FOUNDATION EARTH

2023

LCA METHODOLOGY FOR ENVIRONMENTAL FOOD LABELLING

BETA VERSION 1.0

Foundation Earth is an independent, non-profit organisation established to issue front-of-pack environmental scores on food products, enabling consumers to make more sustainable buying choices and providing industry with the data needed to improve the sustainability of their value chains. We bring together expert scientists and leading figures from food production and retailing across the UK and EU who all share a vision of a future food industry that doesn't destroy the planet.

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This methodology was developed in collaboration with Blonk Consultants and the German Institute of Food Technologies (DIL) - Deutsches Institut für Lebensmitteltechnik, and supported by EIT Food.

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Abbreviations and definitions

Abbreviation	Full name
FE	Foundation Earth
FU	Functional unit
LCA	Life Cycle Assessment
PEF	Product Environmental Footprint
SKU	Stock Keeping Unit
Primary data	Supply-chain specific data

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1. Introduction

Foundation Earth (FE) is an independent, non-profit organisation established to issue front-of-pack environmental scores on food products, enabling consumers to make more sustainable buying choices. FE would like to encourage the use of primary data from food producers to calculate their environmental scores.

FE started their scoring method based on a farm to shelf methodology developed using data from the academic paper Poore & Nemecek (2018). It assesses a food product's environmental impact through four key criteria: water usage, water pollution, biodiversity loss and carbon footprint. Those impacts are transferred to a single score, the impacts are weighted 49% to carbon footprint and 17% each for water usage, water pollution and biodiversity loss. The single combined score results in a label from A+ to G. For each nutritional category a different grading system is developed, so it is possible to compare products within a specific product category.

Following European policy developments on green claims, FE have moved their scoring system to the European Commission's (EC) Product Environmental Footprint (PEF) method using a cradle to grave Life Cycle Assessment (LCA) including preparation, food waste at consumer and end-of-life emissions. In this method all 16 EF impact categories are included and aggregated to a single score (PEF method). This single score is translated into an A+ to G label in a similar way to the previous farm to shelf 'FE method' mentioned above.

Regardless of the chosen methodology, multiple choices must be made when setting up the LCA models: allocation, use of primary and background data, approach for data gaps, data quality, modelling of packaging material with recycled content and returnable packaging.

As far as possible, FE intends to align with the PEF. The PEF framework already gives some guidance on several LCA modelling issues, and PEF category rules (PEFCR) have already been developed for several product groups. Within food categories PEFCRs have been developed for beer, dairy, wine, packed water, and pasta. However, for other product categories, no standardised methods are available. A further issue is that the methodologies laid down in the PEFCRs for different product groups can be conflicting.

FE have acknowledged that this gap in the LCA methodology can hinder the fair comparison of environmental labels and have consequently initiated a project to further develop a harmonised LCA methodology based on PEF principles (EC, 2021) and building blocks (PEFCRs/TAB documents).

The following assumptions for the grading system have been utilised in the development of FE's LCA methodology:

- Products should be graded on a stock keeping unit (SKU) level in the country of sale
- Comparison of grades between products of different food categories must be possible (e.g., meat product vs. vegetable product)
- Comparison of grades between products within the same food category must be possible (e.g., carrot vs. tomato or carrot vs. carrot)

FE initiated a development project to provide increased guidance for the calculation of environmental footprints under their PEF based scoring system. This methodology document is the result of this project.

1.1 Process

This FE methodology document is the result of a collaboration project between FE, Blonk Consultants and Deutsches Institut für Lebensmitteltechnik (DIL). A special task force was formed with LCA experts, members of the FE Industry Advisory Group and LCA researchers to provide input and feedback during the development of the methodology. A series of workshops were organised to discuss and provide guidance on a range of different LCA topics to enable the development of a harmonised methodology. Blonk Consultants was responsible for the delivery of the workshops and the preparation of proposals to be considered for inclusion

in the methodology. DIL was responsible for reviewing and testing the methodology. The task force members provided input and feedback on the proposed methodology. FE was responsible for coordinating the workshops and recording key information.

Following the workshop sessions, the draft methodology document was presented to the FE Industry Advisory Group. Feedback was processed by Blonk Consultants and the final Beta Version 1.0 of the methodology document was presented for approval at the FE Scientific Committee.

1.2 Status and validity

This document is a Beta Version outlining the harmonised FE LCA methodology. This guidance aims to enable consistent environmental impact calculations intended for communication of the impact to consumers. The grading methodology to translate the environmental footprint into a final A+ to G score is out of scope of this methodology document, although some recommendations for the further development of the grading system will be mentioned in this LCA methodology. Additionally, the development of a possible verification process of the footprint calculations is not within the scope of this methodology document.

This methodology must be seen as a first attempt towards a harmonised PEF based method. It brings together all the development work that has been done within the PEF so far and considers current methodology development work that is currently happening in, for example, the horticulture, flower, and soft drinks industry. Within the development timeframe for this project, it was not possible to provide a complete and detailed LCA guidance for all aspects related to environmental footprinting of food products. Chapter 7 provides more detail on the limitations of this document. Further developments and additional detailed guidance will be needed to fill in the gaps and further improve the methodology.

Nevertheless, the methodology outlined in this document shall be applied when calculating the environmental footprint for scoring food products under the FE label, until an update is published.

As explained, the FE methodology follows the PEF whenever possible. If, however, the FE methodology deviates from a specific PEFCR, the FE methodology will take precedence. An overview of deviations from the PEFCRs can be found in Chapter 6.

2. Scope

The system boundaries (Section 2.1) define the life cycle stages that should be included in the environmental footprint, and the stages and processes that are out of scope. The product granularity defines how specific the LCA represents one or certain products (Section 2.2). Section 2.3 describes the general definition of a functional unit (FU) for which the environmental impact shall be calculated. The life cycle stages for the LCA methodology are described in Section 2.4. Each subsection of this chapter starts with a text box which provides an overview of the key aspects of each section.

2.1 System boundary

Key aspect: cradle to grave

The system boundary defines which life cycle stages are analysed. To be PEF compliant, all life cycle stages from raw materials up until the end-of-life treatment of a product must be included.

The goal of the FE environmental label is to inform consumers about the environmental impact of the products they purchase. To enable a fair comparison between different products (e.g. pre-cooked vs raw food products), a cradle-to-grave system boundary is preferred. The footprint of food products can significantly change between a cradle-to-retail and cradle-to-grave system boundary (e.g. the carbon footprint of dry tea purchased in the supermarket is around 6 kg CO2-eq/kg product and the footprint of a cup of tea prepared at home is about 0.2 kg CO2-eq/kg product). A drawback of choosing a cradle-to-grave system boundary is that the consumer has influence on the personal transport, use, and waste phase of the product, which is unknown to the food producer. Assumptions for those life cycle stages are therefore necessary to calculate a default footprint. For this reason, specific guidance is provided in this LCA methodology to model the use stages (Appendix I).

The life cycle stages within the cradle-to-grave system boundary can be different for particular product groups. The main life cycle stages of food products are schematically shown in *Figure 1*. All life cycle stages will not necessarily be relevant for all food products. For example, for plant-based food items (such as fruit, vegetables, and meat replacers), the feed production and animal production stages are not applicable.

FIGURE 1. CRADLE TO GRAVE SYSTEM BOUNDARY FOR FOUNDATION EARTH METHODOLOGY.

2.2 Product granularity

Key aspects: the LCAs are product and country specific and shall thus be performed per SKU per country of sale.

The LCAs and thus the environmental labels are product-specific, meaning that the labels are specific for each stock keeping unit (SKU). A SKU is a unique code which identifies a product and its characteristics. At raw material production level, the environmental footprint is differentiated for different types of production systems (e.g. depending on country of origin); at ingredient processor level the LCA is differentiated for different types of processing (e.g. marinated or cut in pieces); at food producer level the LCA is differentiated for the different product compositions, and at packaging level the product-specific types of packaging material (e.g. a combination between plastic and paper) determine the footprint. At retail and consumer level the LCA is differentiated for different types of electricity production mix per country. By combining these differences at all life cycle stages, a unique product is identified at SKU level.

2.3 Functional unit and declared unit

Key aspects functional unit: 1 kg of consumed product.

The FU is defined by specifying what function should be provided by the product, how much, how well and how long. All input and output flows in the analysis are related to the specified FU.

In some cases, products or product groups can fulfill multiple functions and it can be difficult to define one FU. The functions of food intake range from the supply of basic energy, through to even the provision of social or cultural functions. Due to overconsumption, the function of food intake is no longer restricted to the intake of required nutritional values. Because of this wide range of functions, it is not straightforward to state one FU. In this situation the PEF recommends applying a declared unit, such as mass or volume.

The declared unit for the FE LCA methodology is defined as:

$$1\ kg\ of\ consumed\ product$$

The choices for the different aspects of this definition are explained below:

Mass of product

Every product has its own set of nutritional values, which can for example be a combination of proteins, fats, and vitamins. The FE label applies one methodology to several product groups, which makes it impossible to specify one nutritional value as the main function of all products. The LCA methodology follows the PEFCR guidance recommendation to use a declared unit (e.g. mass or volume) in case no single FU can be defined.

Consumed product

The use of consumed product as a basis enables a fair comparison between different types of products:

Comparing on a consumed product basis enables comparison between products with different amount of ingredients used for the preparation of 1 kg of prepared (and consumed) product. For some products, moisture might be lost during preparation (e.g., evaporation of water during frying of meat), whereas for other products, water might be added during preparation (e.g. rice, tea).

- Besides moisture addition or loss, the FU accounts for the edible part of the product rather than the total product weight before preparation. It thus considers unavoidable food waste that is inherent to the type of product. For example, the bones in spare ribs or the shell of an egg are not considered edible and are thus not included in the 1 kg of consumed product. According to the PEFCR guidance '*the FU shall be measured at product consumption level and should exclude inedible parts.'*
- The life cycle stage 'food production' includes the industrial processing of the food products (e.g. cutting and marinating food), which can also include pre-cooking at industrial scale. A fair comparison of raw, pre-cooked, or ready-to-consume product (available at retail) is only possible when comparing prepared and consumed products.

More information on the preparation of the product, including the calculations of the consumed weight, is available in Appendix I.

Grading system

In the Farm to Fork PEF-friendly FE grading system, nutritional content is not considered. This decision may be reassessed in future developments of the grading methodology. Therefore, at present the FU shall be measured at product consumption level and should exclude inedible parts, on the basis of a declared unit of 1kg of consumed product.

2.4 Life cycle stages

Figure 1 in Chapter 2 provides a general overview of the life cycle stages that are included in the system boundaries of the LCA methodology.

According to the PEF guidance, in order to guarantee a minimum level of harmonisation among different PEFCRs, the default life cycle stages presented will, as a minimum, include:

- Raw material acquisition and pre-processing (including the production of parts and unspecified components);
- Production of the main product;
- Product distribution and storage;
- Use stage (if in scope);
- End-of-life (including material recovery / recycling, if in scope).

Life cycle stages can be added or existing stages split if there are good reasons for this, e.g. the life cycle stage 'Raw material acquisition and pre-processing' may be split into 'Raw material acquisition', 'pre-processing', and 'raw materials supplier transport'.

In *Table 1* an overview is shown of the definition of life cycle stages across different standards. It should be noted that the transport stage in the previous FE farm to shelf method represents all transport throughout the life cycle of the product (including transport from farm to processing).

TABLE 1: EXAMPLE OF LIFE CYCLE STAGE DEFINITION IN DIFFERENT STANDARDS.

<table>
<tr><th>Life cycle stage</th><th>PEF guidance</th><th>Beer PEFCR</th><th>Dairy PEFCR</th><th>FoodDrinkEurope standard</th><th>Foundation Earth (old method)</th></tr>
<tr><td>Raw materials</td><td rowspan="4">1. Raw material acquisition and pre-processing</td><td>3. Other raw materials and processing</td><td rowspan="4">1. Raw milk supply</td><td rowspan="4">1. Raw material acquisition and pre-processing</td><td rowspan="4">1. Farming</td></tr>
<tr><td>Crop cultivation</td><td>1. Cultivation of grain for malting</td></tr>
<tr><td>Feed production</td><td rowspan="2">(Feed and animal production not relevant)</td></tr>
<tr><td>Animal production</td></tr>
<tr><td>Ingredient production</td><td rowspan="3">2. Manufacturing</td><td rowspan="2">2. Malting
5. Brewery operations</td><td>3. Non-dairy ingredients supply</td><td rowspan="2">2. Manufacturing</td><td rowspan="2">3. Processing</td></tr>
<tr><td>Food production</td><td>2. Dairy processing</td></tr>
<tr><td>Packaging</td><td>4. Packaging and material production</td><td>4. Packaging</td><td>3. Packaging</td><td>4. Packaging</td></tr>
<tr><td>Transport and distribution</td><td rowspan="2">3. Distribution</td><td rowspan="3">6. Use stage</td><td rowspan="2">5. Distribution</td><td rowspan="2">4. Distribution</td><td>2. Transport</td></tr>
<tr><td>Retail (and consumer transport)</td><td>5. Retail</td></tr>
<tr><td>Use</td><td>4. Use</td><td>6. Use</td><td>5. Use</td><td rowspan="2">(Use and end-of-life excluded)</td></tr>
<tr><td>End-of-life</td><td>5. End-of-life</td><td>7. End-of-life</td><td>7. End-of-life</td><td>6. End-of-life (mainly packaging)</td></tr>
</table>

For the FE methodology, the FoodDrinkEurope standard is applied, with a further split of 'raw material acquisition and pre-processing' into crop cultivation, animal production and ingredient production. This split is made to preserve granularity in the results. This will allow identification of hotspots in the supply chain and enable calculation of data quality rating (DQR) scores for the individual stages. *Table 2* briefly describes the type of activities in each of the life cycle stages.

TABLE 2: OVERVIEW OF LIFE CYCLE STAGES, REPORTING CATEGORY AND CORRESPONDING ACTIVITIES TO BE USED IN THE FE METHODOLOGY.

Life cycle stage	Reporting category	Activities
Crop cultivation	Crop cultivation	Cultivation of crops for food, or as input for feed production. Including farm inputs, farm activities, land use change, and land management emissions.
Feed production	Animal husbandry	Transport and processing of crops and other raw materials into feed.
Animal production		Farm activities and manure management.
Ingredient production	Ingredient production	All activities after farm gate until food production. Transport to and between processing facilities, energy consumption, food losses and other emissions at the processing facility (including slaughterhouse).
Food production	Food production	Transport to food production facility, energy consumption, losses, and other emissions in food production processes (e.g., cutting and marinating).
Packaging	Packaging	Extraction of raw materials, production of packaging and end-of-life of packaging material. Secondary and tertiary packaging is included.
Transport and distribution	Distribution	Transport from food producers to the distribution network. Distribution to the supermarkets via one or more distribution centres. Energy consumption and losses at the distribution centre(s).
Retail		Energy consumption and food losses at supermarkets.
Consumer transport		Transport between the supermarket or other retail outlet and the consumer[1].
Use	Use	Use phase of food products, including refrigerating and preparing the food.
End-of-life	End-of-life	Food waste treatment. (The end-of-life of packaging material is included in the 'Packaging' life cycle stage.)

Additionally, the materiality principle as reported in the PEF shall be followed. Hence, processes and elementary flows may be excluded at levels up to 3% (cumulatively) based on material and energy flows and the level of environmental significance (based on the single score contribution).

