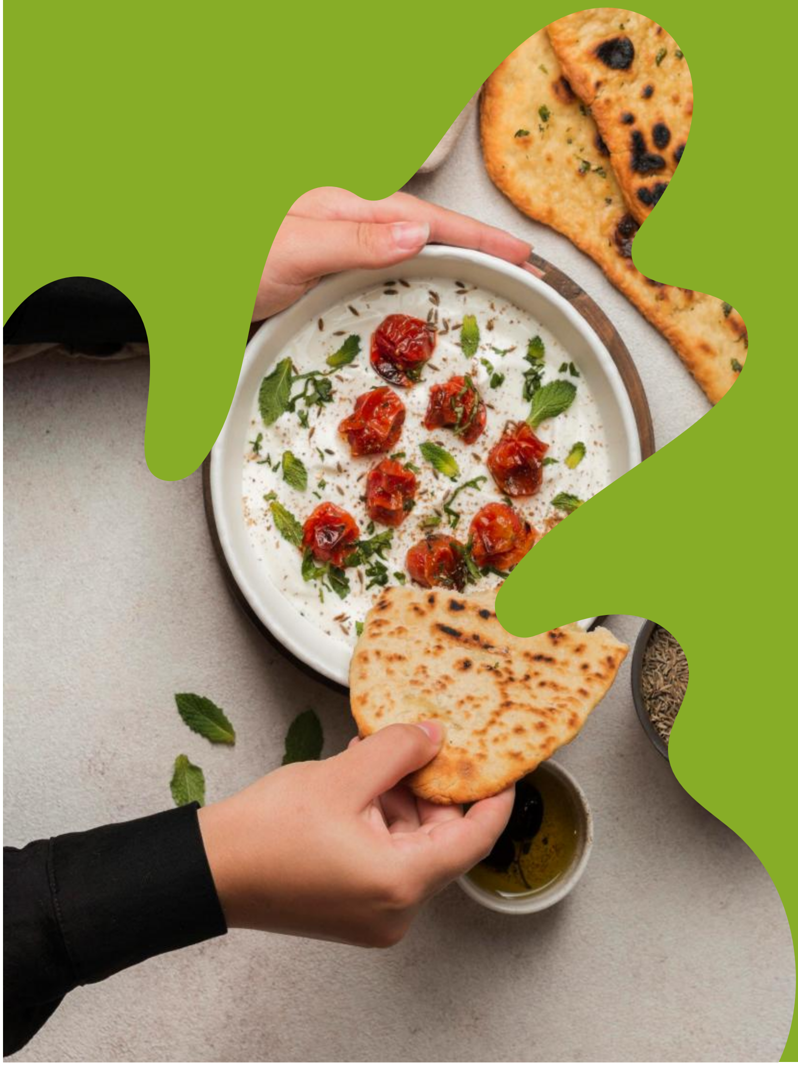
LCA harmonization method for food ecolabelling

LCI databases development and aggregated environmental score calculation methodology report

Beta version



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Disclaimers

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Acronyms

AWMS: Animal Waste Management System

BDOM: Biomass and Dead Organic Matter

CWF: Crop Water Footprint

dLUC: direct Land Use Change

EoL: End-of-Life

EC: European Commission

EFC: Eco Food Choice

DQR: Data Quality Rating

EPD: Environmental Product Declaration

FU: Functional Unit

GLAM: Global Guidance for Life Cycle Assessment

GLFI: Global Feed LCA Institute

ILCD-EL: International Reference Life Cycle Data System – Entry Level

ITC: International Trade Centre

LCA: Life Cycle Impact Assessment

LCI: Life Cycle Inventory

LHV: Lower Heating Value

LUC: Land Use Change

LULUC: Land Use and Land Use Change

NMVOC : Non-Methane Volatile Organic Compounds

PEF: Product Environmental Footprint

PM: Particulate Matter

SALCA: Swiss Agricultural Life Cycle Assessment

SSO: Single Sign On

TAN: Total Ammoniacal Nitrogen

UNSD: United Nations Statistics Division

XER: Excretion Rate

Definitions[1]

Activity data - information which is associated with processes while modelling Life Cycle Inventories (LCI). The aggregated LCI results of the process chains, which represent the activities of a process, are each multiplied by the corresponding activity data and then combined to derive the environmental footprint associated with that process.

Acidification – impact category that addresses impacts due to acidifying substances in the environment. Emissions of NOx, NH3 and SOx lead to releases of hydrogen ions (H+) when the gases are mineralised. The protons contribute to the acidification of soils and water when they are released in areas where the buffering capacity is low, resulting in forest decline and lake acidification.

Additional environmental information – environmental information outside the impact categories that is calculated and communicated alongside the results.

Additional technical information – non-environmental information that is calculated and communicated alongside the results.

Aggregated dataset - complete or partial life cycle of a product system that – next to the elementary flows (and possibly not relevant amounts of waste flows and radioactive wastes) – itemises only the product(s) of the process as reference flow(s) in the input/output list, but no other goods or services. Aggregated datasets are also called 'LCI results' datasets. The aggregated dataset may have been aggregated horizontally and/or vertically.

Allocation – an approach to solving multi-functionality problems. It refers to 'partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems'.

Application specific – generic aspect of the specific application in which a material is used. For example, the average recycling rate of PET in bottles.

Attributional – process-based modelling intended to provide a static representation of average conditions, excluding market-mediated effects.

Average data – production-weighted average of specific data.

Background processes – refers to those processes in the product life cycle for which no direct access to information is possible. For example, most of the upstream life-cycle processes and generally all processes further downstream will be considered part of the background processes.

Benchmark – a standard or point of reference against which any comparison may be made. The term 'benchmark' refers to the average environmental performance of the representative product sold in the EU market.

Characterisation – calculation of the magnitude of the contribution of each classified input/output to their respective impact categories, and aggregation of contributions within each category. This requires a linear multiplication of the inventory data with characterisation factors for each substance and impact category of concern.

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[1] European Commission. (2021). Product Environmental Footprint (PEF) method. Publications Office of the European Union.

Characterisation factor – factor derived from a characterisation model which is applied to convert an assigned life cycle inventory result to the common unit of the impact category indicator.

Classification – assigning the material/energy inputs and outputs tabulated in the life cycle inventory to impact categories, according to each substance's potential to contribute to each of the impact categories considered.

Climate change – impact category considering all inputs and outputs that result in greenhouse gas (GHG) emissions. The consequences include increased average global temperatures and sudden regional climatic changes.

Co-function - any of two or more functions resulting from the same unit process or product system.

Company-specific data – refers to directly measured or collected data from one or more facilities (site-specific data) that are representative for the activities of the company (company is used as synonym of organisation). It is synonymous to 'primary data'. To determine the level of representativeness a sampling procedure may be applied.

