshwater ecotoxicity	Ecotoxicity for aquatic fresh water
	Toxic emissions to water- Marine ecotoxicity	-
	Freshwater eutrophication	Eutrophication- aquatic freshwater
	Marine eutrophication	Eutrophication- aquatic marine
Soil pollution	Toxic emissions to soil -Human toxicity	Human toxicity- cancer effects Human toxicity- non-cancer effects
	Toxic emissions to soil- Terrestrial ecotoxicity	-
	Toxic emissions to soil - Freshwater ecotoxicity	Ecotoxicity for aquatic fresh water
	Toxic emissions to soil- Marine ecotoxicity	-
Land use	Land use	-
Land use change	Land use change	-
Fossil fuel depletion	Fossil fuel depletion	Resource Depletion – fossil
(Other) non-renewable material depletion	(Other) non-renewable material depletion	Resource Depletion –mineral
Scarce water use	Scarce water use	Resource Depletion – water
Soil degradation	Soil Organic Carbon (SOC) loss	Land transformation – SOM (partly)
	Soil erosion	-

	Soil compaction	-
-	-	Ionizing radiation

3. Terminology

Nomenclature differences are summarized below.

- PEF "*impact categories*" can be referred to as *"(sub-) footprint indicators*" in the true price method, while PEF "*impact category indicators*" can be referred to as "*units*". An example of this is that Particulate matter is a PEF impact category, with kg $PM_{2.5}$ -eq as an indicator, while it is a true price footprint indicator with a corresponding unit expressed in kg $PM_{2.5}$ -eq.
- A different definition of what constitutes an '*impact'* is used. This is particularly true for pollution impacts, where in true pricing several PEF impact categories are aggregated under one true price impact, i.e. air pollution, water pollution or soil pollution.
- Moreover, what in PEF are called "*impact assessment models*" for Environmental Footprint studies, they are referred to as "*quantification models*" in the true pricing method. In order to avoid confusion, in the following section true pricing nomenclature will be used.
- *Land transformation* refers to the impact of land use change (hectares) in the true price method, while it refers to a measure of soil organic matter (SOM) loss (kg SOM) in the PEF method.

4. Assessment requirements

The data, scope and reporting requirements in the true price method described in this report are inspired by PEF and often correspond 1:1.

5. Contribution to climate change

The same method is used in true pricing as in PEF, the Bern model. Global Warming Potentials are assessed over a 100-year time frame.

6. Air, water and air pollution

Scope

Two of the footprint sub-indicators of toxicity of the true price method (*human toxicity, freshwater ecotoxicity),* included in the impacts *Air, Water and Soil pollution*, are consistent with the same impacts in the PEF method. As opposed to the true price method, PEF does not distinguish whether these happen through emissions to air, water or soil, but does distinguish two types of human toxicity (carcinogenic and non-carcinogenic). In addition, the true price method includes the sub indicators *terrestrial* and *marine ecotoxicity*, as part of toxic emissions to air, water and soil, which are out of scope in PEF.

The footprint sub-indicators of particulate matter formation, photochemical oxidant formation, acidification, ozone layer depleting emissions and nitrogen deposition, which are included in the impact Air pollution of the true price method, are part of the PEF method as well. Discrepancies are observed in the names of some of the indicators: in PEF, particulate matter/ respiratory Inorganics, photochemical ozone formation, ozone depletion and eutrophication- terrestrial, respectively.

The footprint sub-indicators *freshwater eutrophication* and *marine eutrophication* are part of the PEF method as well. Freshwater and marine eutrophication relate to PEF's indicator *eutrophication -aquatic freshwater* and *eutrophication- aquatic marine*, respectively.

Method

All Air, Water and Soil pollution footprint indicators in true pricing use Recipe 2016 as a quantification method (Huijbregts et al., 2016), with the exception of *nitrogen deposition*. The choice to consistently use ReCiPe to start with underlies all the differences between PEF and the true pricing method. The reason for this choice is that ReCiPe is a complete and well accepted impact assessment method with a good degree of geographical detail, providing country specific data for most impacts globally. Furthermore, ReCiPe also includes country-specific end-point characterization factors which are useful for monetisation, by quantifying the effects of each impact on ecosystems and human health in a consistent way.