2.4.1 Food waste in the supply-chain

Food loss rates across the entire life cycle of the product shall be included. At the very least a differentiation must be made between losses during distribution and retail and losses during the consumer use phase. If specific loss rates in the supply chain are known (primary data), these shall be considered. In this case, the datapoint would be rated as measured primary data (Section 3.4) and requirements noted in this guidance for primary data apply (Section 3.2.3). As supply chain specific (measured) loss rates will be difficult to obtain in many cases, country or region-specific food loss data may be obtained from literature, if the source is: publicly available; published by either a sector organisation or an independent research institute. The data would be rated as estimated primary data (Section 3.4) and requirements noted in this guidance for primary

[1] This stage is included in the 'distribution' reporting category, in line with the PEF guidance (EC, 2021).

data apply (Section 3.2.3). In the case that no suitable specific source is found, the food loss rates as presented in Appendix F of the PEF guidance shall be used (EC, 2021).

2.4.2 Additional guidance on use stage

The use stage can result in a high overall environmental contribution for many food products. As the use stage is calculated using many modelling assumptions, the real contribution is affected by potentially very high uncertainties (EC, 2021).

The use stage includes all activities and products that are needed for the proper use of the product (i.e. the provision of the original function is kept throughout its lifetime). For example, the provision of tap water when cooking pasta (EC, 2021). The use phase assessment for food products shall consider different aspects, such as, but not limited to:

- The type (ambient, chilled, frozen) and estimated duration of storage;
- The variability or the typical use, supported with local consumer insight studies where available;
- Instructions required for the use;
- Additional material, equipment or process required for the consumption that are dependent of the product design (such as the energy needed for hot water in the making of a hot beverage) (FoodDrinkEuropeEurope, 2022).

Dependent and independent processes

The use stage often involves multiple processes. A distinction shall be made between (i) product independent and (ii) product dependent processes. This LCA methodology requires the inclusion of product dependent processes and allows for exclusion of product independent processes in the life cycle inventory of the use stage.

(i) Product independent processes have no relationship with the way the product is designed or distributed. The use stage process impacts will remain the same for all products in this product (sub) category even if the producer changes the product's characteristics. Therefore, they don't contribute to any form of differentiation between two products or might even hide the difference. Examples are the use of a glass for drinking wine (as the product doesn't determine a difference in glass use) or the washing machine used for heavy laundry detergents (capital good) (EC, 2021).

(ii) For the food and drink sector, this refers to products that indirectly require energy (fuels or electricity) or materials during their use phase (e.g. additional ingredients, accessories), and which are not defined by the design of a product. Additional examples: consumer cup (as the product does not determine a difference in cup, dishwashing, energy and water required for the additional water boiled (e.g. if boiling 1L of water for a 100 ml cup of tea, the energy and water required for the 900 ml extra) (FoodDrinkEuropeEurope, 2022).

(iii) Product dependent processes are directly or indirectly determined or influenced by the product design or are related to instructions for use of the product. These processes depend on the product characteristics and therefore contribute to differentiation between two products. All instructions provided by the producer and directed towards the consumer (through labels, websites or other media) shall be considered as product dependent. Examples of instruction are guidance on how long the food must be cooked, how much water must be used, or in the case of drinks the recommended serving temperature and storage conditions. An example of a direct dependent process is the energy use of electric equipment when used in normal conditions (EC, 2021).

For the food and drink sector, this refers to food and drink products that directly consume energy

(fuel or electricity) or materials during their use phase, and which are defined by the design of a product. Additional examples: electricity used for a beverage vending machine, electricity used in a coffee machine (FoodDrinkEuropeEurope, 2022).

To have an indication of dependent processes (i.e. amount of water, energy consumed in cooking), PEF defaults are available in Appendix I. If better information is available, either from on-pack instructions (as defined by the product manufacturer) or from industry knowledge on consumer behavior, then it shall be used. Also, the most common way of cooking the product in the region/country of assessment can be considered (FoodDrinkEuropeEurope, 2022).

Use phase per food category

In the case that product and supply chain specific (or primary) data on storage and preparation can be obtained, this shall be used to model the use phase of the product. As mentioned in the paragraph on product dependent processes above, primary data includes all instructions regarding storage conditions and preparation provided by the producer and directed towards the consumer (through labels, websites, or other media).

If no primary data can be obtained, it is important that the use phase is modelled consistently between similar products. For this reason, specific guidance to model the use phase is provided in this LCA methodology. The PEF guidance provides specific guidance for some food products as described in *Table 3* of this document. This list, however, does not cover all food categories which are in scope for the FE food label. Based on the PEF guidance and FoodDrinkEurope guidance, a specified description of use phase activities per food category has been defined according to the food categories of the European Food & Safety Agency (EFSA, 2011). The use phase activities can be found in Appendix I and shall be used if no primary data is available for the use phase. The use phase characteristics are defined based on expert judgement and discussions among the methodological advisors and task force (as defined in the Goal and Scope Chapter).

The following generic rules apply for the definition of the use phase of food items, regardless of whether primary data is used:

- Additional ingredients shall be included if these are liquids which are integrated in the consumed product. This mainly applies to powders that require the addition of liquids to make them consumable, e.g. the addition of water to tea and (instant) coffee. If specific instructions (through on-pack labels, websites, or other media) for the type of added liquid are available, those shall be followed (e.g. the addition of semi-skimmed milk to chocolate powder)[2]. In the case that no instructions are provided, or no explicit type of liquid is instructed, it may be assumed that the added liquid is tap water. Ingredients which are recommended by the food producer, but not integrated in the consumed product, and not required to make the product consumable (such as the addition of minced meat to pasta-sauce) shall not be included in the use phase of the product.
- The default storage condition for canned products is ambient, no energy inputs for this storage type are to be included in the LCA. This overrules Appendix I storage conditions in the case of inconsistencies.
- For sauces which are consumed warm, energy used to heat up to 100 degrees shall be included. This shall include energy used to heat up added water to 100 degrees.

[2] This choice is made to encourage food producers to promote sustainable consumer choices.

3. Life cycle inventory

The LCA is to be performed using a combination of primary and secondary data. The level of primary data used, and the data quality of both primary and secondary data is to be determined and published to enable transparency around the data quality within the calculation. Section 3.1 specifies which processes and activities shall be considered in the LCA. The requirements regarding primary data are specified in Section 3.2. Section 3.4 describes the data quality assessment method. Guidance on the use of secondary data is provided in Section 3.3.

3.1 Included processes

The processes and activity data which shall be included in the LCA according to the FE methodology are specified per life cycle stage in *Table 3*. In the following paragraphs, additional guidance is provided on what data shall be based on primary (supply chain specific) data and what can be obtained from secondary sources.

TABLE 3: PROCESSES OR ACTIVITY DATA WHICH SHALL BE INCLUDED IN THE LCA, DEFINED FOR EACH OF THE LIFE CYCLE STAGES BASED SEVERAL RELEVANT SOURCES.

Life cycle stage	Activity data	Reference methodology
Crop cultivation	Relevant cultivation inputs & outputs: e.g., fertiliser use; yield; co-products	PEF Guidance, FoodDrinkEuropeEurope
Feed production	Processing impact per feed component Ration composition Compound feed composition	PEFCR Feed
Animal production	Productivity Energy consumption Manure management (type of system) Feed conversion ratio or amount of feed	PEFCR Dairy, FCR Red Meat
Ingredient production (including slaughterhouse)	Transport to processing facility Productivity Economic value of co-products Energy consumption	PEF guidance, FoodDrinkEuropeEurope
Food production	Transport to processing facility Energy consumption Amount and type of additional ingredients and auxiliary materials Food losses and other waste Productivity/output Energy production (emission factors)	PEFCR Dairy, PEFCR Dry Pasta, PEFCR Beer, PEFCR Wine, FoodDrinkEuropeEurope
Packaging	Type of packaging material (primary, secondary and tertiary) Amount of material per type (virgin and recycled) (primary, secondary and tertiary) Extraction of raw material Production of packaging material	PEF guidance, FoodDrinkEuropeEurope
Transport and distribution	Average time in distribution centre Use of electricity, heat, refrigerants Per transport leg: Average distance, type of vehicle	PEF guidance, FoodDrinkEuropeEurope

	Emission factors per type of transport Emission factors for energy use, refrigerant leakage	
Retail	Use of electricity, heat, refrigerants Food losses Emission factors per type of transport Emission factors for energy use, refrigerant leakage	PEF guidance, FoodDrinkEuropeEurope
Consumer transport	Transport distance and mode	PEF guidance, FoodDrinkEuropeEurope
Use	Energy requirement for chilled or frozen storage Preparation method and required inputs (heat, frying oil)	PEF guidance, FoodDrinkEuropeEurope
End-of-life	Food waste percentage and destination Recycling rates for packaging	PEF guidance, FoodDrinkEuropeEurope

3.2 Primary data requirements

The environmental labels are product specific, and LCAs are to be performed at a product level. To generate results that reflect the environmental footprint of a specific product, value chain specific data is to be used for the main activities in several life cycle stages. The PEF Method (EC, 2021) does not specify the datapoints for which primary (i.e. value chain specific) data shall be collected. Some PEFCRs do specify more detailed company specific data requirements (such as the Dairy PEFCR). In general, the PEF recommends using primary data for the processes that contribute most to the total environmental footprint. For most food products, primary agri production (cultivation of crops and/or animal production on farm) is a significant contributor to the total environmental footprint. Meanwhile, access to primary farm data is sometimes limited for food producers. Based on discussions with industry experts, a specific primary data requirement list has been drawn up for two groups of food producers: Category 1 and Category 2. The data points defined as 'Primary' are the minimal primary data requirements, additional primary data is preferred and encouraged for all life cycle stages.

3.2.1 Primary data requirements for Category 1 food producers

A Category 1 food producer is defined as a food producer, for which primary production (either crop cultivation for plant-based foods, or animal production for animal-based foods) either falls within company boundaries or takes place at a Tier 1 supplier, meaning there is no intermediate actor between primary production and the food producer. In both cases, the food producers are expected to be in contact or be able to get into contact with the primary producers (farms) to obtain primary data. Typically, the Category 1 food producer is a company or cooperative providing fresh produce or minimal processed produce to retail outlets.

The data requirements for company-specific data per life cycle stage are specified in *Table 4*. As the table shows, primary data is required for key parameters in crop cultivation for plant-based foods, or key parameters in animal production for animal-based foods. In addition, primary data is required for food production and packaging (if relevant).

TABLE 4: PRIMARY DATA REQUIREMENTS FOR CATEGORY 1 FOOD PRODUCERS FOR EACH LIFE CYCLE STAGE.

Life cycle stage	Activity data	Data source
Crop cultivation	For feed: All cultivation inputs: e.g., fertiliser use; yield **For plant-based foods: All cultivation inputs: e.g., fertiliser use; yield**	Secondary from allowed databases **Primary**
Feed production	**Ration composition** **Compound feed composition**	**Primary** **Primary**
Animal production	**Productivity** **Energy consumption** **Manure management (type of system)** **Feed conversion ratio or amount of feed**	**Primary** **Primary** **Primary** **Primary**
Slaughterhouse	Transport to facility Productivity Economic value of co-products **Energy consumption**	Primary or assumption Primary or PEF default Primary; PEF default **Primary**
Food production	Transport to processing facility **Energy consumption** **Amount and type of ingredients and auxiliary materials** **Food losses and other waste** **Productivity/output** Energy production (emission factors)	Primary or PEF default **Primary** **Primary** **Primary** **Primary** Secondary from allowed databases
Packaging (For primary, secondary and tertiary packaging)	**Type of packaging material** **Amount of material per type (virgin/recycled)** **Recycled content** Extraction of raw material Production of packaging material	**Primary** **Primary** **Primary** Secondary from allowed databases
Transport and distribution	Average time in distribution centre Use of electricity, heat, refrigerants Per transport leg: average distance & type of vehicle Emission factors per type of transport Emission factors for energy use, refrigerant leakage	Secondary: PEF default Secondary: PEF default Secondary: PEF default Secondary from allowed databases Secondary from allowed databases
Retail	Use of electricity, heat, refrigerants Food losses Emission factors per type of transport Emission factors for energy use, refrigerant leakage	Secondary: PEF default Secondary: PEF default Secondary from allowed databases Secondary from allowed databases
Consumer transport	Transport distance and mode	Secondary: PEF defaults
Use	Energy requirement for chilled or frozen storage Preparation method and required inputs (heat, frying oil)	Secondary: specification in guidance
End-of-Life	Food waste percentage and destination Recycling rates for packaging	Secondary: PEF defaults

3.2.2 Primary data requirement for Category 2 food producers

A Category 2 food producer is defined as a food producer for which primary production (either crop cultivation for plant-based foods, or animal production for animal-based foods) does not fall within company boundaries, nor does it take place at a Tier 1 supplier. A wide variety of ingredients might be used in food products, which are delivered through different intermediate actors. Therefore, it is expected to be the exception for food processors to have, or obtain, access to primary data on primary production. Typically, the Category 2 food producer is a company which processes different kinds of ingredients into foods, for delivery to retail outlets.

The data requirements for company specific data per life cycle stage are specified in *Table 5*. As the table shows, primary data is not required for crop cultivation or animal production (although is encouraged) but is required for food production and packaging. Criteria for secondary data are explained in 3.4.2.

TABLE 5: PRIMARY DATA REQUIREMENTS FOR CATEGORY 2 FOOD PRODUCERS FOR EACH LIFE CYCLE STAGE.

Life cycle stage	Activity data	Data source
Crop cultivation	All cultivation inputs: e.g., fertiliser use; yield	Secondary from allowed databases
Feed production	Processing impact per feed component Ration composition Compound feed composition	Secondary from allowed databases
Animal production	Productivity Energy consumption Manure management (type of system) Feed conversion ratio or amount of feed	Secondary from allowed databases
Ingredient production (including slaughterhouse)	Transport to processing facility Productivity Economic value of co-products Energy consumption	Secondary from allowed databases
Food production	Transport to processing facility **Energy consumption** **Amount and type of ingredients and auxiliary materials** **Food losses and other waste** **Productivity/output** Energy production (emission factors)	Primary or PEF default **Primary** **Primary** **Primary** **Primary** Secondary from allowed databases
Packaging	**Type of packaging material** **Amount of material per type (virgin/recycled)** **Recycled content** Extraction of raw material Production of packaging material	**Primary** **Primary** **Primary** Secondary from allowed databases Secondary from allowed databases
Transport and distribution	Average time in distribution centre Use of electricity, heat, refrigerants Per transport leg: average distance & type of vehicle Emission factors per type of transport	Secondary: PEF default Secondary: PEF default Secondary: PEF default Secondary from allowed databases

	Emission factors for energy use, refrigerant leakage	Secondary from allowed databases
Retail	Use of electricity, heat, refrigerants Food losses Emission factors per type of transport Emission factors for energy use, refrigerant leakage	Secondary: PEF default Secondary: PEF default Secondary from allowed databases Secondary from allowed databases
Consumer transport	Transport distance and mode	Secondary: PEF defaults
Use	Energy requirement for chilled or frozen storage Preparation method and required inputs (heat, frying oil)	Secondary: specification in guidance
End-of-Life	Food waste percentage and destination Recycling rates for packaging	Secondary: PEF defaults

3.2.3 Data sampling procedure

The requirements as laid down in the PEF guidance regarding primary data collection are to be followed. With regard to sample size this implies that the minimum applied sample size for company-specific data is $\sqrt{n}$ in case of n entities in one sub-population. This means, for example, that data shall be gathered for a representative $\sqrt{n}$ number of processing facilities in the food processing stage. Another example, for food producers is that if a distinction is made between organic and regular production, and production systems are significantly different in the north and the south of the country of origin, then four production system groups (organic-north; organic-south; regular-north; regular-south) are distinguished and a sample of $\sqrt{n}$ is considered for each of the four groups. This approach is compliant with the PEF Method (EC, 2021).