Company-specific dataset – refers to a dataset (disaggregated or aggregated) compiled with company-specific data. In most cases the activity data is company-specific while the underlying sub-processes are datasets derived from background databases.

Comparison – a comparison, not including a comparative assertion, (graphic or otherwise) of two or more products based on the environmental life cycle results.

Consumer – an individual member of the general public purchasing or using goods, property or services for private purposes.

Co-product – any of two or more products resulting from the same unit process or product system.

Cradle to gate – a partial product supply chain, from the extraction of raw materials (cradle) up to the manufacturer's 'gate'. The distribution, storage, use stage and end of life stages of the supply chain are omitted.

Cradle to grave – a product's life cycle that includes raw material extraction, processing, distribution, storage, use, and disposal or recycling stages. All relevant inputs and outputs are considered for all of the stages of the life cycle.

Data quality – characteristics of data that relate to their ability to satisfy stated requirements. Data quality covers various aspects, such as technological, geographical and time-related representativeness, as well as completeness and precision of the inventory data.

Data quality rating (DQR) - semi-quantitative assessment of the quality criteria of a dataset, based on technological representativeness, geographical representativeness, time-related representativeness, and precision. The data quality shall be considered as the quality of the dataset as documented.

Direct elementary flows (also named elementary flows) – all output emissions and input resource uses that arise directly in the context of a process. Examples are emissions from a chemical process or fugitive emissions from a boiler directly onsite.

Direct land use change (dLUC) – the transformation from one land use type into another, which takes place in a unique land area and does not lead to a change in another system.

Disaggregation – the process that breaks down an aggregated dataset into smaller unit process datasets (horizontal or vertical). The disaggregation may help make data more specific. The process of disaggregation should never compromise or threaten to compromise the quality and consistency of the original aggregated dataset.

Downstream – occurring along a product supply chain after the point of referral.

Ecotoxicity, freshwater – impact category that addresses the toxic impacts on an ecosystem, which damage individual species and change the structure and function of the ecosystem. Ecotoxicity is a result of a variety of different toxicological mechanisms caused by the release of substances with a direct effect on the health of the ecosystem.

EF-compliant dataset – dataset developed in compliance with the EF requirements, regularly updated by DG JRC[2].

Elementary flows – in the life cycle inventory, elementary flows include 'material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation'. Elementary flows include, for example, resources taken from nature or emissions into air, water, and soil that are directly linked to the characterisation factors of the impact categories.

Environmental aspect – element of an organisation's activities or products or services that interacts or can interact with the environment.

Environmental footprint impact assessment – phase aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product. The impact assessment methods provide impact characterisation factors for elementary flows, to aggregate the impact so as to obtain a limited number of midpoint indicators.

Environmental footprint impact assessment method – protocol for converting life cycle inventory data into quantitative contributions to an environmental impact of concern.

Impact category – class of resource use or environmental impact to which the life cycle inventory data are related.

Environmental impact – any change to the environment, whether adverse or beneficial, that wholly or partially results from an organisation's activities, products or services.

Environmental mechanism – system of physical, chemical and biological processes for a given impact category linking the life cycle inventory results to EF category indicators.

Eutrophication – impact category related to nutrients (mainly nitrogen and phosphorus) from sewage outfalls and fertilised farmland that accelerate the growth of algae and other vegetation in water.

The degradation of organic material consumes oxygen, resulting in oxygen deficiency and, in some cases, fish death. Eutrophication translates the quantity of substances emitted into a common measure, expressed as the oxygen required for the degradation of dead biomass.

To assess the impacts due to eutrophication, three impact categories are used: eutrophication, terrestrial; eutrophication, freshwater; eutrophication, marine.

Extrapolated data – data from a given process that is used to represent a similar process for which data is not available, on the assumption that it is reasonably representative.

Flow diagram – schematic representation of the flows occurring during one or more process stages within the life cycle of the product being assessed.

Foreground elementary flows - direct elementary flows (emissions and resources) for which access to primary data (or company-specific information) is available.

Foreground processes – those processes in the product life cycle for which direct access to information is available.

Functional unit (FU) – defines the qualitative and quantitative aspects of the function(s) and/or service(s) provided by the product being evaluated. The functional unit definition answers the questions 'what?', 'how much?', 'how well?', and 'for how long?'.

Gate to gate – a partial product supply chain that includes only the processes carried out on a product within a specific organisation or site.

Gate to grave – a partial product supply chain that includes only the distribution, storage, use, and disposal or recycling stages.

Global warming potential (GWP) – An index measuring the radiative forcing of a unit mass of a given substance accumulated over a chosen time horizon. It is expressed in terms of a reference substance (for example, CO2-equivalent units) and specified time horizon (e.g. GWP 20, GWP 100, GWP 500 – for 20, 100 and 500 years respectively).

Human toxicity – cancer – impact category that accounts for adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin – insofar as they are related to cancer.

Human toxicity - non cancer – impact category that accounts for the adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin – insofar as they are related to non-cancer effects that are not caused by particulate matter/respiratory inorganics or ionising radiation.

Indirect land use change (iLUC) – this occurs when a demand for a certain land use leads to changes, outside the system boundary, i.e. in other land use types. These indirect effects may be mainly assessed by means of economic modelling of the demand for land or by modelling the relocation of activities on a global scale.

Input flows – product, material or energy flow that enters a unit process. Products and materials include raw materials, intermediate products and co-products.

Intermediate product – output form of a unit process that in turn is input to other unit processes which require further transformation within the system. An intermediate product is a product that requires further processing before it is saleable to the final consumer.

Ionising radiation, human health – impact category that accounts for the adverse health effects on human health caused by radioactive releases.

Land use (LU) – impact category related to use (occupation) and conversion (transformation) of land area by activities such as agriculture, forestry, roads, housing, mining, etc.

Land occupation considers the effects of the land use, the amount of area involved and the duration of its occupation (changes in soil quality multiplied by area and duration). Land transformation considers the extent of changes in land properties and the area affected (changes in soil quality multiplied by the area).

Life cycle – consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.

Life cycle approach – takes into consideration the spectrum of resource flows and environmental interventions associated with a product from a supply-chain perspective, including all stages from raw material acquisition through processing, distribution, use, and end of life processes, and all relevant related environmental impacts (instead of focusing on a single issue).

Life cycle assessment (LCA) – compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

Life cycle impact assessment (LCIA) – phase of life cycle assessment that aims to understand and evaluate the magnitude and significance of the potential environmental impacts for a system throughout the life cycle.

The LCIA methods used provide impact characterisation factors for elementary flows to aggregate the impact, to obtain a limited number of midpoint and/or damage indicators.

Life cycle inventory (LCI) - the combined set of exchanges of elementary, waste and product flows in a LCI dataset.