ReCiPe is also used by PEF for *photochemical oxidant formation*, *freshwater* and *marine eutrophication* although they use an older version, Recipe 2008 (Goedkoop et al., 2013), which can lead to differences in units and quantification results.

Table 13 gives an overview of the different methods and units that can be found in true pricing and PEF.

Table 13: True pricing (TP) and PEF quantification methods and units used in pollution footprint indicators.

TP name	PEF name	TP method	PEF method	TP unit	PEF unit
Particulate matter formation	Particulate matter/ Respiratory Inorganics	Recipe 2016	RiskPoll	kg PM2.5 equivalent	kg PM2.5 equivalent
Human toxicity	Human toxicity- cancer effects, Human toxicity- non-cancer effects	Recipe 2016	USEtox	DALY	CTU_h (Comparative Toxic Unit for humans)
Photochemical oxidant formation	Photochemical ozone formation	Recipe 2016	LOTOS-EUROS model (as applied in Recipe 2008)	kg NO_x -eq kg NMVOC	kg NMVOC -eq
Acidification	Acidification	Recipe 2016	Accumulated Exceedance model	kg SO_2 -eq	mol H^+ -eq
Ozone layer depleting emissions	Ozone depletion	Recipe 2016	EDIP model	kg CFC-11 -eq	kg CFC-11 -eq
Nitrogen deposition	Eutrophication -terrestrial	-	Accumulated Exceedance model	kg NH_3 kg NO_x	mol N -eq
Freshwater ecotoxicity	Ecotoxicity for aquatic fresh water	Recipe 2016	USEtox	kg 1,4-DCB -eq	CTU_e (Comparative Toxic Unit for ecosystems)
Freshwater eutrophication	Eutrophication-aquatic freshwater	Recipe 2016	EUTREND model (as applied in Recipe 2008)	kg P-eq to freshwater	kg P-eq to freshwater

Marine eutrophication	Eutrophication-aquatic marine	Recipe 2016	EUTREND model (as applied in Recipe 2008)	kg N-eq to marine water	kg N-eq to marine water

For all toxicity indicators the USEtox model is adopted by PEF, which has factors for *human* and *freshwater ecotoxicity*. ReCiPe also builds on the USEtox model, but factors and units can differ. It was chosen because it has a broader coverage of indicators, including also *marine* and *terrestrial ecotoxicity*. *Terrestrial ecotoxicity* is particularly important for agriculture due to the use of pesticides and their influence on bees and other insects.

PEF measures *acidification* in mol H^+ equivalents using the accumulated exceedance model. ReCiPe uses kg SO2-eq.

For *particulate matter formation* and *ozone layer depleting emissions* both methods use PM2.5 equivalents and CFC-11 equivalents respectively as a measure, although with different underlying methods.

Nitrogen deposition (terrestrial eutrophication) is not present in ReCiPe. PEF measures it in mol N-eq using the accumulated exceedance model. In the true pricing method this model is used and integrated with research on the related monetary costs, which leads to a different measurement unit (kg NOx and kg NH3).

7. Fossil fuel and (other) non-renewable material depletion

Both the true price method and PEF include *fossil fuel depletion* and *material depletion*. *Fossil fuel depletion and other non-renewable material depletion* in true pricing follow the ReCiPe life cycle impact assessment method (Huijbregts et al., 2016). These are measured in kg oil equivalent and kg Cu equivalent respectively.

In PEF, *fossil fuel depletion* is expressed in MJ, as implemented in the CML method which is based on (van Oers et al., 2002). The use of MJ or kg oil equivalent to assess depletion of fossil fuels is expected to provide similar results.

For *other non-renewable material depletion* the model recommended by PEF is the Abiotic Resource Depletion, “ultimate reserves” version, described in (van Oers et al., 2002), and is quantified in kg of antimony-equivalent (Sb-eq) (Fazio et al., 2018).