The primary data shall be representative of the current operation and shall not be older than 5 years.

Data shall be gathered for the most recent 12 month period for which data is available. The intention of the 12 month period is to level out any seasonal differences. In the case that the production cycle exceeds 12 months, then data shall be gathered for the entire production cycle.

At cultivation, for annual crops, an assessment period of at least three years shall be used to level out differences in crop yields related to fluctuations in growing conditions over the years such as climate, pests, and diseases (as indicated in the PEF). For perennial plants (including entire plants and edible portions of perennial plants) a steady state situation (i.e. where all development stages are proportionally represented in the studied time period) shall be assumed and a three year period shall be used to estimate the inputs and outputs (as indicated in the PEF).

3.3 Secondary data

To be fully PEF compliant, either PEF-compliant datasets shall be used (EF database) or the data quality of all other used datasets shall be assessed with the Data Quality Rating formula. Currently, EF 3.0 is not yet available and there is an ongoing discussion whether the expired EF 2.0 can still be used. This discussion makes it unclear whether it is possible to be fully PEF compliant at the moment. Currently, PEFCRs do not exist for all product groups within the scope of this methodology description, so no EF 2.0 data is available for all food product categories. Furthermore, the PEF compliant databases are not always transparent due to the fact that they report aggregated results, so it is not possible to derive the contribution of different life cycle stages from the available information. Finally, EF 2.0 and EF 3.0 data is only allowed to be used for PEF

compliant studies and it is not permitted to use this data outside the PEF framework. It is probable that the EF 4 datasets will be made available (open source), but it is likely that it will still take several years to develop and publish those. This means that for the FE LCA methodology other commercial or non-commercial databases will need to be used. A starting point for selection of background databases are the suppliers of the EF datasets like EcoInvent (Ecoinvent, 2019) or Agri-footprint (Blonk et al., 2022).

3.3.1 Preference hierarchy for secondary data

The LCA methodology provides recommended data sources to be used for secondary data (or sub-processes) for each life cycle stage. The following hierarchy shall be applied when selecting background data to be used:

1. Preferably, the same data sources will be used for all product groups for consistency and the specific data sources are to be selected for their suitability (in terms of completeness and data quality) for the specific processes. The data quality of the recommended databases is high enough for application in the LCA methodology, as they have been determined by evaluation of available databases according to the criteria set by the FE LCA task force (see paragraph 3.3.2 *Criteria for secondary data sources*).
2. A list of alternative data sources which may be used is provided below. Those data sources match fewer criteria as set by the FE LCA task force but comply with most of them. The use of these data sources will be associated with a lower background data quality unless a certain dataset is only available in the alternative data source (see Section 3.4 about data quality assessment).
3. In the case that no suitable datapoint is found in the sources described in point 1 and 2, a proxy shall be selected. *Appendix III.* provides an approach to select a suitable proxy. The use of a proxy will be associated with a lower data quality score (see *chapter about data quality assessment*).

3.3.2 Criteria for secondary data sources

Together with the task force members a set of criteria for the selection of preferred background databases have been drafted. These criteria have been set to make fair comparison possible and, as far as possible, to align with PEF:

- PEF compliant farm emission modelling
- PEF compliant LUC modelling
- Peat emissions
- Multi impact assessment (all relevant activity data available)
- Representativeness of datasets (e.g., country average)
- Consistent use of data sources of key parameters (e.g., fertiliser application, yields)
- Compliant with FE allocation methods
- Transparent (well documented methodology report)
- Frequently reviewed and updated (<5 years old)
- Externally reviewed
- Availability of food products

We selected the most applied background databases in the feed & food industry to assess:

- EcoInvent 3.9
- Agri-footprint 6.2
- GFLI
- World Food Life cycle Database (WFLDB)
- Agribalyse

EcoInvent, Agri-footprint and WFLDB are suppliers of PEF data. GFLI is mentioned as an alternative data source in the PEF. Agribalyse was added to the assessment as this database has a high availability of food products. The results of the qualitative assessment can be found in *Appendix II.* Evaluation of databases

3.3.3 Selection of preferred data source

Not every database complies with all the criteria set above. When selecting the preferred database, the overall results of the assessment were used, but in addition, the availability of food and feed ingredient items in the specific database have also been considered. If alternative data sources are required, any of the above-mentioned databases can be used (considering the data quality score).

TABLE 6: PREFERRED DATA SOURCE.

Life cycle stage	Background data needs	Preferred data source	Alternative data source
Independent of life cycle stage	Energy production Transport processes Packaging material production	EcoInvent EcoInvent EcoInvent	WFLDB / Agribalyse / Agri-footprint / EcoInvent
Crop cultivation	Agrochemical production	EcoInvent or Agri-footprint	
Animal production	Feed ingredient production	Agri-footprint or GFLI	
Ingredient & food production	Fruit & vegetables	WFLDB	
	Coffee, cocoa	WFLDB	
	Animal & marine products	Agri-footprint[3]	
	Vegetable oils, starch products, grains, sugar	Agri-footprint	
	Other ingredients	WFLDB or Agri-footprint	

Some specific considerations when selecting the preferred data source per food/feed ingredient category are:

- EcoInvent is the most used database for energy, transport and material processes
- GFLI is the global initiative of the feed industry and accepted by the industry as standard (Agri-footprint contains the same processes as GFLI so can also be used)
- WFLDB has the highest availability for fruit and vegetable production (with European scope)
- Agri-footprint has the highest availability for commodity agro-production and uses consistent data sources (with European scope)

3.3.4 Proxy methodology

When performing a food product LCA, data gaps are frequently encountered. An approach to fill those data gaps is necessary to make a fair comparison between different product footprints possible. As different LCA practitioners will make use of different background databases (allowed in this FE methodology) it becomes very time consuming at this stage to provide proxies for all kind of ingredients in all available databases. Hence, a more generic proxy methodology is proposed.

[3] In the process for raw milk production in Agri-footprint, the allocation keys shall be adapted to biophysical allocation. Allocation factor (AF) are provided by PEFCR Dairy:

$$AF = 1 - 6.04\ x\ \frac{M_{meat}}{M_{milk}}$$

When the process/product is not available in the background database (for the specific origin), the proxy methodology shall be used as described in *Appendix III*. Appendix III. Alternatively, the LCA practitioner can try to model the missing process/product based on value chain specific information combined with estimates and/or literature, considering the calculation rules as described in this document.

3.4 Data quality assessment

Data quality is a measure of the condition of a certain data point based on parameters such as accuracy, completeness, consistency, reliability, or others. Data quality is important as a complementary assessment of the applicability of (LCA) environmental results. Importantly, data quality shall assess both data source (primary/secondary) and the background data used in the LCA models. The scoring/grading system could also be connected to data quality ratings in e.g. bonus/malus points (though, the grading method is out of scope of the current LCA methodology).

According to the PEF, Data Quality Rating (DQR) shall be calculated as:

$$DQR = \frac{\overline{Te_R}+\overline{G_R}+\overline{Ti_R}+\bar{P}}{4}$$

*Where **TeR** is the Technical Representativeness, **GR** is the Geographical Representativeness, **TiR** is the Time Representativeness and **P** is the Precision, and values are 1 to 5.*

With the PEF DQR method, precise, accurate data quality ratings can be calculated. However, the PEF DQR method is very time consuming, complex to apply and it is difficult to interpret the results from it. Additionally, not all background databases contain DQR scores, which makes it impossible to apply in a FE method.

3.4.1 Approach

For the new methodology, a simplified approach to data quality assessment that is based on the PEF recommendations has been developed. While the PEF rating system requires numerical scoring for four quality characteristics (time representativeness, geographical representativeness, technological representativeness, and precision), a more qualitative approach has been developed which will ease the assessment and its interpretation. See *Appendix IV.* Example of data quality assessment for an example of the data quality assessment method.

Similarly to the PEF DQR method, both the foreground and background data shall be assessed. The following aspects shall be considered,

[accuracy foreground data; year foreground data; accuracy background data].

Multiple categories have been defined and can be found in *Table 7: Data quality assessment*.

TABLE 7: DATA QUALITY ASSESSMENT.

	Quality rating category	Definition
Foreground accuracy	Measured	Datapoint is measured/documented by the data provider (e.g., kWh from electricity bill, number of grams in a recipe)
	Estimate	Datapoint is estimated (e.g., plant average electricity consumption or based on expert judgement) or based on literature (representative technology)
	Default	Datapoint is a default value provided by the PEF/FE methodology
Background accuracy	Primary	Datapoint is connected to a process that is based on primary data (the process is supply chain specific)
	Good	Datapoint is connected to a background dataset that matches the product and country of origin
	Middle	Datapoint is connected to a background dataset that matches the product but not the country (origin not known or not available in background database)
	Low	Datapoint is connected to a background dataset that does not match the product, a proxy is chosen as followed by FE proxy methodology

When connecting background data and assessing the data quality, the following rules shall be applied:

- When the process/product is not available in the background database (for the specific origin) the proxy methodology shall be used as described in Appendix III. The background accuracy is to be defined accordingly.
- When a process/product from an alternative background database (as defined in *Table 6*) is used, the quality rating of the background accuracy is downgraded one level unless the dataset is only available in the alternative database.
- Each process in the LCA model shall be assessed separately.
- Direct (farm) emissions:
    - Emissions from fertiliser application are to be assessed as one process (1 foreground data quality rating for N, P and K application)
    - Emissions from manure are to be assessed as one process (1 foreground data quality rating for activity data related to emission from manure)
    - Emissions from animals are to be assessed as one process (1 foreground data quality rating for activity data related to enteric emissions)
    - Background processes are not assessed (as there is no connection to background process)

The following section presents examples of how the data quality rating is to be practically applied:

1. Primary data for electricity consumption given by food producer at their factory and matched to the country grid would become [**measured; 2022; good**]
2. A PEF default for refrigerant leakage at retail where there is no foreground data, connected to a generic refrigerant production dataset would become [**default; n.d.; middle**]

3. Using a proxy of wheat cultivation for a feed ingredient, while knowing the exact quantity, would become [**measured; 2022; low**]

4. Using wheat (RER) instead of wheat (NL) cultivation for a feed ingredient, while knowing the exact quantity, would become [**measured; 2022; middle**]

3.4.2 Weighing the data quality ratings

Similarly, to the PEF DQR method, the data quality assessment shall be weighted based on the contribution of the process to the total environmental single score (see also Chapter on impact assessment method).

For each life cycle stage that is modelled, the contribution to the total single score impact for each process to that life cycle stage is calculated. To assess the total data quality assessment, the specific rating of each process is weighted based on the single score contribution to the total footprint of that life cycle stage (see also use case in *Appendix IV. Example of data quality assessment*).

Additionally, some key parameters in LCA, which are not reflected in the contribution to the total impact, but do have a significant effect on the total impact, are weighted:

- Mass balance (yield in case for farm production)
- Allocation keys (in case of multifunctional processes)

The PEFCR for feed (European Commission, 2020) provides fixed weighing factors for those parameters for both farm production and further processing.

Farm production	**Weight**
Yield	12.5%
Allocation keys	2.5%
Processing	
Mass balance	2.5%
Allocation keys	10%

This means that the following activity (foreground) data shall be assessed:

- Yield / mass balance
- Relative price (economic allocation), DM content (mass allocation) or energy content (energy allocation)

Background accuracy is not assessed (as there is no connection to a background database).

The other foreground data assessment is rescaled to 100% (hence maintaining the relative values).

3.4.3 Reporting data quality rating

The data quality rating shall be aggregated and reported for each life cycle stage (as defined in Section 3.4.1 Life cycle stages).

In the case that primary data is available on the production of inputs (e.g. for food processing life cycle stage, some food ingredients are based on primary production data), the data quality assessment of the underlying processes are aggregated based on the contribution of that input to the single score of the life cycle stage (see also use case in *Appendix IV. Example of data quality assessment*).

The foreground accuracy score for each life cycle stage is then aggregated to an overall foreground accuracy score based on the single score contribution of each life cycle stage.

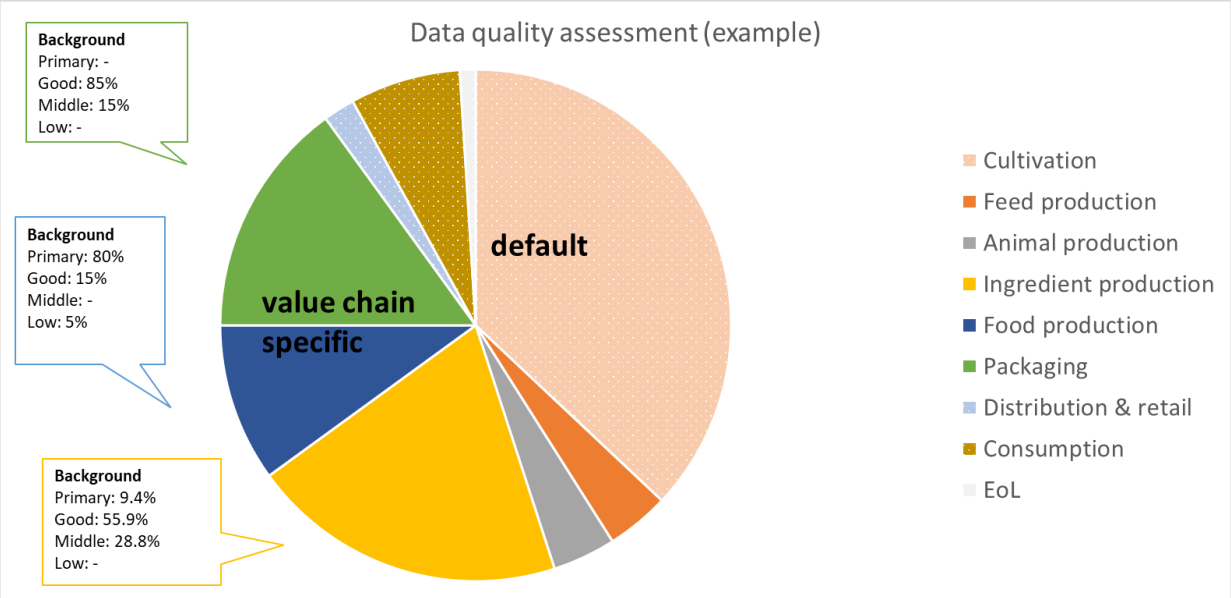
The data quality assessment is reported in a pie diagram showing the share of ‘value chain specific’ data (foreground accuracy ‘measured’ or ‘estimate’) and ‘default’ (foreground accuracy ‘default).

See a reporting example below.

Data quality assessment report

Overall foreground accuracy:
Good 45.4%
Estimate 1.6%
Default 53.0%
Year: 2021 (rounded)

TABLE 8: EXAMPLE OF DATA QUALITY REPORT.