Life cycle inventory (LCI) dataset - a document or file with life cycle information of a specified product or other reference (e.g., site, process), covering descriptive metadata and quantitative life cycle inventory. A LCI dataset could be a unit process dataset, partially aggregated, or an aggregated dataset.

Material-specific – a generic aspect of a material. For example, the recycling rate of polyethylene terephthalate (PET).

Multi-functionality – if a process or facility provides more than one function, i.e. it delivers several goods and/or services ('co-products'), then it is 'multifunctional'. In these situations, all inputs and emissions linked to the process will be partitioned between the product of interest and the other co-products, according to clearly stated procedures.

Non-elementary (or complex) flows – in the life cycle inventory, non-elementary flows include all the inputs (e.g. electricity, materials, transport processes) and outputs (e.g. waste, by-products) in a system that need further modelling efforts to be transformed into elementary flows.

Synonym of 'activity data'.

Normalisation – after the characterisation step, normalisation is the step in which the life cycle impact assessment results are divided by normalisation factors that represent the overall inventory of a reference unit (e.g. a whole country or an average citizen).

Normalised life cycle impact assessment results express the relative shares of the impacts of the analysed system, in terms of the total contributions to each impact category per reference unit.

Displaying the normalised life cycle impact assessment results for the different impact topics next to each other shows which impact categories are affected most and least by the analysed system.

Normalised life cycle impact assessment results reflect only the contribution of the analysed system to the total impact potential, not the severity/relevance of the respective total impact. Normalised results are dimensionless, but not additive.

Output flows – product, material or energy flow that leaves a unit process. Products and materials include raw materials, intermediate products, co-products and releases. Output flows are also considered to cover elementary flows.

Ozone depletion – impact category that accounts for the degradation of stratospheric ozone due to emissions of ozone-depleting substances, for example long-lived chlorine and bromine containing gases (e.g. chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons).

Partially disaggregated dataset - a dataset with an LCI that contains elementary flows and activity data, and that yields a complete aggregated LCI data set when combined with its complementing underlying datasets.

Particulate matter – impact category that accounts for the adverse effects on human health caused by emissions of particulate matter (PM) and its precursors (NOx, SOx, NH3).

Photochemical ozone formation – impact category that accounts for the formation of ozone at the ground level of the troposphere caused by photochemical oxidation of volatile organic compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx) and sunlight.

Population - any finite or infinite aggregation of individuals, not necessarily animate, subject to a statistical study.

Primary data – data from specific processes within the supply chain. Such data may take the form of activity data, or foreground elementary flows (life cycle inventory). Primary data are site-specific, company-specific (if multiple sites for the same product) or supply chain specific.

Primary data may be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, material/product balances, stoichiometry, or other methods for obtaining data from specific processes in the value chain. Primary data is a synonym of 'company-specific data' or 'supply chain specific data'.

Product – any good or service.

Product category – group of products (or services) that can fulfil equivalent functions.

Product flow – products entering from or leaving to another product system.

Product system – collection of unit processes with elementary and product flows, performing one or more defined functions, which model the life cycle of a product.

Raw material – primary or secondary material used to produce a product.

Reference flow – measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit.

Refurbishment – the process of restoring components to a functional and/or satisfactory state compared to the original specification (providing the same function), using methods such as resurfacing, repainting, etc. Refurbished products may have been tested and verified to function properly.

Releases – emissions to air and discharges to water and soil.

Representative sample – a representative sample with respect to one or more variables is a sample in which the distribution of these variables is exactly the same (or similar) as in the population of which the sample is a subset.

Resource use, fossil – impact category that addresses the use of non-renewable fossil natural resources (e.g. natural gas, coal, oil).

Resource use, minerals and metals – impact category that addresses the use of non-renewable abiotic natural resources (minerals and metals).

Reviewer – independent external expert conducting the review of the PEFCR and possibly taking part in a reviewer panel.

Sample – a subset containing the characteristics of a larger population. Samples are used in statistical testing when population sizes are too large for the test to include all possible members or observations. A sample should represent the whole population and not reflect bias toward a specific attribute.

Secondary data (also called background data) – data that is not from a specific process within the supply-chain of the company.

This refers to data that is not directly collected, measured or estimated by the company, but rather sourced from a third party LCI database or other sources. Secondary data includes industry average data (e.g., from published production data, government statistics and industry associations), literature studies, engineering studies and patents) and may also be based on financial data and contain proxy and other generic data. Primary data that go through a horizontal aggregation step are considered to be secondary data.

Sensitivity analysis – systematic procedures for estimating the effects of the choices made regarding methods and data on the results.

Site-specific data – directly measured or collected data from one facility (production site). A synonym of 'primary data'.

Single overall score – sum of the weighted results of all environmental impact categories.

Specific data – directly measured or collected data representative of activities at a specific facility or set of facilities. A synonym of 'primary data'.

Subdivision – subdividing involves disaggregating multifunctional processes or facilities to isolate the input flows directly associated with each process or facility output. The process is investigated to see whether it may be subdivided. Where subdivision is possible, inventory data should be collected only for those unit processes directly attributable to the products/services of concern.

Sub-processes – processes used to represent the activities of the level 1 processes (=building blocks). Sub-processes may be presented in their (partially) aggregated form (see Figure 1).

Supply chain – all of the upstream and downstream activities associated with the operations, including the use of sold products by consumers and the end-of-life treatment of sold products after consumer use.

Supply chain-specific – refers to a specific aspect of a company's specific supply chain. For example, the recycled content of aluminium produced by a specific company.

System boundary – definition of aspects included or excluded from the study. For example, for a cradle-to-grave analysis, the system boundary includes all activities ranging from the extraction of raw materials, through processing, distribution, storage and use, to the disposal or recycling stages.

System boundary diagram – graphic representation of the system boundary defined for the study.

Temporary carbon storage – this happens when a product reduces the greenhouse gases in the atmosphere or creates negative emissions, by removing and storing carbon for a limited amount of time.

Uncertainty analysis – procedure for assessing uncertainty in the results of the study due to data variability and choice-related uncertainty.

Unit process – smallest element considered in the LCI for which input and output data are quantified.

Unit process, black box – process chain or plant-level unit process. This covers horizontally averaged unit processes across different sites. Also covers multi-functional unit processes where the different co-products undergo different processing steps within the black box, hence causing allocation problems for this dataset4.

Unit process, single operation - unit operation type unit process that cannot be further subdivided. Covers multi-functional processes of the unit operation type5.

Upstream – occurring along the supply chain of purchased goods/ services prior to entering the system boundary.

Verification – conformity assessment process carried out by an environmental footprint verifier to demonstrate whether the study has been carried out in compliance with Annex I

Waste – substances or objects which the holder intends (or is required) to dispose of.