8. Scarce water use

Water use is commonly included among environmental sustainability indicators for products in Life Cycle Assessment (European Commission, 2013; Huijbregts et al., 2016). Both PEF and true price methods focus on the *depletion of scarce water*. The inclusion of consideration of local scarcity in the assessment of this impact is in line with the water use method of the UNEP SETAC Life Cycle Initiative (United Nations Environment Programme (UNEP), 2016). Both methods measure *scarce water use* in m^3 although with different underlying methods.

PEF adopts the Swiss Ecoscarcity model, while in true pricing blue water use is quantified based on the blue water methodology of the Water Footprint Network (Hoekstra et al., 2011) and adjusted for scarcity with the WWF water risk filter ‘physical scarcity’ indicator, which is available for most countries (WWF, n.d.). This is chosen as it is an indicator based on a combination of various existing scarcity indexes, including the World Resource Institute’s Baseline Water Stress index, the Global Aridity Index, the Water Footprint Network’s Blue Water Scarcity, LCA characterisation factors from the AWARE model (which are among the most used in LCA), the Standardized Precipitation and Evaporation Index as well as water depletion and drought models.

9. Soil degradation, land use and land use change

Special attention should be given to the *soil and land impacts*. Within the true price methodology the *soil degradation* impact is measured using three footprint indicators: *soil erosion*, *soil organic carbon (SOC) loss* and *soil compaction*. *Soil degradation* is partly covered by PEF through *land transformation*. This should not be confused with the impact *land use change* which is part of the true price method.

Land use change and *land use* are intended in the true price method as, respectively, change of land cover, measured in hectares of various biomes, and use of land as a scarce resource, displacing nature, reducing biodiversity and ecosystem services, measured in hectares*years of various biomes. Both these two impacts are not part of the PEF set of indicators.

Land transformation in PEF represents the loss of soil organic matter (SOM) from a specific land use. This aligns better with the true price footprint indicator *soil organic carbon (SOC) loss* than *land use change*, since SOC refers to the carbon content of SOM (a component of SOM that can be measured). On the other hand, *land use change* under the true pricing method, represents changes in land cover that can affect ecosystem services, measured in hectares. In this method, *soil degradation* is specified separately from *land use and biodiversity* because it focusses solely on the effects on soil.

The quantification models utilised in both methods also differ. PEF adopts the Soil Organic Matter model, developed by Milà i Canals (Milà i Canals et al., 2007), while in true pricing the model developed by IPCC to quantify difference in C-stocks (IPCC, 2006) is used to measure the footprint indicator *SOC loss*.

Annex 3: Overview of case studies

The development of the set of documents described in section 0.4.3 *Documents of the true price method* was supported by six case studies. The content of the different documents was tested for applicability and clarity for the six products shown in Table 14. The social impact specific modules were not part of the case studies.

Table 14: Overview of products and relevant geographical areas included in the case studies.

Product	Country of production
Pork	Netherlands
Table potato	Netherlands
Lettuce mix (vertical farming)	Netherlands
Lime	Colombia
Flower bulbs (tulip)	Netherlands
Mussels	Netherlands

Annex 4: Allocation methods

Three key principles to consider when allocating, are transparency, traceability and no over- or undercounting. *Transparency* requires that the choice of allocation method shall always be transparently reported and explained. *Traceability* that the allocation method and its consequences should always be traceable in all calculations. *No over- or undercounting* requires that all impacts are counted exactly once if one would – hypothetically – assess the true price gap for all end products of a process. Two more pragmatic principles to apply are the *use of readily available studies*, and a *feasible analysis*.

From a theoretical perspective, in LCA and cost-benefit analysis the preferred allocation approach is developing scenarios of what would happen if a product would not be produced. In LCA this is called consequential LCA. This requires, distinguishing between co-products that have a supply driven or demand driven market. A similar but more pragmatic approach is system expansion or substitution (Ekvall et al., 2016). Next to assessing the processes for the product in scope, one would need to fully analyse the co-products, as well as alternative production ways to obtain the co-products. However, consequential LCA and system expansion are in many cases difficult to calculate. For the scope of true pricing, we suggest that this allocation approach is allowed, when LCA studies are readily available. We do not recommend performing this analysis oneself for the purpose of true pricing. Please note that the same allocation method should be used throughout an assessment.