3.4.4 Tooling

Even though the proposed data quality assessment method below is a simplification of the PEF DQR, we recommend developing specific tooling to perform the proposed data quality assessment. Specifically, the aggregation and reporting of the data quality score can be time consuming without proper tools.

4. Calculation methodology

In LCA, several modelling choices need to be made with regards to important topics such as multifunctionality, emissions modelling, or end-of-life. These modelling choices affect the results and are often caused by inconsistencies between different LCA methodologies. In this chapter, the most relevant modelling choices are considered and recommendations on how to develop a consistent approach are presented.

4.1 Allocation

Whenever a process provides more than one function (e.g. delivering several goods and/or services), it is considered multifunctional. Multifunctionality implies that it can be difficult to divide the environmental burden of the process between its different functions. According to the ISO 14044 standard, allocation should be avoided by, for instance, subdividing the process into multiple sub-processes to correctly share the environmental burden. When allocation cannot be avoided, then multiple approaches can be applied.

Following the PEF and the different PEFCRs present certain inconsistencies that need to be solved. For example, the recommended allocation at dairy processing is economic in the Feed PEFCR but dry matter-based in the Dairy PEFCR. To allow fair comparisons for food products of different food categories, allocation type needs to be harmonised for each process.

In the table below, the allocation approaches are listed per reporting category, and their choice justified. The PEF, together with the relevant PEFCRs, are the leading documents for the proposed approaches. The Hortifootprint Category Rules (HFCR) (Helmes et al., 2020) are used instead of the Flori-PEFCR, as the final version has not been published yet.

The allocation type as listed in *Table 9* shall be applied.

TABLE 9: ALLOCATION APPROACHES, PER REPORTING STAGE.

Reporting category	Allocation type	Justification
	Economic, between main product and co-products	Recommended in the PEF
Crop cultivation	Energy, between different energy outputs (e.g., electricity and heat production) at CHP (combined heat and power) in greenhouse cultivation	Recommended in the HFCR
	Area, for multiple crops in greenhouse (net area)	Recommended in the HFCR
Animal husbandry	Economic, at feed production	Recommended in the Feed PEFCR

	Biophysical, for dairy (IDF, 2015) and small ruminants farming. Economic, for other animals farming[4]	Recommended in the PEF
	Economic, at slaughterhouse. Default allocation keys as provided by the PEF shall be applied[5].	Recommended in the PEF
	Economic, for manure production. If manure has no economic value at farm gate, cut-off is applied	Recommended in the PEF
Ingredient production	Economic	To be consistent with most of the other allocation approaches (PEFCR feed, draft PEFCR olive oil, PEFCR pasta)
Food production	Economic	To be consistent with most of the other allocation approaches (PEFCR feed, draft PEFCR olive oil, PEFCR pasta)
Packaging	Not relevant	
Distribution	Volume, for retail and distribution storage spaces	Recommended in the PEF
	Mass, for transport or volume, if transport limited by volume	Recommended in the PEF
Use	Not relevant	
End-of-life	Circular Footprint Formula	Recommended in the PEF

Prices needed for economic allocation shall be used from the different PEFCRs if available. For poultry, economic values for allocation are provided and extracted from the Agri-footprint Methodology (Blonk Consultants, 2019) and summarised in the table below.

[4] Biophysical allocation would be the preferred method for all farm systems. As no sound methodology is available for other animal types then ruminants is available, economic allocation is chosen as preferred method and currently applied as best practice in industry. Economic allocation factors for pig production is provided by the footprint category rules for red meat. Economic allocation factors for poultry production is provided in *Table 10: Economic allocation data for poultry* production.

[5] Before applying allocation, grouping of different meat types is necessary. In this case, as in the PEF, meat for human consumption is considered all part of the same group

TABLE 10: ECONOMIC ALLOCATION DATA FOR POULTRY PRODUCTION.

Product	Unit	Economic value
Meat	Euros / kg live weight	0,176
Egg	Euros/ kg egg	0,854

If not available in the PEFCR, prices shall be representative for the region in scope and shall be the average prices for a recent 3 year-period. Taxes, transport, and insurance should not be included in the price.

4.2 Emissions modelling

Emissions modelling is an important component of certain stages of the supply chain, and crop cultivation and animal farming in particular. Emissions modelling refers to the accounting of emissions that originate from a process, for instance as a result of combustion, oxidation, or dissolution. The proposed approach follows the PEF when possible. Whenever the PEF lacks guidance (animal farming), additional approaches based on the PEFCRs and best available standards are presented.

It is important to note that the proposed approaches to emission modelling for both crop cultivation and animal farming focuses on Low Tier levels. This choice is taken in order to ensure consistency and comparability throughout different supply chains over precision. Higher Tier levels are currently not permissible. This approach is subject to modification in a future update of this methodology in the case that the technical committee of the EC proposes a different approach.

The recommended modelling approach for emissions related to peatland, land use change, and carbon sequestration are discussed later in this document.

4.2.1 Crop cultivation

In crop cultivation, the same approach as in the existing PEF is followed for the modelling of the direct and indirect emissions. The following emissions shall be included in the modelling:

- From pesticides application:
    - Emissions to air (PEF recommendation 9%)
    - Emissions to soil (PEF recommendation 90%)
    - Emissions to water (PEF recommendation 1%)
- From fertilisers application:
    - NH_3, to air (from N-fertiliser application)
    - N_2O, to air (direct and indirect) (from N-fertiliser application)
    - CO_2, to air (from lime, urea, and urea-compounds application)
    - NO_3, to water unspecified (leaching from N-fertiliser application)

  - PO_4, to water unspecified or freshwater (leaching and run-off of soluble phosphate from P-fertiliser 2110 application)
  - P, to water unspecified or freshwater (soil particles containing phosphorous, from P-fertiliser 2112 application)
  - Heavy metals
- From rice cultivation (methane)
- From other activities including seed material, peat to soil, lime, machine use, N from crop residues

Emissions from fertilisers application shall be modelled following the Tier 1 approach as proposed in the IPCC and summarised in table 14 from the PEF (EC, 2021).

4.2.2 Animal farming

Emissions modelling for animal farming systems shall include, as a minimum, emissions from enteric fermentation, from manure handling in the stable, during on-farm manure storage and during pasture.

The emission models to be used are extracted from: the Dairy PEFCR (European Commission, 2018), the LEAP guidelines (FAO, 2016) and the PEF pilot Red Meat (Technical Secretariat for the Red Meat Pilot, 2019). Specific information per animal system is provided below, including the recommended Tier levels for the emissions modelling. The reported emission models are to be intended as recommendations based on best practices and expert judgement. More simplified emission models (e.g. IPCC Tier 1) are also allowed as long as all relevant emission flows are included.

TABLE 11: RECOMMENDED EMISSION MODELS FOR ANIMAL FARMING.

Animal system	Emission flows to be included	Emission models	Documentation
Beef and Dairy	Methane (CH_4) from enteric fermentation	IPCC Tier 2	Dairy PEFCR (European Commission, 2018)
	CH_4 from manure	IPCC Tier 2	Dairy PEFCR (European Commission, 2018)
	Direct dinitrogen monoxide (N_2O) from manure (storage, excretion, and application)	IPCC Tier 2	Dairy PEFCR (European Commission, 2018)
	Indirect N_2O from leaching of manure (storage, excretion and application)	IPCC Tier 2	Dairy PEFCR (European Commission, 2018)
	Indirect N_2O from volatilisation of ammonia (NH_3) and nitrogen oxides (NOx)	IPCC Tier 2	Dairy PEFCR (European Commission, 2018)
	NH_3 and NOx	EMEP/EAA tier 2	Dairy PEFCR (European Commission, 2018)

	Non-methane volatile organic compounds (NMVOC) from manure	EMEP/EAA tier 2	Dairy PEFCR (European Commission, 2018)
	Particulate matter (PM2.5 and PM10) from animal housing	EMEP/EAA tier 2	Dairy PEFCR (European Commission, 2018)
	Phosphate (PO_4-) from manure (excretion and application)	Amount of phosphorus applied	Dairy PEFCR (European Commission, 2018)
	Phosphorus (P) from manure (excretion and application)	Amount of phosphorus applied	Dairy PEFCR (European Commission, 2018)
	Nitrate (NO_3) from manure (excretion and application)	IPCC Tier 1	Dairy PEFCR (European Commission, 2018)
	Heavy metals from manure (application)	Heavy metal emissions from field inputs shall be modelled as emission to soil and/or leaching or erosion to water.	Dairy PEFCR (European Commission, 2018)
Poultry	Methane (CH_4) from enteric fermentation	Considered negligible (0.01-2g per head per year according to the LEAP)	LEAP guidelines on poultry production (FAO, 2016)
	CH_4 from manure	IPCC Tier 2	LEAP guidelines on poultry production (FAO, 2016)
	Direct dinitrogen monoxide (N_2O) from manure (storage, excretion and application)	IPCC Tier 2	LEAP guidelines on poultry production (FAO, 2016)
	Indirect N_2O from leaching of manure (storage, excretion and application)	IPCC Tier 2	LEAP guidelines on poultry production (FAO, 2016)
	Indirect N_2O from volatilisation of ammonia (NH_3) and nitrogen oxides (NOx)	IPCC Tier 2	LEAP guidelines on poultry production (FAO, 2016)
	NH_3 and NOx	EMEP/EAA tier 2	LEAP guidelines on poultry production (FAO, 2016)
	Non-methane volatile organic compounds (NMVOC) from manure	EMEP/EAA tier 2	LEAP guidelines on poultry production (FAO, 2016)

	Particulate matter (PM2.5 and PM10) from animal housing	EMEP/EAA tier 1	LEAP guidelines on poultry production (FAO, 2016)
Pig	Methane (CH_4) from enteric fermentation	IPCC Tier 2	PEF pilot Red Meat (Technical Secretariat for the Red Meat Pilot, 2019)
	CH_4 from manure	IPCC Tier 2	PEF pilot Red Meat (Technical Secretariat for the Red Meat Pilot, 2019)
	Direct dinitrogen monoxide (N_2O) from manure (storage, excretion and application)	IPCC Tier 2	PEF pilot Red Meat (Technical Secretariat for the Red Meat Pilot, 2019)
	Indirect N_2O from leaching of manure (storage, excretion and application)	IPCC Tier 2	PEF pilot Red Meat (Technical Secretariat for the Red Meat Pilot, 2019)
	Indirect N_2O from volatilisation of ammonia (NH_3) and nitrogen oxides (NOx)	IPCC Tier 2	PEF pilot Red Meat (Technical Secretariat for the Red Meat Pilot, 2019)
	NH_3 and NOx	EMEP/EAA tier 2	PEF pilot Red Meat (Technical Secretariat for the Red Meat Pilot, 2019)
	Non-methane volatile organic compounds (NMVOC) from manure	EMEP/EAA tier 2	PEF pilot Red Meat (Technical Secretariat for the Red Meat Pilot, 2019)
	Particulate matter (PM2.5 and PM10) from animal housing	EMEP/EAA tier 2	PEF pilot Red Meat (Technical Secretariat for the Red Meat Pilot, 2019)

At this moment, despite the fact that no guidance is provided for other animal systems such as fish, goat, sheep, or ducks, the emissions coming from such animal systems shall be accounted for.

4.2.3 Emissions from drained peat soils

When cultivation occurs on peat soil, significant GHG emissions can occur. Most importantly, CO_2 emissions occur from carbon oxidation and N_2O emissions occur from nitrogen mineralisation. Despite the fact that peatland emissions are usually difficult to estimate, the PEF states that *drained peat soils shall include carbon dioxide emissions on the basis of a model that relates the drainage levels to annual carbon oxidation.* Emissions from drained peat soil will also be included in the EF datasets that are about to be published.

As a minimum, CO_2 emissions from drained peat soils shall be included. Default emissions factors are provided by the IPCC (IPCC, 2014), or emissions factors are provided in a country's National Inventory Report. In the case that the background data used does not include emissions from drained peat soils, it is necessary to calculate them in addition.

4.2.4 Emissions from land use change

Emissions from land use change shall be accounted for as indicated in the PEF. These refer to the emissions of carbon as CO_2 initially stored in biomass and lost due to change in land use (e.g. from forest to cropland or from grassland to cropland).

Following the PEF implies the application of the PAS 2050 approach (BSI, 2012), hence the implementation of a direct land use accounting approach that considers an equal amortisation of the emissions over a period of 20 years. This approach is extensively described in the PAS 2050 Annex B (BSI, 2012).

Additionally, the GHG Protocol for land management draft (WRI-WBCSD, 2022) - regarding the allowed chain-of-custody systems in the case that land use change free certifications are to be included - shall be followed.

4.2.5 Carbon sequestration

Carbon sequestration is a highly debatable topic due to the lack of consensus on accounting methodologies and the lack of available data. For the moment, we recommend following the (conservative) PEF approach and not to account for any carbon sequestration. When a robust accounting methodology becomes available within the PEF framework, carbon sequestration could be included in a further development of the Foundation Earth methodology.

4.3 End-of-life

The Circular Footprint Formula (CFF) shall be applied for the modelling of the End-of-Life of products as indicated in the PEF. The CFF is a way to divide benefits and burdens of recycling and energy recovery from waste incineration, and consists of three parts:

- Material: production and shaping impact of virgin and recycled material input and credit for recycling at end of life
- Energy: emissions and avoided emissions related to waste incineration with energy recovery
- Disposal: emissions from landfilling

$$\text{Material } (1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

$$\text{Energy } (1-B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

$$\text{Disposal } (1-R_2-R_3) \times E_D$$

FIGURE 2: THE CIRCULAR FOOTPRINT FORMULA.

The parameters of the CFF can be found in the PEF Appendix (EC, 2021), to be used as defaults in the case that primary data is not available.

5. Impact assessment

As indicated in the PEF, environmental impacts shall be calculated for all 16 impact categories, also reported in the table below.

TABLE 12: IMPACT CATEGORIES

Impact category	Indicator	Unit	Robustness
Climate change	Radiative forcing as Global Warming Potential (GWP100)	kg CO_2 eq	I
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11 eq	I
Ionising radiation, Human Health	Human exposure efficiency relative to U235	kBq U235 eq	II
Photochemical ozone formation, Human Health	Tropospheric ozone concentration increase	kg NMVOC eq	II
Particulate matter	Human health effects associated with exposure to small particulate matter (PM2.5)	Disease incidences	I
Human toxicity, cancer	Comparative Toxic Unit for humans (CTUh)	CTUh	III/interim
Human toxicity, non-cancer	Comparative Toxic Unit for humans (CTUh)	CTUh	III/interim
Acidification (terrestrial and freshwater)	Accumulated Exceedance (AE)	mol H+ eq	II
Eutrophication freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P eq	II
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N eq	II
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq	II
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTUe)	CTUe	III/interim
Land use	Soil quality index (Biotic production, Erosion resistance, Mechanical filtration, Groundwater replenishment)	Dimensionless (pt)	III
Water use	User deprivation potential (deprivation-weighted water consumption)	m^3 world eq.	III
Resource use, fossils	Abiotic resource depletion (ADP fossil)	MJ	III
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq	III

After the characterisation step, impacts shall be aggregated into a single score, as indicated in the PEF. This aggregation occurs by evaluating the relevance and robustness of each of the impact categories and calculating weighting factors (already provided by the PEF). The weighting factors are reported in the table below.