Water use – impact category that represents the relative available water remaining per area in a watershed, after demand from humans and aquatic ecosystems has been met. It assesses the potential for water deprivation, to either humans or ecosystems, based on the assumption that the less water remaining available per area, the more likely it is that another user will be deprived.

Weighting – a step that supports the interpretation and communication of the analysis results. The results are multiplied by a set of weighting factors (in %), which reflect the perceived relative importance of the impact categories considered. Weighted results may be directly compared across impact categories, and also summed across impact categories to obtain a single overall score.

1– Introduction

1.1 - General

This methodological report is a product of the Eco Food Choice (EFC) project, a European initiative funded by the LIFE program and comprising partners from France, Spain, Germany, and the Netherlands. The main objective of the EFC project is to create the necessary conditions for the development of harmonised environmental food databases and a common methodology for environmental labelling across Europe. This effort aims to provide the continent with an operational, collectively supported environmental labelling system that facilitates a shift towards more sustainable and healthier food consumption patterns.

The EFC project is structured into several work packages, one of which is dedicated to environmental data and the development of new datasets, along with a harmonised Life Cycle Assessment (LCA) methodology. This report addresses the methodological challenges of food product ecolabelling and responds to the need for guidance on methodological convergence among existing and future initiatives. It outlines the development of a harmonised LCA methodology, which is part of the second work package of the EFC project. This report also outlines recommendations and challenges related to the third work package of the EFC project. This work package aims at providing methodological harmonisation guidance to calculate a food environmental score by aggregating LCA scores and complementing them with additional indicators.

This proposed harmonised LCA approach aligns with the most recent version of the PEF methodology wherever possible, while also addressing its limitations and strengthening the overall methodological framework. Thus, any deviation from PEF methodology is timely indicated.

Terminology Note

The terminology in this beta version of the EFC method reflects the current stage of development and may be updated in the final version (expected November 2026) to improve consistency with the PEF framework and relevant official standards. This includes the use of normative terms such as *shall*, *should*, and *may*. Other technical terms, definitions, and phrasing may also be updated to improve clarity, consistency with the PEF framework, and alignment with stakeholder feedback.

1.2 - Process development

The development of this methodology document was led by Work Package Two in the EFC project, divided into several subtasks following the life cycle assessment methodology. It also includes subtasks related to Work Package Three of the project, particularly in relation to aggregation into a single score and grading. This way, the main topics and aspects of improvement were addressed. Each subtask was led by a member of the project team, who oversaw developing an initial proposal, which was later discussed and reviewed by other subtask members. Thus, each subtask member contributed with inputs and feedback that were gathered and adapted to the initial subtask proposal. Topics that did not have a consensus were documented, including a minority statement that reflected the diverging view and its reasoning. Some of them were also brought up to the Technical Advisory Board to get additional views. The final decision was, in any case, a majority decision, ideally unanimous.

1.3 - Status of the development

The present methodology report corresponds to a Beta Version, outlining the harmonised life cycle methodology for ecolabelling of agrifood products. Methodological improvements were selected and prioritised with a strong focus on operationalisation and pragmatism. Whenever a scientifically preferable option was identified but required more time for consideration, it was documented for future development in the final version of the methodology. Further potential improvements were also identified during the process and are presented in Chapter 9. These will inform our roadmap towards the final version of our method, scheduled for release in November 2026.

This report places more emphasis on certain methodological issues (such as toxicity, biodiversity, and data collection) because they are more debated, or particularly relevant for the applicability of a harmonised LCA-based ecolabel in the food sector. Other topics are treated more briefly, not because they are unimportant, but because they are either well established or of lower immediate priority. These aspects will be further elaborated in the final version, informed by the public consultation detailed below.

The ongoing public consultation on this beta version with several stakeholder groups across Europe will inform the final methodology, scheduled for release in November 2026. A feedback form is being shared with this report for this purpose. All feedback will be thoroughly considered, although not all comments can receive a personalised answer. Dedicated online meetings with the Committees of the EFC project (Committee of Countries, Stakeholders Committee, Technical Advisory Board, Retailer Webinar, and others) will be organised in late 2025 and mid-2026 to refine the methodological guidance and co-develop the final version, scheduled for release in November 2026. In addition, environmental score calculations and sensitivity analyses will be conducted by the Eco Food Choice consortium and partners to test the present guidance and anticipate the outcomes of product scoring. We therefore expect tangible, and for some aspects possibly significant, changes between the beta and final version.

1.4 - Geographic validity

This EFC harmonised LCA methodology is primarily valid for agrifood products consumed in the European Union. The methodology aims to best reflect the situation for products consumed on the European market, including imported ones.

2- Scope

2.1 - Functional unit

The chosen functional unit for environmental labeling for the Eco Food Choice methodology is weight-based (per 1kg or 100g of consumable product at the consumer level). It accounts for losses across the product's life cycle (production, processing, packaging, distribution, etc.). This weight-based approach is the most used in scientific literature and regulatory frameworks due to its simplicity and broad applicability. Mass-based FU has been identified as the best pragmatic solution, offering consistency across food categories while allowing for future refinements in environmental labeling methods.

- What: Food or drink product; packed (or not) consumed by the consumer.
- How much: Per weight
- How well: Suitable for human consumption
- How long: Before the expiration date

2.2 - System boundaries

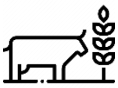
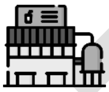
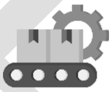
This methodology adopts the Cradle-to-Grave approach, including all stages from raw material acquisition and pre-processing, production of the main product, product distribution and storage, use stage, and end-of-life treatment of the product (if applicable). This is consistent with the defined functional unit. The potential exclusion of any process shall be explained and justified.

2.3 - Life cycle stages

The table below presents the ten life cycle stages that shall be considered and the activities involved. In particular, *raw material acquisition and pre-processing* is split into 4 stages, so it better reflects the agri-food supply chain, and it eases the identification of hotspots. In cases of non-food waste and food losses and waste generated throughout the life cycle stages, the modelling criteria outlined in Section 4 - Life cycle stages should be followed. Default values can be consulted in Section 3.5 - Default values. Additional life cycle stages should be provided if needed, with the corresponding support.

Table 2.1. Life cycle stages definition and activities involved.

	Life cycle stage
1	Raw material acquisition 
2	Crop cultivation

	
3	Animal production 
4	Feed production 
5	Food and ingredient processing 
6	Packaging production 
7	Distribution 
8	Retail 
9	Use & preparation 
10	End-of-Life 

2.4 - Cut-off

According to the PEF method (European Commission, 2021), processes and elementary flows may be excluded up to 3.0% (cumulatively) of the single overall score, based on material and energy flows and the level of environmental significance. The processes subject to a cut-off shall be made explicit and justified, in particular regarding the environmental significance of the cut-off applied. The cut-off shall be considered in addition to the cut-off already included in the background datasets. The processes that (cumulatively) account for less than 3.0% of the material and energy flow, as well as the environmental impact for each impact category, may be excluded. The following processes can be excluded based on the aforementioned cut-off criteria:

- Production and transportation of capital goods (including infrastructure) and their end-of-life, unless there is evidence from previous studies that they are relevant (e.g., greenhouses), or they are already part of the background processes. However, utility use in/by these capital goods is considered.