In attributional LCA, an allocation factor is developed to allocate a certain percentage of the impact of a process to the main output and another share to the co-product(s). The allocation factor may be based on physical or economic characteristics (Schrijvers et al., 2020).

The basic principle of economic allocation is that "having determined the various functional flows of a multi-functional process, all other flows need to be allocated to these functional flows according to their shares in the total proceeds" (Guinée et al., 2004), where proceeds stands for financial revenues. Economic allocation has the advantage that it can be applied for all products, data are easy to find, and it reflects the value ratio between products from the business perspective. Allocation basis like the cereal unit[14], energy content, total weight and protein content are often used for allocation in LCA. The main drawbacks of these approaches are that they are often difficult to quantify, and they are either developed for a specific type of analysis only (e.g., food only, or energy only, or land use only) or, if they are sufficiently generic, they don't reflect the actual value ratio between products (e.g., mass). As a result, economic allocation is recommended as a default allocation method in true pricing.

[14] Cereal units are based on the feed value of a product compared with barley and are being used already for a long time in German statistics. The cereal unit for animals is based on the amount of cereal units that are needed to produce it (Brankatschk & Finkbeiner, 2014).

Annex 5: Recommendations for further development

In this document a first version of the true price assessment method is presented. The following points require additional discussion and development for a following draft.

- Inclusion of a worked out example

The current version of the method is, on several places, illustrated with examples. Expanding these by working out a full example to illustrate the method can help the analyst to better understand the steps that are described. It is recommended to add a worked-out example in the next version of the method.

- Thorough review of relation with LCA standards

Attention has been given to the relation of the true pricing method with existing guidelines for LCA, especially ISO 14040, ISO 14044 and the Product Environmental Footprint recommendations. This method builds upon good practices to a large extend and similarities and deviations are mentioned throughout the document. However, a detailed review of the relation from these guidelines can clarify more about the correspondence between the true pricing method and LCA's, which can provide clarity to e.g., LCA practitioners.

- Levels of accuracy

As mentioned in section 0.5, the accuracy of a true price assessment is determined by its completeness, the underlying assumptions and calculations, and the quality of the data. Developing a system that allows for communicating a range of accuracy levels is a recommendation for a next version of the method. A classification of accuracy levels could facilitate the comparison between different true price studies.

- Testing the results

Currently, the testing step of the study is mainly described as high-level recommendations and does not include specific requirements to follow. A recommendation for the next version of the method is to give further guidance for testing, for example by elaborating on how to perform uncertainty analysis.

- Attributional vs consequential LCA

In the field of LCA, a distinction is made between attributional and consequential modelling. The type of modelling can influence the outcome and conclusion of the analysis. For the next version, it is recommended to review the current best practices in LCA in relation to these types of modelling, and how this relates to the assessment types of true pricing.

- Including consumer- and end-of-life impacts

Consumer and end-of-life impacts could be excluded from the system boundaries in specific cases of a true price assessment when this is in line with the goal and intended audience of the study. Whether guidelines in these regards can be formulated in the assessment method remains open for discussion.

- Crop rotation

Currently, the impact of crop rotation in the true price of a product is briefly covered in the assessment method. A high level approach is provided to guide the assessment of products that are part of a rotation cycle, however specific guidelines on true pricing are not yet available. It is recommended to develop such guidelines following state-of-the LCA standards, as much as possible.

Annex 6: Report template example

In this annex an example table of contents for a true price report is provided.

1. Introduction
2. Goal and Audience
3. Method
    3.1. Product definition
    3.2. Product lifecycle
    3.3. Impacts in scope
    3.4. Data
    3.5. Monetisation factors
4. Results
5. Discussion and limitations
6. Conclusion and next steps