	Aggregated weighting set	Robustness factors	Calculation	**Final weighting factors**
WITH TOX CATEGORIES (not applied in pilot phase)	(50:50)	(scale 1-0.1)		
	A	B	C=A*B	C scaled to 100
Climate change	12.9	0.87	11.18	**21.06**
Ozone depletion	5.58	0.6	3.35	**6.31**
Human toxicity, cancer	6.8	0.17	1.13	**2.13**
Human toxicity, non-cancer	5.88	0.17	0.98	**1.84**
Particulate matter	5.49	0.87	4.76	**8.96**
Ionizing radiation, human health	5.7	0.47	2.66	**5.01**
Photochemical ozone formation, human health	4.76	0.53	2.54	**4.78**
Acidification	4.94	0.67	3.29	**6.2**
Eutrophication, terrestrial	2.95	0.67	1.97	**3.71**
Eutrophication, freshwater	3.19	0.47	1.49	**2.8**
Eutrophication, marine	2.94	0.53	1.57	**2.96**
Ecotoxicity, freshwater	6.12	0.17	1.02	**1.92**
Land use	9.04	0.47	4.22	**7.94**
Water use	9.69	0.47	4.52	**8.51**
Resource use, minerals and metals	6.68	0.6	4.01	**7.55**
Resource use, fossils	7.37	0.6	4.42	**8.32**

FIGURE 3: WEIGHTING FACTORS FOR CALCULATING THE SINGLE SCORE.

6. Deviations from the PEF

This chapter provides a condensed explanation of all the deviations that have been proposed in the FE methodology compared to the PEF or the sector PEFCRs, in order to create a harmonised method.

TABLE 13: OVERVIEW OF THE DEVIATIONS FROM THE PEF

Topic	Conflict/issue	Harmonisation/ solution	Deviates from
Functional unit	Sector PEFCRs use different functional units, such as the Feed PEFCR where the functional unit is 1 ton of animal feed as fed or the Pasta PEFCR where the functional unit is 1 kg of dry pasta	Using 1kg of consumed product as functional unit allows for a fair comparison between different food products, it is simple to apply and communicate, and can easily be translated to different units if needed (e.g., nutritional values)	All sector PEFCRs
Life cycle stages	Each sector PEFCRs define their own stages as these are highly dependent on what the sector's typical supply chains look like.	The defined life cycle stages are always applicable and provide an insightful break down of all food products' life cycle. These are based on the PEF general recommendations with a finer granularity for the relevant stages such as crop cultivation and animal farming	All sector PEFCRs
System boundaries	PEFCRs use different system boundaries, specifically for the use stage (for example, the packed water PEFCR includes dishwashing and cup production)	Additional guidance is provided on what processes to include, raw-to-cooked ratios, and cooking methods	PEFCR packed water (dishwashing and cup production) PEFCR dairy (dishwashing)
Secondary data	EF 3.0 is not yet available, and EF 2.0 is expired. EF datasets are only allowed to be used in a PEF study. The availability of EF data is limited for certain food product categories	Alternative and more extensive sources of secondary data are provided, carefully selected based on strict criteria	All sector PEFCRs
DQR	No DQR available in all background databases. PEF DQR method is considered very time consuming, complex to apply and difficult to interpret results	A simpler and more applicable approach to data quality assessment is provided	PEF guidance

Allocation	Different allocation at dairy processing (e.g., whey production): economic allocation in PEFCR feed vs. mass allocation in PEFCR dairy	Economic allocation (to align with allocation type in other feed & food processing steps)	Dairy PEFCR
	Different allocation at crop cultivation for Grape production – allocation of co-products (grape must and grape pomace): mass allocation in PEFCR wine vs economic allocation in PEF guidance for cultivation of crops and feed PEFCR		Wine PEFCR
	Different allocations at food production: mass allocation in pasta PEFCR (although pasta waste is considered 0% allocation anyway) and wine PEFCR		Pasta PEFCR and wine PEFC

7. Limitations & future developments

This Beta Version 1.0 of the FE methodology aims to cover all of the most relevant aspects of LCA applied to food products. However, methodology, data and guidance gaps will still remain. It is expected that specific topics will be further developed in the future, in particular:

- Primary data requirements: the proposed approach to data requirements is based on expert judgement and is meant to encourage companies to collect a considerable amount of primary data. It is possible that by piloting this methodology LCA practitioners realise that the requirements are either too strict, or could be stricter, depending on what data is available. This especially applies to the proposed categorisation between food producers and food processors.

- Secondary data: this methodology gives guidance for the use of secondary data. Several issues can be expected in the use and need for secondary data:
    - Data gaps: it is probable that there will be data gaps for many specific food ingredients, and that no datasets are available within the data sources listed. Further development of good secondary data is recommended.
    - Compatibility with impact assessment method: it is likely that not all data sources will be fully compatible with the impact assessment method. Specifically for land use and water consumption, regionalised flows are necessary which are not always available. Further compatibility assessment is recommended.

- Data quality assessment: the proposed simplified approach requires testing as it is still questionable whether the results of such approach are easy enough to assess while at the same time remaining usable and insightful. The methodology might be refined based on the findings of the piloting phase.

- Carbon sequestration: for the moment, the rather conservative approach (as also indicated in the PEF) is applied (carbon sequestration not included). However, as newer methodologies develop and as the interest on carbon sequestration rises, it is important to revaluate the inclusion of carbon sequestration in LCA calculations.

- Impact assessment: despite the fact that all impact categories are included in the single score calculations, there is still an existing debate on the robustness of the toxicity impact categories and their potential exclusion from single score calculation for communication to consumers. This aspect will be evaluated in the case that the PEF position on these impact categories changes in the future.

- Biodiversity: another very relevant aspect related to farming practices, is for the moment only indirectly considered (i.e., some impact categories do have an effect on biodiversity but a category specifically referring to biodiversity is not available). This limitation is, however, intrinsic to the PEF method and is not based on any choice made within this FE methodology, despite the importance of assessing biodiversity being recognised.

8. References

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Appendix I. Use phase modelling

TABLE 14: OVERVIEW OF STORAGE CONDITIONS AND PREPARATION

Exposure hierarchy (L1)	Exposure hierarchy (L2)	Storage conditions	Preparation
Alcoholic beverages	Alcoholic beverages	Ambient (unless differently specified in the categories below)	None
	Beer and beer-like beverage	Chilled according to PEFCR Beer	None
	Mixed alcoholic drinks	Chilled	None
	Unsweetened spirits and liqueurs	Ambient	None
	Wine and wine-like drinks	Chilled only for sparkling and white and rosé wines according to PEFCR Wine	None
Animal and vegetable fats and oils and primary derivatives thereof	Animal and vegetable fats and oils and primary derivatives thereof	Ambient	None
	Animal and vegetable fats/oils	Ambient	None
	Fat emulsions and blended fats	Ambient	None
Coffee, cocoa, tea and infusions	Hot drinks and similar (coffee, cocoa, tea and herbal infusions)	Ambient	Heating to 100 degrees
	Ingredients for coffee	Ambient	Boiling of water: amount specified in *Table 19*.
	Ingredients for cocoa	Ambient	Dilution with water, powder to water 1:9, heating to 100 degrees
	Ingredients for tea and herbal infusions	Ambient	Boiling of water: amount specified in *Table 19*.
Composite dishes	Dishes, incl. Ready to eat meals (excluding soups and salads)	50% Chilled & 50% frozen	Microwave warming
	Fried or extruded cereal, seed or root-based products	Chilled	Microwave warming
	Soups and salads	Chilled	Microwave warming for soups, None for salads
	Spoonable desserts and ice creams (generic)	Chilled or frozen, same as storage method at retail	None
Eggs and egg products	Processed eggs	Ambient	50% boiling & 50% frying
	Unprocessed eggs	Chilled	50% boiling & 50% frying
Fish, seafood, amphibians, reptiles and invertebrates	Amphibians, reptiles, snails, insects	50% Chilled & 50% frozen	50% boiling & 50% frying
	Crustaceans	50% Chilled & 50% frozen	50% boiling & 50% frying
	Fish (meat)	50% Chilled & 50% frozen	Frying
	Fish and seafood processed	50% Chilled & 50% frozen	Frying
	Fish offal	50% Chilled & 50% frozen	Frying
	Molluscs	50% Chilled & 50% frozen	Boiling
	Sea urchins and other echinoderms	50% Chilled & 50% frozen	Boiling
	Other food for infants and children	Ambient	None

Food products for young population	Processed cereal-based food for infants and young children	Ambient	Addition of tap water and heating if required for consumption.
	Ready-to-eat meal for infants and young children	Ambient	Microwave warming
Fruit and fruit products	Fruit and fruit products	50% Chilled & 50% ambient	Consider loss of product weight due to peeling
	Fruit used as fruit	50% Chilled & 50% ambient	Consider loss of product weight due to peeling
	Processed fruit products	50% Chilled & 50% ambient	None
Fruit and vegetable juices and nectars (including concentrates)	Concentrated or dehydrated fruit/vegetables juices	30% chilled, 70% ambient (based on PEFCR packed water)	None
	Extracts of plant origin	30% chilled, 70% ambient (based on PEFCR packed water)	None
	Fruit / vegetable juices and nectars	30% chilled, 70% ambient (based on PEFCR packed water)	None
	Fruit and vegetable juices and nectars (including concentrates)	30% chilled, 70% ambient (based on PEFCR packed water)	None
	Liquid or gel separated from plant RPCs	30% chilled, 70% ambient (based on PEFCR packed water)	None
Grains and grain-based products	Bread and similar products	Ambient	None
	Breakfast cereals	Ambient	None
	Cereals and cereal primary derivatives	Ambient	None
	Fine bakery wares	Ambient	None
	Pasta, doughs and similar products	Ambient	Boiling
Legumes, nuts, oilseeds and spices	Legumes	Ambient	Boiling
	Nuts, oilseeds and oilfruits	Ambient	None
	Processed legumes, nuts, oilseeds and spices	Ambient	None
	Spices	Ambient	None
Major isolated ingredients, additives, flavours, baking and processing aids	Food additives other than flavours, colours and artificial sweeteners	Ambient	None
	Food colours	Ambient	None
	Food flavourings	Ambient	None
	Isolated proteins and other protein products	Ambient	None
	Maltodextrins and similar	Ambient	None
	Miscellaneous agents for food processing	Ambient	None
	Starches	Ambient	None
Meat and meat products	Animal liver and other non-muscle edible offal	Chilled	Frying
	Animal meat dried	Ambient	None
	Animal mechanically separated meat (MSM) (in processed foods and snacks)	Frozen	Frying
	Canned-tinned meat	Ambient	Frying
	Mammal and bird meat	Chilled	Frying
	Marinated meat	Chilled	Frying

	Meat and meat products	Chilled	Frying
	Meat specialties	Chilled	Frying
	Preserved/processed fat tissues	Ambient	None
	Processed whole meat products	Chilled	Frying
	Sausages	Chilled	Frying
Milk and dairy products	Cheese	Chilled	None
	Dairy dessert and similar	Chilled	None
	Fermented milk or cream	Chilled	None
	Milk and dairy powders and concentrates	Ambient	Dilution with water, powder to water 1:9 (PEFCR Dairy: DM of dried semi-skimmed milk is 96.4% and of fresh semi-skimmed milk 10.5%)
	Milk, whey and cream	Chilled	None
Other ingredients	Artificial sweeteners (e.g., aspartam, saccharine)	Ambient	None
Products for non-standard diets, food imitates and food supplements	Food for particular diets	Ambient	None
	Food supplements and similar preparations	Ambient	None
	Meat and dairy imitates	Chilled	Frying
	Products for non-standard diets, food imitates and food supplements	Ambient	None
Seasoning, sauces and condiments	Condiments (including table-top formats)	Chilled	None, for concentrates or powders: addition of water, and heating to 100 degrees
	Dessert sauces/toppings	Chilled	None
	Mixed and other not listed condiments	Ambient	None
	Savoury extracts and sauce ingredients	Ambient	Addition of water, and heating to 100 degrees
	Seasoning, sauces and condiments	Ambient	None
	Seasonings	Ambient	None
	Seasonings and extracts	Ambient	None
Starchy roots or tubers and products thereof, sugar plants	Starchy root and tuber products	Frozen or chilled, same as storage method at retail	50% boiling & 50% frying
	Starchy roots and tubers	Ambient	50% boiling & 50% frying
	Starchy roots or tubers and products thereof, sugar plants	Ambient	50% boiling & 50% frying
	Sugar plants	Ambient	50% boiling & 50% frying
Sugar and similar, confectionery and water-based sweet desserts	Confectionery including chocolate	Ambient	None
	Sugar and other sweetening ingredients (excluding intensive sweeteners)	Ambient	None
	Sugar and similar, confectionery and water-based sweet desserts	Ambient	None
	Table-top sweeteners formulations	Ambient	None
	Water-based sweet desserts	Frozen or chilled, same as storage method at retail	None
	Algae and prokaryotes organisms	50% Chilled & 50% ambient	None

Vegetables and vegetable products	Bulb vegetables (garlic and onions)	50% Chilled & 50% ambient	50% boiling & 50% frying
	Flowering brassica (broccoli and cauliflower)	50% Chilled & 50% ambient	Boiling
	Flowers used as vegetables	50% Chilled & 50% ambient	Frying
	Fruiting vegetables (mainly pumpkin and sweet corn)	50% Chilled & 50% ambient	Boiling
	Fungi, mosses and lichens (mainly mushrooms)	50% Chilled & 50% ambient	Frying
	Herbs and edible flowers	50% Chilled & 50% ambient	None
	Leafy vegetables (cole/brassica, lettuce, spinach)	50% Chilled & 50% ambient	None
	Legumes with pod	50% Chilled & 50% ambient	Boiling
	Processed or preserved vegetables and similar (such as tomator concentrate)	50% Chilled & 50% ambient	Heating to 100 degrees
	Root and tuber vegetables (excluding starchy- and sugar-) (mainly carrots and read beats)	50% Chilled & 50% ambient	50% boiling & 50% none
	Sprouts, shoots and similar (such as tauge)	50% Chilled & 50% ambient	None
	Stems/stalks eaten as vegetables (mainly leek)	50% Chilled & 50% ambient	50% boiling & 50% frying
	Vegetables and vegetable products	50% Chilled & 50% ambient	50% boiling & 50% frying
Water and water-based beverages	Beverages concentrates	30% chilled, 70% ambient (based on PEFCR packed water)	Dilution with water: Concentrate to water 1:8
	Drinking water	Chilled according to PEFCR packed water	None
	Water and water-based beverages	30% chilled, 70% ambient (based on PEFCR packed water)	None
	Water based beverages	30% chilled, 70% ambient (based on PEFCR packed water)	None

Additional guidance for preparation

Main parameters determining the impact of the use stage are the energy use for preparation, and mass losses or gains during the preparation process. Where the PEF guidance, or specific PEFCRs provide guidance, this shall be used. In cases where no guidance is provided in the PEF, some general assumptions are taken in the definition of the use stage. These are specified in the tables below.