- Production and transportation of intermediate packaging materials used along the value chain, including secondary and tertiary packaging.
- Production and transportation of cleaning agents, medicine, antibiotics, insemination material and comparable inputs.
- Storage operations for non-feed ingredients.

More details on background data requirements can be found in Section 3.8 – Secondary data.

[*] Note: Impact categories are detailed in Sections 5.1 - Method and environmental indicators, 6-Biodiversity impacts, and 8.2 - Weighting.

3- Life Cycle Inventory

3.1 – Included processes

Processes included in each life cycle stage are presented in Table 3.1. The table below details the type of processes, as guidance. Data requirements for life cycle inventories as well as allocation are also described in this chapter. Details of modelling choices are described in Section 4 - Life cycle stages.

Table 3.1. Overview of the activities included in the life cycle stages

Life cycle stage	Processes	Activities
Raw material acquisition	Activities related to resource extraction, raw material production, pre-processing of materials and starting materials used as input for cultivation	- Production and transport of fertilizers and manure - Production and transport of plant protection products - Production and transport of capital goods - Production and transport of starting material - Production and transport of growing media - Production and transport of 'other' materials (e.g., bedding materials, trellis system)
Crop cultivation	Cultivation of crops for food, or as input for feed production	- Use of resources (land, water) - Energy (fuel, electricity) - Emission from fertilizers, manure, land transformation
Animal production	Farm activities and manure management.	- Feed transport - Feed additives and minerals - Young animals - Energy - Water use - Emissions from enteric fermentation and manure management
Feed production	Transport and processing of crops and other raw materials into feed.	- Production of feed additives minerals - Processing of crops - Processing of animal - Transport of (dry feed) ingredients - Energy use
Food and ingredient processing	Transport to food production facility, energy consumption, losses, and other emissions in food production processes	- Transport to facility - Processing of animals - Processing of crops into food ingredients - Processing of food ingredients into final food products
Packaging production	Extraction of raw materials, production of packaging and end-of-life of packaging material	- Production of materials for packaging -Transport of materials

Distribution	Transport from food producers to the distribution network	- Transport from food production to distribution centers and retailers - Energy and water use at the distribution centers - Food waste
Retail	Energy consumption and food losses at supermarkets	- Energy and water use at retail - Food waste
Use & preparation	Use phase of food products, including consumer transportation, energy inputs for the use/consumption of the food product	- Water and energy use - Use of other food components
End-of-Life	Only includes food waste treatment	- End of life of edible food losses - End of life of consumer packaging - End of life of growing media - Transport to the waste treatment facility

3.2 – Allocation: Handling multi-functional processes

3.2.1 – Allocation approaches per life cycle stage

Several methodological options are available to model multifunctionality. For food product labelling, however, where tens of thousands of products need to be assessed in automated, batch-style calculations, there are limited alternatives to allocation, which is thus the recommended approach here. Multiple allocation approaches can be applied. Table 3.2 presents the allocation approaches recommended by Eco Food Choice for each life cycle stage and indicates whether these approaches are also applied in the EF method and selected PEFCRs.

Table 3.2 Allocation approaches per life cycle stage

Life cycle stage	Activity	Allocation	In accordance with
Crop cultivation	Between main and co-products	Economic	PEF, PEFCR Feed
	CHP-systems in greenhouses	Energy	FloriPEFCR
	Multiple crops in greenhouses	Area-time	FloriPEFCR
Feed production	Between main and co-products	Economic	PEFCR Feed for food producing animals
Animal production	Dairy	Economic	Result of discussion in consortium and TAB
	Other animals (within farm module)	Economic	PEF (partly) Result of discussion in consortium and TAB
	Manure exported to other farms	Cut-off, no allocation[i]	PEF (default option)
	Dead animals	Cut-off, no allocation[ii]	
	Slaughterhouse	Economic	PEF
	All processes, except dairy for food	Economic	PEF

Food ingredient processing & production	Dairy processing for food	Dry matter mass	PEFCR for Dairy, based on International Dairy Federation (2022)
Packaging	See End-of-life 'consumer packaging'		
Distribution	Energy use	Volume	PEF
	Transport	Mass	PEF
	Trunk (consumer transport)	Volume	PEF
Retail	Energy use	Volume	PEF
Consumption	Energy usage fridge	Volume	PEF
End-of-life	Consumer packaging	Circular Footprint Formula	PEF
	Edible food waste	50% trashed (i.e., incinerated and landfilled), 25% composted and 25% methanised, liquid food waste: wastewater treatment	PEF
	Growing media	Cut-off, no allocation[iii]	Growing Media Environmental Footprint Guidelines

[i]Manure is considered to have no economic value at the farm gate, and as such regarded as residual product of the animal production. The animal system accounts for the environmental burden of on-farm storage. The environmental burden of application of the manure and the processing stages following on-farm storage to produce organic waste products are attributed to the plant system applying the manure/ organic waste product.
[ii]No impact is allocated to the dead animal from the farm. The impact of dead animals on feed conversion and nitrogen balance is considered, as data is collected per year. The dead animals are treated via rendering, and the impact of that process is attributed to the products from rendering.
[iii]Most of the growing media are either composted or used for field application as soil improvers and are treated as a residual product of the grower as such. All emissions related to the C-content of the growing media are attributed to the first crop, while the treatment of the growing media for processing into a soil improver is attributed to the plant system applying the soil improver.

3.2.2 - How to determine economic allocation factors

Economic allocation refers to allocating inputs and outputs associated with multi-functional processes to the co-product outputs in proportion to their relative market values. The market price of the co-functions should refer to the specific conditions and stage of the process in which the co-products are produced. Prices should refer to the value immediately after production, the revenue of the producer (not the price at the consumer). Taxes, transport, and insurance should not be included in the price.

Prices shall be representative of the region in scope and shall be the average prices for a recent 3-year period. For global commodities, regional prices are expected to align with global prices; whereas for regional-only commodities, prices are expected to remain regional. Therefore, we propose a regional approach to reason about allocation factors that can be applied in different types of multifunctional processes. [59,60]

A single data source of price information is lacking. Established databases and methods (e.g., Agribalyse, Agrifootprint, EcoInvent, PEF, PEFCRs) can be used to reason about allocation factors that can be applied in different types of multifunctional processes.