TABLE 15: DEFAULT VALUES USED FOR CALCULATIONS REGARDING FOOD PREPARATION

Parameter	PEF default
Inedible part	Not provided in PEF, see *Table 20:*
Raw to cooked	Not provided in PEF, see *Table 20:*
Oil input frying	0.005 kg/kg
Butter input	Not considered
Energy cooking	Dependent on product type, specified below
Fraction electric cooking	25%
Fraction gas cooking	75%

Energy for cooking is determines based on a number of factors:

- Type of preparation technique
- Mass of food (and water) input for preparation
- Fraction of electric and natural gas cooking, although for some preparations it is 100% electric

TABLE 16: OVERVIEW OF PREPARATION TECHNIQUES AND AMOUNT OF INPUT PER KG OF INPUT

Preparation technique	Electricity (kWh)	Energy source	Oil use	Water?
Deep frying	0.667 (default value)	Always electric	0.005 kg/kg	-
Pan frying	See *Table 17*	25% electric, 75% natural gas	0.005 kg/kg	-
Boiling	See *Table 18*	25% electric, 75% natural gas	-	Yes, defaults per group
Water cooker	0.127 kWh/kg (default value)	Always electric	-	Yes, product specified
Oven	3000 W * time (default = 20 min)	Always electric	-	-
Microwave	1100 W * time (default = 7 min)	Always electric	-	-
Chilled at consumer	77.7 kWh/ton	Always electric	-	-
Freezing at consumer	294 kWh/ton	Always electric	-	-
No preparation	-	-	-	-

TABLE 17: BAKING TIME ON LOW AND HIGH HEAT FOR "PAN FRYING" PREPARATION OPTION

Product category (PEF)	Baking time low (600 W)	Baking time high (3500 W)
Meat and meat alternatives	4 min	7 min
Other foods	8 min	0 min
Fruit and vegetables	3 min	7 min
Grain products	8 min	0 min

TABLE 18: BOILING TIME AND ADDED WATER PER KG OF PRODUCT FOR "BOILING" PREPARATION OPTION

Product category (PEF)	Boiling time	Added water (L/kg)
Meat and meat alternatives	120 min	0.2
Fruit and vegetables	11 min	0.7
Grain products	15 min	1.5
Other foods	5 min	5
Prepared/processed meals (chilled)	10 min	5
Product category (in line with L1 or L2 categories)	**Boiling time**	**Added water (L/kg)**
Meat and meat products	120 min	0.2
Fish, seafood, amphibians, reptiles and invertebrates	10 min	0.05

Unprocessed eggs	5 min	5
Vegetables and vegetable products	11 min	0.7
Starchy roots or tubers and products thereof, sugar plants (e.g., Potatoes)	20 min	0.8
Cereals and cereal primary derivatives (based on rice)	15 min	1.5
Pasta, doughs and similar products	10 min	5

TABLE 19: INPUTS AND ADDED WATER FOR BEVERAGES PREPARED AT CONSUMERS

Beverage	Input (kg/kg)	Water added	Comment
Coffee (beverage)	0.05833	1.10	Based on PEF data (7g/120 ml)
Coffee	0.05833	1.10	Based on PEF data (7g/120 ml)
Coffee drink, espresso	0.1325	1.10	Based on PEF data (5.3g/40 ml)
Coffee drink, café americano	0.05833	1.10	Based on PEF data (7g/120 ml)
Instant coffee, liquid	0.05833	1.10	Based on PEF data (7g/120 ml)
Tea	0.01	1	
Black tea, infusion	0.01	1	
Fruit tea, infusion	0.01	1	
Lemonade	0.12	0.88	
Lemonade (light)	0.08	0.92	
Soup vegetable based dried packet prep	0.16	0.84	
Stock from cube prepared	0.226	0.774	

TABLE 20: DEFAULT RAW-2-COOKED RATIOS & EDIBLE FRACTION (EXTRACTED FROM GLOBODIET METHODOLOGY (EPIC-SOFT) AND (VOEDSEL CONSUMPTIE PEILING 2019-2021, 2023

Product category	Product	Edible fraction	R2C	Boiled	Baked	Roasted	Fried
Potatoes and other tubers							
	Jerusalem artichoke	0.8	0.98		0.80	0.80	0.60
	Pom/ sweet potato, other starchy tubers	0.84	0.98		0.80	0.80	0.60
	Yam	0.81	0.98		0.80	0.80	0.60
	Cassava	0.9	0.98		0.80	0.80	0.60
Potatoes							
	Spiced potatoes cubes/slices/wedges/baby potatoes		0.8	0.98	0.80	0.80	0.80
	Baby potato	0.8	0.98	0.98	0.80	0.80	0.80
	Duchess potatoes		0.7		0.80	0.80	0.80

	Potato wedges		0.8	0.98	0.80	0.80	0.80
	Potato figures		0.8		0.80	0.80	0.80
	Potato cubes		0.8	0.98	0.80	0.80	0.80
	Potato	0.8	0.98	0.98	0.80	0.80	0.80
	Potato croquette/product		0.7		0.80	0.80	0.80
	Potato slices		0.8	0.98	0.80	0.80	0.80
	Fries, normal/n.s.		0.58		0.70	0.70	0.58
	Oven fries		0.7		0.70	0.70	0.58
	Ras®fries		0.7		0.80	0.80	0.80
	Potato gnocchi without filling		1.03	1.03			
	Rösti		0.7		0.80	0.80	0.80
Unclassified, mixed salad/vegetables							
	Vegetable mix for macaroni/spaghetti		0.83				
	Vegetable mix for hotchpotch		0.86				
	Vegetable mix, Japanese/Mexican/Italian/Dutch/stir fry		0.8				
	Vegetable mix, mushrooms		0.73				
	Soup vegetables, for vegetable/pea soup		0.85				
	Vegetable mix, noodles		0.84				
	Peas and carrot		0.9				
	Vegetable mix, macedoine		0.95				
	Vegetable mix, n.s.		0.82				
	Snow peas and carrot		0.91				
	Raw vegetables		0.67				
	Soup vegetables, n.s.		0.85				

	Vegetable mix, Mexican		0.95			
	Vegetable fries		0.58	0.70	0.70	0.58
Leafy vegetables (except cabbage)						
	Lambs/Lollo Bionda/rosso, lettuce	0.9	0.6			
	Kelp/Seaweed, n.s.		0.95			
	Romaine/Batavia lettuce	0.8	0.6			
	Endive	0.85	0.67			
	Endive in sauce		0.67			
	Grape leaf		0.6			
	Chicory	0.9	0.65			
	Leafy vegetables	0.85	0.65			
	Water/Chinese spinach	0.9	0.6			
	Purslane	0.95	0.6			
	Turnip greens	0.9	0.37			
	Oak lettuce	0.8	0.6			
	Frisée lettuce	0.85	0.7			
	Iceberg lettuce	0.8	0.7			
	Lettuce head/ dandelion lettuce/ lettuce n.s./ lettuce red/spinach	0.8	0.6			
	Rocket	0.8	0.7			
	Corn salad	0.95	0.58			
	Chard	0.5	0.6			
	Spinach in cream		0.6			
	Elephant ear	0.51	0.65			
	Cress	0.7	0.6			

	Watercress	0.95	0.6			
	Chicory	0.9	0.8			
	Seaweed, nori		0.95			
Fruiting vegetables						
	Palm hearts, canned		0.98			
	Zucchini, n.s. yellow/green	0.9	0.88			
	Tomato	0.95	0.78			
	African eggplant	0.85	0.9			
	Artichoke	0.45	0.9			
	Eggplant	0.8	0.93	0.40	0.40	0.40
	Pickle	0.95	1			
	Avocado	0.72	0.99			
	Plantains	0.75	0.9			
	Butterbeans/green beans/ green pods	0.95	0.88			
	String beans	0.95	0.91			
	Vegetable, fruit, n.s.	0.83	0.9			
	Cucumber	0.9	0.88			
	Garter	0.95	0.88			
	Lady's fingers/gumbo	0.95	0.95			
	Bell pepper, yellow	0.74	0.87	0.85	0.85	
	Bell pepper, green/n.s./ orange/ red	0.8	0.87	0.85	0.85	
	Pods	0.9	0.91			
	Pumpkin	0.75	0.9	0.85	0.85	
	Indian beans/Bitter melon	0.9	0.9			

	Spanish pepper	0.87	0.9	0.85	0.85
	Sugar snap pea	0.9	0.91		
	Tomato. Normal/n.s./vine/beef	0.95	0.78		
	Tomato, cherry	0.95	0.8		
	Samphire		0.9		
Root vegetables					
	Turnip	0.75	0.9		
	Parsnip	0.9	0.9		
	Red beet	0.8	0.85		
	Vegetable, tuber, root, n.s.	0.8	0.9		
	Burdock root	0.9	0.9		
	Celeriac	0.7	0.86		
	Swede	0.8	0.92		
	Kohlrabi	0.8	0.9		
	Radish	0.95	0.95		
	Horseradish	0.9	0.95		
	Radish (Big white root vegetable)	0.85	0.95		
	Salsify	0.65	0.9		
	Carrot, n.s./winter carrot	0.9	0.9		
Cabbages					
	Brown mustard/mustard greens	0.85	0.77		
	Broccoli	0.55	0.94		
	Cabbage, white	0.75	0.94		

	Kale	0.55	0.8
	Cabbage, Chinese	0.85	0.7
	Cabbage, Green/savoy, Brussel sprouts	0.8	0.8
	Cabbage, n.s./oxheart	0.85	0.8
	Cabbage, red/white	0.85	0.93
	Red cabbage with apple		0.93
	Sauerkraut		0.95
	Bok choy	0.85	0.7
	Roman cauliflower	0.75	0.94
Mushrooms			
	Mushrooms/shiitake	0.92	0.6
	Chanterelles/Oyster mushrooms	0.9	0.57
	Mushrooms, n.s.	0.9	0.6
Grain and pot vegetables			
	Peas	0.35	0.92
	Capuchins		0.98
	Corn	0.7	0.99
	Broad beans	0.45	0.94
Stalk vegetables, sprouts			
	Onion, Sweet	0.95	0.81
	Garlic	0.85	0.85
	Leek	0.8	0.81

	Leek in cream		0.81	
	Shallot	0.75	0.81	
	Onion, normal (brown peel)/spring/n.s./red	0.95	0.81	
	Alfalfa		0.8	
	Asparagus, green/n.s./white	0.8	0.91	
	Bamboo shoots	0.8	0.96	
	Celery	0.7	0.83	
	Vegetable, stalk, n.s.	0.8	0.96	
	Vegetable, sprout, n.s.	0.65	0.82	0.65
	Soy sprouts	0.65	0.82	0.65
	Fennel	0.85	0.83	
Legumes				
	Beans, pinto/brown/white/flageolets/capuchins	2.6	0.98	
	Lentils, red/brown/n.s./black Kidney beans	2.35	0.98	
	Split peas/ green split peas/yellow/beans aduki/yellow eye beans/ peas, dry n.s.	2.5	0.98	
	Beans, dried, n.s. / red kidney beans	2.38	0.98	
	Beans, mung	2.44	0.98	
	Beans, black eye	2.64	0.98	
	Peas, chick	2.2	0.98	
	Beans, soy	2.4	0.98	
Unclassified, mixed fruits, nuts				
	Sweet jackfruit, canned			
	Fruit, mixed forest fruits	0.98		

Pear, n.s.	0.8
Prickly pear	0.6
Strawberry	0.95
Apricot	0.78
Pineapple	0.5
Apple	0.85
Awarra fruit	0.85
Banana (normal)	0.7
Berry, blue/red/white	0.98
Berry, huckle	0.98
Berry, goose	0.95
Berry, n.s.	0.95
Black currant	0.98
Starfruit	0.97
Lemon (flesh)	0.52
Cranberry	0.98
Date	0.86
Grapes n.s., blue/white	0.95
Fruit, citrus, n.s.	0.7
Fruit, n.s.	0.75
Fruit, non-citrus, n.s.	0.75
Pomegranate/grapefruit	0.6
Guava	0.9
Persimmon	0.98
Cherry	0.95

	Kiwi, golden/green	0.83	
	Kumquat	0.89	
	Lime	0.99	
	Lychee	0.7	
	Tangerine	0.6	
	Mango	0.84	
	Melon, cantaloupe	0.6	
	Melon/honeydew	0.65	
	Melon, Galia	0.6	
	Melon, cantaloupe/water	0.6	
	Ogen melon	0.55	
	Melon (Cucumis melo)	0.65	
	Tangor	0.76	
	Nectarine	0.83	
	Papaya	0.7	
	Passion fruit	0.55	
	Pear, hand	0.87	
	Pear, cooking	0.8	1.9
	Peach	0.835	
	Pomelo	0.59	
	Plums	0.92	
	Orange	0.7	
	Melogold grapefruit	0.6	
	Tamarind	0.41	
	Jamaican tangelo	0.65	

Nuts, peanuts, seeds		
	Coconut	0.6
	Peanuts, n.s.	0.75
	Almonds	0.4
	Chestnuts	0.75
	Hazel, nuts	0.45
	Macadamia, nuts	0.35
	Nuts, n.s.	0.75
	Para, nuts	0.46
	Pecan, nuts	0.49
	Pistachio	0.5
	Walnuts	0.6
	Peanuts, normal	0.75
	Pumkin seeds	0.54
	Seeds, n.s.	0.9
	Sunflower seeds	0.54
Olives		
	Olives, n.s., green/black	0.75
	Olives, filled, green	
Pasta, rice, other grain		
	Pasta/dough, lentils	2.7
	Filled tortellini/filled ravioli/cannelloni	2.3

	Quinoa	3.5					
	Rice, enriched with fibers/mixed with grain and nuts	2.8					
	Buckwheat/bulgur/barley/groats/ grain n.s./oat	3.5					
	Couscous/millet/noodles/spiced instant noodles	3					
	Pasta, gluten free	2.7					
	Pasta, lasagna/unfilled pasta/unfilled whole wheat/pasta n.s./pasta enriched with fiber	2.7					
	Rice, n.s./wild/white	2.8					
	Rice, brain	2.6					
	Rye/wheat/vermicelli	3.5					
Unclassified and combined meat							
	Meat mixed with plant-based product		0.8	0.70	0.75	0.75	0.80
	Meat, n.s.		0.7	0.65			
	Gyros, n.s.		0.7	0.75	0.75	0.70	0.70
	Schnitzel, not filled, not coated		0.7	0.80	0.80	0.80	0.70
Unclassified, mixed							
	Minced meat, mixed/n.s.		0.85	0.70	0.75	0.75	0.85
Beef							
	Tournedos/steak/sirloin steak, beef		0.8	0.65	0.70	0.70	0.80
	Steak, brisket, beef		0.6	0.65	0.70	0.70	0.60
	Minced meat, beef		0.85	0.70	0.75	0.75	0.85
	Stew, meat		0.8	0.70	0.75	0.75	0.80