3.2.3 - Crop rotation and allocation of emissions

The variety in terms of rotation schemes is very high, which provides a big challenge in developing modelling rules which apply to specific rotation schemes. General allocation rules are provided to consider crop rotation:

- Impacts linked to the production of these, P and K and to emissions linked to their spreading are allocated to each crop in proportion to exports.
- The nitrogen available for the crop receiving the input is allocated to it. The rest is allocated equally among all the crops in the rotation.
- The impact of production and the emissions of nitrogen supplied in mineral form to a crop are fully attributed to that crop.
- The impact of nitrate emissions during intercropping is attributed to the previous crop.
- The impact of nitrogen production from crop residues and the N2O emissions induced by these residues is attributed to the crop that produced them.

These general rules are based on the Agribalyse method, which uses information from the Agreste cropping practices survey from 2006, in which over 14,000 plots have been surveyed over a period of 2001-2005. Over 4000 different rotations have been identified, which were brought down to 34 major crop succession groups (Jouy & Wissocq, 2011[27]). The implementation of the approach, using "corrective flows", is described in the Agribalyse 3.2 methodology document, Sheet n°16: Allocation of basic manure and organic fertilizers in crop succession[7].

Allocation in the context of attributional versus consequential modelling

ISO 14044 and ISO 14067 provide a hierarchy to decide on the allocation approach. The first step in the hierarchy is applying substitution (also called system expansion). The second step in the hierarchy is using an underlying physical relationship. The third and last step in the hierarchy is applying another relationship between the co-products. In agri-food, mostly the third and last step is applied for allocation, economic allocation in particular.

The ISO standards have been developed for all types of LCA, both consequential and attributional. Consequential LCA is applied mostly for investigating long-term effects of policy decisions. To investigate these long-term effects and the *changes in impact* that they could bring, applying substitution is a neat approach. Attributional approach is used to investigate the *absolute impacts* of a product or service. In doing so, the substitution approach forces the user to make a lot of assumptions about the so-called avoided burdens. These tend to be quite arbitrary assumptions/choices about the quality and function of the co-product versus the substitution product. The second and third steps of ISO's hierarchy are more appropriate to analyse the absolute impact of products and services, using an attributional approach. Since PEF is meant for analysing and communicating absolute impacts of products, it makes sense to apply the attributional approach. This also means that the substitution approach to allocation is not the preferred option in the context of PEF. Hence, we see that in PEF, the most applied allocation approaches, especially for agri-food products, are economic allocation and biophysical allocation. Particularly for agricultural and food products, applying substitution is very complex, as most substitutions for co-products come from multifunctional processes themselves.

An advantage of economic allocation is that it reflects the market and leads to incentives that promote sustainable production and consumption. Functions of co-products can change; whey, at one point, went from a 'waste' stream to a highly valued stream. In agri-food, the products with the highest value functions are often not the products with the highest mass. There are a lot of wet co-products. For this reason, mass allocation is not often applied. The ISO hierarchy is also often misinterpreted. Mass allocation tends to be interpreted as the second step in the hierarchy, while in fact mass does not reflect an underlying physical relationship (A2 amendment ISO 14044). Using underlying physical relationships for allocation has its limitations when there is limited capacity to independently vary the production of co-products.

In economic allocation the impact of processes is best attributed according to the revenue of the co-products to avoid that impacts are allocated to 'wasted' co-products, decreasing the incentive to make the process more sustainable; In the Netherlands applying biophysical allocation to sheep husbandry would attribute almost 25% to the wool, which is wasted in the Netherlands, while economic allocation would allocate this impact mostly to the sheep meat.

In some cases, PEF does require the use of system expansion/substitution, for instance, when applying the Circular Footprint Formula. The A2 amendment to ISO 14044 also describes that system expansion can often be a straightforward choice for energy products, as it is in the case of incineration with energy recovery. Agricultural systems are complex. For complex

3.3 - Resource use

3.3.1 - Crop water use

Crop Water Footprint (CWF) can be obtained from the latest enhanced datasets, a global process-based crop model developed by Mialyk and al. (2024) [29], for 175 individual crops. The model is based on FAO's AquaCrop model and simulates the daily crop growth and vertical water balance considering local environmental conditions, crop characteristics, and farm management. The model separates blue and green water, the former being the one considered for the EFC method. In the upcoming versions of the Eco Food Choice method, specific local data may be required if available.

3.3.2 - Greenhouse gases modelling

Two subjects are covered: biogenic carbon modelling and GHG modelling in relation to Land Use and Land Use Change (LULUC).

The PEF general guidelines (mainly based on PAS2050) state that the sub-categories 'Climate change –fossil', 'Climate change – biogenic' and 'Climate change - land use and land use change' shall be reported separately, if they show a contribution of more than 5% each to the total score of climate change.

Biogenic & Fossil

For "Climate change – biogenic", for food products, a simplified modelling approach could be used only if the flows which influence the results of climate change impact (namely, biogenic methane emissions) are modelled. The simplified approach avoids modelling human digestion while eventually arriving at a zero balance. In this case, the following rules apply:

- Only the emission 'methane (biogenic)' is modelled;
- No further biogenic emissions and uptakes from the atmosphere are modelled;
- If methane emissions are both fossil and biogenic, the release of biogenic methane shall be modelled first, followed by the remaining fossil methane.

Land use and land use change (LULUC)

Following the PEF, only direct land use change (dLUC) shall be considered. Direct land use change occurs as the result of a transformation from one land use type into another, which takes place in a particular/ certain piece of land cover, possibly leading to changes in the carbon stock of that specific piece of land, but not in other systems. It does not consider the global food system and its interlinkages.

Table 3.3. summarises the methodological choices currently considered most relevant for modelling GHG emissions in relation to LUC in the context of ecolabeling.

Table 3.3. Summary of the approaches applied to LULUC

Topic	EFC methodological guideline
Approach	Stock difference approach over 20 years inventory Quantification of the GHG flows linked to a transformation, i.e. a change in land use or management, by calculating the difference in carbon stocks at equilibrium between the current situation and the previous situation
Data sources to model dLUC	**Spatially-explicit data** is preferred if available, if not, statistical models (also known as normative models, which use land use statistics to estimate LUC.)
Allocation method of dLUC	**Crop-specific data** (where land-use changes are allocated only to the crop responsible for the transformation) is preferred.