	Brisket, beef		0.6	0.65	0.70	0.70	0.60
	Steak, n.s.		0.8	0.65	0.70	0.70	0.80
	Stew meat with lining of fat /steak to stew in microwave		0.6	0.65	0.70	0.70	0.60
	Steak, n.s./beef n.s.		0.7	0.65			
	Steak, rib,/brisket n.s./ stew meat n.s.		0.6	0.65	0.70	0.70	0.60
	Tenderloin/beef poulet/beef strips/rib eye/roast beef		0.8	0.65	0.70	0.70	0.80
	Roulade, beef		0.6	0.65	0.70	0.70	0.60
	Shank, beef	0.5	0.8	0.65	0.70	0.70	0.80
	Schnitzel, beef, not coated		0.7	0.65	0.75	0.75	0.70
	Tartar, beef		0.8	0.70	0.75	0.75	0.80
	T-bone steak, beef	0.85	0.8	0.65	0.70	0.70	0.80
Veal							
	Veal, tenderloin/brisket/steak/sirloin steak/fricandeau/lean steak/steak n.s./escalope/poulet/veal strips/roulade/schnitzel (not coated)/tournedos		0.7	0.65	0.75	0.75	0.70
	Shank, veal	0.5	0.7	0.65	0.75	0.75	0.70
	Minced meat, veal		0.65	0.65	0.75	0.75	0.65
	Cutlet, veal	0.85	0.7	0.65	0.75	0.75	0.70
	Veal, n.s.		0.68	0.65	0.75	0.75	0.68
Pork							
	Slice of bacon		0.6	0.70			
	Pork fillet/fricandeau/tenderloin/slice of pork meat/slice of ham/lean slice of pork meat/slice of pork meat n.s./slice of pork meat, shoulder/pork n.s./escalope/roulade/tenderloin/loin/rib/schnitzel (not coated)		0.7	0.65	0.75	0.70	0.70

	Minced meat, pork		0.75	0.65	0.75	0.70	0.75
	Ham, pork, on bone	0.86	0.7	0.65	0.75	0.70	0.70
	Slice of ham, pork		0.7	0.75	0.75	0.75	0.70
	Porkchop	0.93	0.7	0.65	0.75	0.70	0.70
	Porkchop	0.86	0.7	0.65	0.75	0.70	0.70
	Rib, Pork	0.5	0.75	0.75	0.75	0.70	0.75
	Pork poulet/strips of pork/gyros/sparerib		0.7	0.75	0.75	0.70	0.70
Lamb							
	Lamb poulet/gyros/minced meat/tenderloin/slice of meat/escalope/strips of lamb/roulade		0.7	0.68	0.75	0.75	0.70
	Leg of lamb	0.8	0.7	0.68	0.75	0.75	0.70
	Lamb chop	0.7	0.7	0.68	0.75	0.75	0.70
	Cutlet, lamb	0.79	0.7	0.68	0.75	0.75	0.70
	Lamb shoulder/lamb n.s.	0.8	0.7	0.68	0.75	0.75	0.70
	Lamb, back	0.7	0.7	0.68	0.75	0.75	0.70
	Short saddle, lamb	0.85	0.7	0.68	0.75	0.75	0.70
	Leg of sheep	0.8	0.7	0.68	0.75	0.75	0.70
	Minced meat, sheep/Turkish minced meat sheep		0.7	0.68	0.75	0.75	0.70
	Cutlet, sheep	0.7	0.7	0.68	0.75	0.75	0.70
	Sheep, n.s.	0.8	0.7	0.68	0.75	0.75	0.70
Horse							
	Horse steak/stew meat/slice of horsemeat/horse n.s./roast beef horse		0.7	0.65			

Goat							
	Goat chop	0.8	0.7	0.68	0.75	0.75	0.70
	Goat, n.s.		0.7	0.68	0.75	0.75	0.70
Rabbit							
	Rabbit, Breast, with bone, tame	0.5	0.75	0.68	0.88	0.88	
	Rabbit, tame, n.s.	0.64	0.75	0.68	0.88	0.88	
	Rabbit leg, tame	0.7	0.75	0.68	0.88	0.88	
	Rabbit back, tame	0.6	0.75	0.68	0.88	0.88	
Poultry							
	Poultry, n.s.	0.65	0.7	0.75			
	Steak, ostrich	0.8	0.7	0.75			0.75
	Fillet, ostrich/ostrich n.s.		0.7	0.75			0.75
	Chicken thighs (Not smoked)		0.7	0.75			0.75
	Chicken breast/fillet	0.65	0.7	0.75			
	Chicken drumsticks	0.8	0.7	0.75			
	Minced meat, chicken	0.8	0.85	0.70	0.75	0.75	0.85
	Whole chicken/chicken chop		0.7	0.75			
	Chicken, n.s.	0.65	0.7	0.75			
	Chicken leg (whole leg)	0.8	0.7	0.75			
	Chicken strips (Not smoked)	0.65	0.7	0.75			0.75
	Roulade, chicken	0.8	0.7	0.75			
	Chicken soup	0.65	0.65		0.70	0.70	
	Dutch chicken wings/poussin	0.8	0.7	0.75			

	Chicken wings	0.65	0.7	0.75		
Turkey						
	Turkey steak/fricandeau/tenderloin/escalope/roulade		0.7	0.75		0.75
	Turkey, breast	0.68	0.7	0.75		
	Turkey, drumstick	0.67	0.7	0.75		
	Turkey fillet		0.7	0.75		0.75
	Turkey chop/turkey n.s.	0.67	0.7	0.75		
	Strips of turkey/schnitzel (uncoated)		0.7	0.75		0.75
	Tournedos, turkey	0.6	0.7	0.75		
	Turkey wing	0.75	0.7	0.75		
Duck						
	Duck breast/drumstick/leg/duck n.s.	0.67	0.6			
	Fillet, duck		0.6			
Goose						
	Goose drumstick/wing/goose n.s.	0.67	0.65			
	Goose fillet		0.65			
Game						
	Red deer steak		0.75			
	Rabbit	0.73	0.75	0.68	0.88	0.88
	Leg of rabbit (game)	0.8	0.75	0.68	0.88	0.88

	Meat, game-, n.s.	0.7	0.7	0.75		
	Pheasant	0.58	0.7	0.75		0.75
	Quail	0.55	0.75			
	Partridge	0.55	0.7	0.75		0.75
Hot processed meat						
	Soup meatballs/meatballs ready to eat		0.98			
	Meatballs, factory made raw		0.9	0.85	0.87	0.87	0.90
	Meatball, made at home, raw		0.9	0.85	0.87	0.87	0.90
	Schnitzel (meat, no chicken/turkey)		0.7	0.75	0.70	0.70	0.70
	Schnitzel, Turkey, coated		0.7	0.75	0.70	0.70	0.70
	Schnitzel, pork, coated		0.7	0.75	0.70	0.70	0.70
	Schnitzel, chicken, coated with corn/breadcrumbs		0.7	0.75			0.70
	Bacon strips, cubes, n.s.		0.6	0.70			
	Schnitzel, meat, filled and coated/nuggets/chicken nuggets/cordon bleu		0.8				
	Burger, beef		0.75	0.70	0.75	0.75	0.75
	Meatball		0.9	0.85	0.87	0.87	0.90
	Lamb shawarma		0.7	0.68	0.75	0.75	0.70
	Burger, (meat) n.s.		0.75	0.70	0.75	0.75	0.75
	Cordon bleu, (minced meat)		0.8				
	Minced meat hotdog/chicken minced meat hotdog		0.9				
	Burger		0.75	0.70	0.75	0.75	0.75
	Bacon strips, lean		0.6	0.70			
	Bacon strips,		0.3	0.70			
	Bacon for sauerkraut		0.8				

	Sausage, BBQ/bratwurst/chipolata/sausage n.s.		0.75	0.95	0.75	
	Bacon		0.6	0.70		
	Beam mash/black pudding		0.8			
	Salted, smoked pork loin		0.95			
	Smoked bacon/breakfast bacon		0.6	0.70		
Organ meat						
	Heart	0.85	0.6			0.55
	Brains		0.8			
	Liver/kidneys		0.7			
	Stomach	0.9	0.9			
	Organ meat, n.s.		0.75			
	Tongue	0.8	0.85			
	Sweetbread		0.9			
Vegetarian meat replacers						
	Vegetarian fish product/steak/cordon bleu/vegetable burger/fillet/schnitzel/strips/nuggets/cheese schnitzel/seitan/minced meat/meatballs/falafel	n.a.	0.95			
	Vegetarian frankfurter	n.a.	1			
	Tempeh	n.a.	0.91			
	Bean curd/Tofu	n.a.	0.94			
	Vegetarian burger (no vegetable burger)	n.a.	0.95			
Seafood						
	Fruits de mer		0.75			

Fish						
	Anchovies	0.76	0.9	0.80	0.75	0.70
	Perch	0.5	0.9	0.80	0.75	0.90
	Smoked red herring	0.65	0.9	0.80	0.75	0.90
	Red herring	0.55	0.9	0.80	0.75	0.90
	European flounder	0.45	0.9	0.80	0.75	0.90
	Bream/halibut	0.5	0.9	0.80	0.75	0.90
	Trout/brill/herring n.s.	0.55	0.9	0.80	0.75	0.90
	Herring, pan	0._	0.9	0.80	0.75	0.90
	Cod	0.8	0.9	0.80	0.75	0.90
	Carp	0.55	0.9	0.80	0.75	0.90
	Coalfish	0.4	0.9	0.80	0.75	0.90
	Mackerel/pangasius/weever	0.6	0.9	0.80	0.75	0.80
	Eel	0.7	0.9	0.80	0.75	0.65
	Gurnard	0.5	0.9	0.80	0.75	0.90
	Ray	0.74	0.9	0.80	0.75	0.90
	Sardine	0.6	0.9	0.80	0.75	0.70
	Common dab	0.6	0.9	0.80	0.75	0.90
	Haddock	0.45	0.9	0.80	0.75	0.90
	Plaice	0.6	0.9	0.80	0.75	0.90
	Pike	0.6	0.9	0.80	0.75	0.90
	Zander	0.5	0.9	0.80	0.75	0.90
	Smelt	0.6	0.9	0.80	0.75	0.90
	Sprat	0.65	0.9	0.80	0.75	0.80

	Stockfish	0.6	0.9	0.80	0.75	0.90
	Turbot	0.55	0.9	0.80	0.75	0.90
	Tilapia/sole (fish)/tuna/fish n.s./white fish n.s./sea fish n.s./freshwater fish n.s.	0.6	0.9	0.80	0.75	0.90
	Whiting/salmon	0.65	0.9	0.80	0.75	0.90
	Salmon trout	0.55	0.9	0.80	0.75	0.90
	Monkfish/tench	0.6	0.9	0.80	0.75	0.90
	Wolf eel	0.5	0.9	0.80	0.75	0.90
Crustaceans, molluscs						
	Shrimp, pink	0.5	0.75			
	Slug, wine	0.2	0.9			
	Coquille	0.3	0.9			
	Shrimp, Dutch	0.5	0.75			
	Prawn, n.s.	0.5	0.9	0.80	0.80	0.75
	Shrimp, n.s.	0.5	0.75			
	Octopus	0.8	0.5			
	Crab	0.25	0.9			
	Lobster	0.36	0.9			
	Mussels	0.24	0.67			
	Oysters	0.15	0.8			
	Shellfish	0.3	0.9			
	Slugs	0.2	0.9			
	Mollusks, n.s.	0.4	0.7			

Fish products, fish in crumbs						
	Caviar/surimi/spawn	n.a.	0.9			
	Fried pieces cod fish (coated)/fried cod, whole fish, coated/haddock liver/fish burger, coated/ fish fillet, coated/ fish products, coated/ fish schnitzel/fish stick	n.a.	0.9			
Amphibians and reptiles						
	Frog legs	0.65	0.8			
Eggs						
	Egg		1	1.00	0.85	0.90
Insects						
	Insects	0.8				
Deep fried products						
	Croquette, n.s.		0.9			
	Fried and coated cheese		0.95			
	Spring roll, n.s.		0.85			

Appendix II. Evaluation of databases

Criteria			Databases				
Aspect	Specific item	Explanation	Agri-footprint 6.3	Agribalyse 3.1	World Food LCA Database (WFLDB)	Ecoinvent v3.9	Global Feed LCA Initiative (GFLI) - V2 (2022)
Quality	Externally reviewed	Is the database externally reviewed?	No	Yes	Yes	Yes	Partly
	Extensive methodology report	Is activity data and modelling approach well defined?	Yes	Yes	Partly	Partly	Yes
Completeness	Geographical scope	Is there worldwide coverage?	Yes	No	Partly	Yes	Yes
	Coverage of different food categories	Are all food categories covered?	Partly	Yes	Partly	Partly	No
	Impact categories	Multi impact assessment?	Yes	Partly	Partly	Yes	Yes
Accessibility	Accessibility	Is it open source?	No	Yes	No	No	Yes
Methodology alligned with PEF	Direct farm emissions	Modelling PEF aligned?	Yes	Partly	Yes	Yes	Partly
	LUC emissions incl. carbon sequestration	Modelling PEF aligned?	Yes	Partly	Partly	Yes	Yes
	Peat emissions	Modelling PEF aligned?	Yes	No	Yes	No	Yes
	Representativeness and comparability of cultivation datasets	Farm modelling based on consistant representative data sources?	Yes	Partly	Partly	Partly	Yes
	Allocation	Allocation alligned with PEF/FE method?	Yes	Yes	Yes	Yes	Yes
Up-to-date	Reference time	Is the database <10 years old?	Yes	Yes	Yes	Yes	Yes
	Update frequency	Is the database being updated once every 3 years?	Yes	Partly	Yes	Yes	Yes
TOTAL Yes			10	6	6	8	10
TOTAL Partly			1	5	6	3	2

FIGURE 4: EVALUATION OF DATABASES, RESULTS.

FoodEx2 top level categories	Agri-footprint 6.3	Agribalyse 3.1	WFLDB	Ecoinvent	GFLI
Grains and grain-based product	Yes	Yes	Yes	Yes	No
Vegetables and vegetable products	Yes	Yes	Yes	Yes	No
Starchy roots or tubers and products thereof, sugar plants	Yes	Yes	Yes	Yes	No
Legumes, nuts, oilseeds and spices	Yes	Yes	Yes	Yes	No
Fruit and fruit products	No	Yes	Yes	Yes	No
Meat and meat products	Yes	Yes	Yes	Yes	No
Fish, seafood, amphibians, reptiles and invertebrate	No	Yes	No	Yes	No
Milk and dairy products	Yes	Yes	Yes	Yes	No
Eggs and egg products	Yes	Yes	No	No	No
Sugar and similar, confectionery and water-based sweet desserts	Yes	Yes	No	Yes	No
Animal and vegetable fats and oils and primary derivatives there	Yes	Yes	Yes	Yes	No
Fruit and vegetable juices and nectars (including concentrates)	No	Yes	Yes	No	No
Water and water-based beverages	No	Yes	No	No	No
Alcoholic beverages	No	Yes	No	No	No
Coffee, cocoa, tea and infusions	No	Yes	Yes	No	No
Food products for young population	No	Yes	No	No	No
Products for non-standard diets, food imitates and food supplement	No	No	Yes	No	No
Composite dishes	No	Yes	No	No	No
Seasoning, sauces and condiments	No	Yes	Yes	No	No
Major isolated ingredients, additives, flavours, baking and processing aids	No	No	Yes	No	No
Other ingredients	No	No	Yes	No	No
TOTAL # categories covered	9	18	14	10	0

FIGURE 5: EVALUATION OF DATABASES, INCLUSION OF FOOD PRODUCTS.

Appendix III. Proxy methodology

When performing a food product LCA, data gaps are encountered quite often. An approach to fill those data gaps is necessary to make a fair comparison between different product footprints possible. As different LCA practitioners will make use of different background databases (allowed in this Foundation Earth methodology) it becomes very time consuming at this stage to provide proxies for all kind of ingredients in all available databases. Hence, a more generic proxy methodology is proposed.

For this proxy methodology the different L1 and L2 food ingredient categories of the European Food & Safety Agency (EFSA, 2011) shall be applied (see full table with categories in Appendix I. Use phase modelling). Some L2 categories have been adapted below to better reflect ingredients with a similar footprint profile (meat and dairy products and fruits).

TABLE 21: FOOD INGREDIENT CATEGORIES.

Exposure hierarchy (L1)	Exposure hierarchy (L2) (adapted)
Coffee, cocoa, tea and infusions	Coffee
	Cocoa
	Tea and herbal infusions
Fruit and fruit products	Apples and pears
	Citrus (oranges, grapefruits, mandarins, and limes)
	Stone fruit (nectarines, apricots, peaches, and plums)
	Tropical and exotic (bananas and mangoes)
	Berries (strawberries, raspberries, blueberries, kiwifruit, and passionfruit)
	Melons (watermelons, rock melons and honeydew melons)
	Heated greenhouse cultivated fruits
	Concentrated or dehydrated fruit/vegetables juices

Fruit juices and nectars (including concentrates)	Extracts of plant origin
	Fruit / vegetable juices and nectars
	Fruit concentrates
Legumes, nuts, oilseeds and spices	Legumes
	Nuts
	Oilseeds and oilfruits
	Spices
Meat and meat products	Red meat products
	Chicken products
	Fish wild caught
	Aquaculture fish
	Eggs
Milk and dairy products	Cheese
	Dairy dessert and similar
	Yoghurts or Cream
	Dairy powders and concentrates
	Milk
Vegetables and vegetable products	Algae and prokaryotes organisms
	Bulb vegetables (garlic and onions)
	Flowering brassica (broccoli and cauliflower)
	Flowers used as vegetables
	Fruiting vegetables (mainly pumpkin and sweet corn)
	Fungi, mosses and lichens (mainly mushrooms)
	Herbs and edible flowers
	Leafy vegetables (cole/brassica, lettuce, spinach)
	Legumes with pod
	Processed or preserved vegetables and similar (such as tomato concentrate)
	Root and tuber vegetables (excluding starchy- and sugar-) (mainly carrots and read beats)
	Sprouts, shoots and similar (such as tauge)
	Stems/stalks eaten as vegetables (mainly leek)
	Vegetables and vegetable products

When available in the used database, the country dataset representing the correct food ingredient for the correct country shall be selected. If this selection is not possible, then the following hierarchy shall be followed when selecting a proxy.

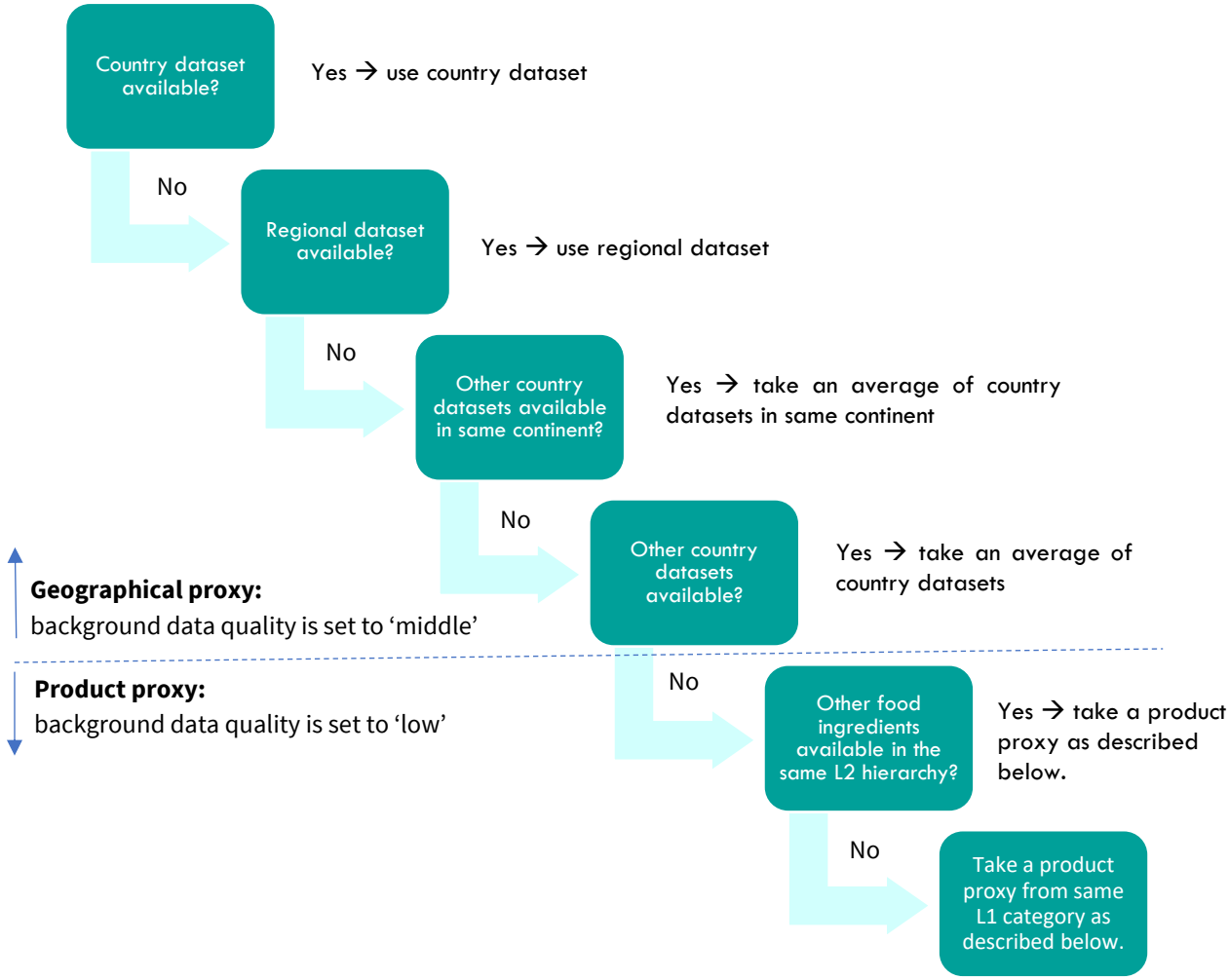


FIGURE 6: PROXY SELECTION APPROACH.

In case a product proxy is needed, the following steps shall be taken (not necessary when a geographical proxy is selected):

1. Identify available datasets within the same food ingredient category (L2 when other food ingredients are available in the same L2 hierarchy, else L1)
2. Take a random sample of minimal 10 (or less if not available) different food ingredients within food ingredient category
3. Adjust the footprint of the food ingredients in the sample, based on the DM % of the food ingredient that you are looking a proxy for (for protein rich ingredient, adjust also for protein content).
4. Take the average footprint of this sample

When looking for available datasets in this stepwise approach, the same regional hierarchy as above shall be followed.

When selecting a geographical proxy, the background data quality score decreases from good to middle.

When selecting a product proxy, the background data quality score decreases to low.

For feed ingredients, the proxy methodology from the GFLI (GFLI, 2020) shall be applied.

Appendix IV. Example of data quality assessment

Data quality assessment calculation example for fictional mix of margarine with butter

The following calculation example describes the data quality assessment for a fictional product containing soybean oil and butter. The data quality is assessed throughout several life cycle stages for which some primary data is used. On primary production level, dairy production is assessed. At ingredient processing level, raw milk processing and soybean oil pressing are considered. At food processing level, the mixing of ingredients and processing into margarine/butter products is considered. The last considered step is packaging material production.

Part 1: Data quality assessment

Primary production

Dairy production

Inputs and outputs	Quantity	Unit	Single score contr. Background data (cradle two stage)	Rescaled single score for foreground data	Foreground accuracy	Foreground year	Background accuracy
Outputs:							
Milk production	1	kg		12,5%	good	2020	Not relevant
Live weight	0,05	kg					
Allocation data milk	88%	%		2,5%	good	2012	Not relevant
Allocation data milk	12%	%					
Inputs:							
Feed intake	2	kg	50%	43%	good	2015	good
Manure emissions	direct emissions		20%	17%	default	2018	
Animal emissions	direct emissions		20%	17%	good	2020	middle
Electricity	1000	kWh	5%	4%	good	2020	good
Heat	100	MJ	5%	4%	good	2020	good
Results foreground			**80%**	**81%**	**good**		
			20%	**17%**	**default**		
Year			**2017**	**2017**			
Results background			**60%**		**good**		
			20%		**middle**		

Ingredient processing

Milk processing

Inputs and outputs	Quantity	Unit	Single score contr. Background data (cradle two stage)	Rescaled single score for foreground data	Foreground accuracy	Foreground year	Background accuracy
Outputs:							
Processed milk	0,95	liter		2,5%	estimate	2020	Not relevant
Inputs:							
Raw milk	1	liter	80%	78%	good	2020	primary
Electricity	1000	kWh	5%	5%	estimate	2018	good

Heat	100	MJ	15%	15%	good	2018	good
Result foreground			**95%**	**93%**	**good**		
			5%	**7%**	**estimate**		
Year			**2020**	**2020**			
Results background			**80%**		**primary**		
			20%		**good**		

Soybean oil pressing

Inputs and outputs	Quantity	Unit	Single score contr. Background data (cradle two stage)	Rescaled single score for foreground data	Foreground accuracy	Foreground year	Background accuracy
Outputs:							
Soybean oil nl	1	kg		2,5%	good	2019	Not relevant
Soybean expeller nl	1	kg					
Allocation data soybean oil (price)	5	euro/kg		10,0%	good	2015	Not relevant
Allocatin data expeller (price)	0,5	euro/kg					
Inputs:							
Soybean br	0,2	kg	15%	13%	good	2019	good
Soybean ar	0,6	kg	40%	35%	good	2019	good
Soybean market mix	0,2	kg	20%	18%	good	2020	middle
Electricity nl grid	10	kWh	6%	5%	good	2021	middle
Gas	10	m3	10%	9%	good	2021	good
Transport truck default	200	km	6%	5%	estimate	2021	middle
Transport sea default	6000	km	3%	3%	estimate	2021	middle
Result foreground			**91%**	**92%**	**good**		
			9%	**8%**	**estimate**		
Year			**2020**	**2019**			
Result background			**65%**		**good**		
			35%		**middle**		

Food processing

Margarine/butter production

Inputs and outputs	Quantity	Unit	Single score contr. Background data (cradle two stage)	Rescaled single score for foreground data	Fore-ground accuracy	Fore-ground year	Back-ground accuracy
Outputs:							
Margarine/butter product	1	kg		2,5%	good	2021	
Inputs:							
Soybean oil nl	0,6	kg	70%	68%	good	2021	primary
Taste mix (default for tasteners)	0,1	kg	5%	5%	good	2021	low (proxy)
Water	0,2	kg	2%	2%	good	2021	good
Processed milk	0,1	kg	10%	10%	good	2021	primary
Electricity solar nl	10	kWh	1%	1%	good	2021	good
Gas	10	m3	8%	8%	good	2021	good
Transport truck 30t EURO5	100	km	4%	4%	good	2021	good
Result foreground			**100%**	**100%**	**good**		
			0%	**0%**	**estimate**		

Year	**2021**	**2021**	
Result background	**80%**	**primary**	
	15%	**good**	
	5%	**low**	

Packaging

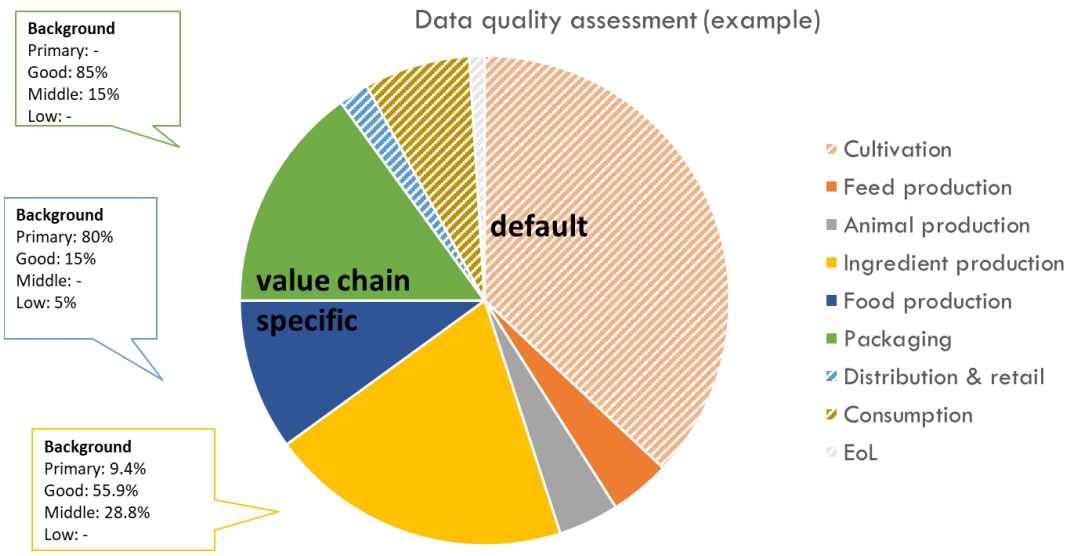
Inputs and outputs	Quantity	Unit	Single score contr. Background data (cradle two stage)	Rescaled single score for foreground data	Foreground accuracy	Foreground year	Background accuracy
Outputs:							
Packaging	1	piece		2,5%	good	2021	
Inputs:							
PP	0,02	kg	80%	78%	good	2021	good
Carton	0,01	kg	5%	5%	good	2021	good
Electricity nl grid	10	kWh	15%	15%	good	2021	middle
Result foreground			**100%**	**100%**	**good**		
			0%	**0%**	**estimate**		
Year			**2021**	**2021**			
Result background			**85%**		**good**		
			15%		**middle**		

Part 2: Defining total score

Per life cycle stage	Foreground accuracy				Background accuracy			
	Contribution to single score	Good	Estimate	Default	Primary	Good	Middle	Low
Cultivation	**37%**			100,0%				
Feed production	**4%**			100,0%				
Animal production	**4%**	83,0%		17,0%		60,0%	20,0%	
Ingredient production	**20%**	86,1%	8,0%	5,9%	9,4%	55,9%	28,8%	
Food production	**10%**	100,0%			80,0%	15,0%		5,0%
Packaging	**15%**	100,0%			0,0%	85,0%	15,0%	
Distribution & retail	**2%**			100,0%				
Consumption	**7%**			100,0%				
EoL	**1%**			100,0%				

Overall foreground score		
Good	Estimate	Default
45,5%	1,6%	52,9%

The total score can be visually represented in a diagram such as shown below, where the striped areas represent impacts calculated with default data, and the solid-coloured parts represent impact from primary data points. For each life cycle stage the background data quality is reported.


Data quality assessment (example)
Background
Primary: -
Good: 85%
Middle: 15%
Low: -
Background
Primary: 80%
Good: 15%
Middle: -
Low: 5%
Background
Primary: 9.4%
Good: 55.9%
Middle: 28.8%
Low: -
default
value chain
specific
Cultivation
Feed production
Animal production
Ingredient production
Food production
Packaging
Distribution & retail
Consumption
EoL

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