	Ideally, both crop-specific and spatially explicit data should be used. However, since such data are not always available, spatially explicit data, even if not crop-specific, should be chosen as the next best option. If statistical models are employed, crop-specific data should be prioritised.
Spatial resolution for carbon stock	Regionalised C stocks based on national measurement networks or mechanistic models (Tier 2 or 3 approaches) rather than default factors (Tier 1 approach).
Amortization period / responsibility window Period over which LUC emissions are depreciated	20 years
Amortization method Method defining how much weight is put on recent vs. more historic LUC events e.g., equal, linear	**Equal discounting** (in line with PEF and PAS 2050).
Nitrogen mineralization	Including N_2O emissions from nitrogen mineralization Related to the amount of soil carbon that is lost, based on IPCC 2019 [11]

3.3.3 - Electricity use

For electricity modelling, company-specific data, secondary data, or a mix of both, may be used. Two conditions may be applied:

- Consumption grid mix, including green claimed or tracked electricity,
- And the residual consumption grid mix, which is the unclaimed/untracked electricity.

In the first case, the following minimum criteria must be met to guarantee the integrity of the contractual instruments: convey attributes, be a unique claim, and be as close as possible to the period to which the contractual instrument is applied. Either a supplier-specific electricity product or a supplier-specific total electricity mix could apply under the claimed/tracked electricity context.

Conversely, if the residual consumption grid mix is the case, and if no specific data is available, suitable datasets should be used, considering country consumption mix, energy type and voltage (see Section 3.8 for more information). However, if none of the datasets is suitable, electricity can be modelled as follows: determine the country consumption mix (e.g., X% of MWh produced with wind energy, Y% of MWh produced with combined cycle power plant, etc) and combine them with LCI datasets per energy type and country/region (e.g., LCI dataset for the production of 1MWh wind energy in e.g., Spain). For non-EU countries, the (residual) consumption mix should consider the following parameters: domestic production mix per production technology, import quantity, transmission and distribution losses, and type of fuel supply.

In case of multiple products at a single location (single country/region), physical allocation should be applied. Then, if the consumed electricity comes from more than one (residual) electricity mix, each mix source should be used in terms of its proportion in the total electricity consumed. For multiple products at multiple locations (many countries, more than one electricity mix), each country-specific consumption mix should be physically proportional to the total electricity used. For more guidance, refer to the allocation and data requirement sections.

For on-site electricity generation, two options are presented: when the generation meets the consumption and when generation exceeds consumption.

In both cases, own modelling combined with LCI datasets should be conducted considering fuel type, technology, fuel consumption, efficiency and emissions.

When generation exceeds consumption, physical allocation should be followed. The same allocation approach applies when a cogeneration system (mass-based percentage of electricity and heat) is used. More guidance can be found in Section 3.2 – Allocation: Handling multi-functional processes. If contractual instruments exist, then, country-specific residual consumption grid mix combined with LCI datasets should be applied.

In particular, if carbon dioxide (CO_2) emissions generated from a cogeneration system are used in greenhouse cultivation, it is recommended to use data from direct measurements; otherwise, technical system specifications, public sources or scientific evidence and LCA databases can be used, respectively. Section 3.8 – Secondary data and Section 3.9 – Company-specific data include further guidance.

3.4 - Data quality requirements

Using high-quality data is crucial in LCA modelling to guarantee that the environmental impact results are reliable and accurate. The Data Quality Rating (DQR) offers users additional insights into the quality of the data in the database. The latest revised PEF DQR version adopts a streamlined approach which focuses on evaluating the datasets based on a set of relevant criteria, allowing experts to assess the quality of the data in a timely and agile manner, and avoids a detailed flow-by-flow analysis. In this sense, the data quality criteria shall be evaluated considering the entire system and shall be applied before the creation of any aggregation of sub-processes or elementary flows of the system. Three data quality components shall be assessed:

- *Quality of the inventory values (DQR_{IV})* assesses the quality of the activity data and the elementary flows evaluated through an expert judgement of the entire system before any aggregation, for instance, all processes aggregated inside supporting sub-processes, if any.
- *Quality of the modelling of data connections (DQR_{M})* assesses the quality of the connections between inventory values and the input datasets evaluated through an expert judgement of the entire system.
- *Quality of the included datasets (DQR_{ID})* assesses the quality of the datasets included in the system, evaluated through an expert judgement that takes into consideration the declared DQRs in the metadata of all the datasets used in the system.

Two data quality criteria shall be evaluated for each component: *Precision (P) and Representativeness (R)*. On one hand, precision (P) indicates the way the data is collected and derived and includes the effect of the number of samples and their redundancy, the calculation methods to elaborate data and derive the final values, data sources, and adopted standards. Particularly, precision (P) is not applicable in the DQR_{M}. On the other hand, Representativeness (R), which is related to *technological, geographical, and time*, denotes the accuracy of the data, with reference to the processes and products selected. It characterises the degree to which the collected data describe the system under analysis. It applies to all three components DQR_{IV}, DQR_{ID} and DQR_{M}.

As shown in Table 3.4, the data quality criteria for each component are evaluated using a system that assigns a score from 1 to 5, where 1 is the best and 5 the worst score. Optionally, intermediate ratings, e.g., 1.5, 2.5, can be used. Under this framework, level 4 is the lowest quality level admitted, and hence any DQR worse than 4 is not accepted. The aggregation of the data quality criteria and components in one single score is not required, and hence, the results are reported separately.

Table 3.5 gathers main guiding principles for expert judgement for each component and criteria rating.

Table 3.4. DQR components, criteria, and acceptable data quality criteria rating

	Precision	Representativeness
Inventory values (DQR_{IV})	1 – 4	
Modelling of data connections (DQR_{M})	Not applicable	1 – 4
Input datasets (DQR_{ID})	1 – 4	

Table 3.5. Guiding principles for assessing Precision and Representativeness

	Precision	Representativeness
Inventory values (DQR_{IV})	1. The number of samples varies from large and precise samples or calculations (rating 1) to small, rough, or approximated measurements with questionable precision (rating 5). 2. Redundancy of samples may reinforce the validity of the inventory values. 3. Inventory data shall be estimated based on robust and precise modelling and calculation methods. 4. Inventory data should be based as far as possible on direct measures according to defined standards. 5. When primary information is not available, data could be inferred from other verified sources (e.g., other existing datasets, scientific literature and other publications). 6. The reliability of expert estimates ranges from very precise sources and well-reasoned estimates (rating 3) to unexplained expert opinions without supporting data (rating 5).	1. To determine how closely the inventory data depict the specific product or process under development as described in its detailed name fields and location. 2. Identify whether the differences are small or if they fundamentally change the nature of the product or process being evaluated. 3. The expert should consider whether the differences are small or if they fundamentally change the nature of the product or process being evaluated. 4. For inventory values (estimated or inferred), the expert should assess how representative these are for the dataset under development/evaluation. Completeness is a requirement in this case.

	7. Statistically significant depending on the specific conditions of data measurement and collection.	
Modelling of data connections (DQR_M)	Not applicable	1. The evaluation of the R of the DQR_M should consider the four field names and information included in the metadata field "*process information*" of the selected input datasets, and any other relevant information made available by the data developer. 2. Included datasets shall be technologically, temporally and geographically representative for the activity data collected. 3. The DQR_M of any connection with supporting sub-processes (black boxes) shall be assigned and reported in the metadata of the life cycle model. 4. The presence of data gaps and their relevance.
Included datasets (DQR_{ID})	1. The expert should take into consideration P and R of DQR_{IV} and DQR_{ID} and R of the DQR_M of the EF-compliant process input datasets in the entire life cycle model. 2. The input datasets to be used in the system model shall be methodologically sufficiently consistent with each other and with the inventory data that were specifically collected. 3. ILCD-EL input datasets developed with conceptually different LCA modelling than the EF method, like consequential LCA, are not accepted. 4. It is recommended to give preference to datasets that are supported by comprehensive and unambiguous documentation. 5. ILCD-EL input datasets cannot be rated better than 3.	

The expert (data developer, reviewer) will assess each component and assign a score for each data quality criterion (P, R). The data developer will provide a disaggregated life cycle model of the dataset developed and relevant information regarding data collection to the reviewer, who will have access to the full inventory data and data sources of the entire life cycle model. The following tables describe each data quality criterion rating to guide the evaluation of the two data quality criteria (P and R).

Table 3.6. DQR guide for inventory values.

DQR	Precision	Representativeness
1-Excellent	Inventory values are directly determined through on-site collection and using modelling and calculation methods based on relevant harmonised standards and/or stochastic sampling procedures, or legal schemes or product category rules for the specific technology or process's activity data and emissions under scope. Data is considered statistically significant and externally reviewed or audited under an accredited or legal scheme.	Inventory values represent the same technology and life cycle stages as given in the dataset name, and the specific product and waste inputs and outputs AND the same geography as given in the "location" AND the timespan of the data collection has no time distortions, compared to what is stated in the process name (or the general average situation, if that is the intended process scope).
2-Very good	Inventory values are determined from reliable sources (e.g. government reports, industry databases, evidence-based studies, specific EPDs[4]), using modelling and calculation methods based on relevant harmonised standards or sampling procedures or legal schemes or product category rules for the specific technology or process' activity data and emissions under scope. Data can also be extrapolated from on-site input material stock, purchase values and stoichiometric relationships combined with measured yields and specific waste/by-product data. Data is considered statistically significant and externally reviewed or audited under an accredited or legal scheme.	Inventory values represent the same technology as given in the dataset name, and the specific product and waste inputs and outputs, AND for one of the following aspects, a deviation is allowed (the others being at least as excellent as allowed in level 1): • The geography is not the same, but the relevant geographical aspect (e.g. grid mix, climate conditions) is impact-wise equivalent to the geography as given in the "location". • The timespan of the data collection is not the same, but has impact-wise negligible distortions compared to what is stated in the process name (or the general average situation, if that is the intended process scope).
3-Good	Inventory values are exclusively determined from engineering calculations or models based on relevant standards, sampling procedures, or legal schemes, or product category rules for the specific technology or process activity data and emissions under scope.	Inventory values show a deviation for two of the following aspects (the other being at least as excellent as allowed in level 1): • The technology is not the same but is impact-wise equivalent to the technology as given in the dataset name.

		• The geography is not the same, but the relevant geographical aspect (e.g. grid mix, climate conditions) is impact-wise very similar to the geography as given in the "location". • The time span of the data collection is not the same but has impact-wise only little relevant distortions compared to what is stated in the process name (or the general average situation, if that is the intended process scope).
4-Fair	Inventory values are exclusively determined from literature and expert estimations for this process, technology and emissions under scope. Data is externally reviewed or audited under an accredited or legal scheme or by a qualified expert in the specific field.	Inventory values show a deviation for the following three aspects, as follows: • The technology is not the same but is impact-wise very similar to the technology as given in the dataset name. • The geography is not the same, but the relevant geographical aspect (e.g. grid mix, climate conditions) is impact-wise very similar to the geography as given in the "location". • The time span of the data collection is not the same but has impact-wise only little relevant distortions compared to what is stated in the process name (or the general average situation, if that is the intended process scope).

Table 3.7. DQR guide for data connections.

DQR	Representativeness
1-Excellent match	The technology, geography, and the timespan of data collection represented by the activity data are the same as indicated in the name fields and relevant metadata of the connected included datasets. No data gaps from missing connected datasets (i.e. no datasets of at least "data connection" quality level 4) above one quarter of the allowed maximum cut-off.
2-Very good match	The technology used is the same as indicated in the name fields and metadata of the connected included datasets, AND one of the aspects shows the less good representativeness, among the following (the others being at least as excellent as allowed in level 1): • The geography is not the same, but the relevant geographical aspect (e.g. grid mix, climate conditions) can be considered impact-wise equivalent to the geography as indicated in the name fields and metadata of the included dataset.

	• The timespan of the data collection is not the same, but has impact-wise negligible distortions compared to what is indicated in the name fields and metadata of the included dataset. No data gaps from missing connected datasets (i.e., no datasets of at least "data connection" quality level 4) above half of the allowed maximum cut-off.
3-Good match	Two of the aspects show a less good representativeness, among the following (the other being at least as good as allowed in level 1): • The technology is not the same, but can be considered impact-wise equivalent, as indicated in the name fields and metadata of the included dataset. • The geography is not the same, but the relevant geographical aspect (e.g. grid mix, climate conditions) is impact-wise very similar to the geography as indicated in the name fields and metadata of the included dataset. • The timespan of the data collection is not the same, but has impact-wise only little relevant distortions compared to what is indicated in the name fields and metadata of the included dataset. No data gaps from missing connected datasets (i.e., no datasets of at least "data connection" quality level 4) above three-quarters of the allowed maximum cut-off.
4-Fair match	Three of the aspects show a less good representativeness, among the following: • The technology is not the same, but it is impact-wise very similar to the technology as indicated in the name fields and metadata of the included dataset. • The geography is not the same, but the relevant geographical aspect (e.g. grid mix, climate conditions) is impact-wise very similar to the geography as indicated in the name fields and metadata of the included dataset. • The timespan of the data collection is not the same, but has impact-wise only little relevant distortions compared to what is indicated in the name fields and metadata of the included dataset. No data gaps above the allowed maximum cut-off

3.5 - Default values

Default data apply mainly to the downstream life cycle stages (e.g., packaging, distribution/retailer, consumption, and end-of-life) in the supply chain. Although sometimes these values can be included in the first life cycle stages, for example, transportation distances. Default data are typically data points where food companies do not have information, and to facilitate fair comparison, such data should be standardised per geographical unit to avoid companies/ organisations using their data for those parameters. Default data applies to different parameters, not only limited to default transport scenarios, but also for:

- Default packaging (material types + weight) per product (sub) category (see section 4.6 - Packaging production)
- Reuse rate of packaging material
- Energy use at distribution centres and retail
- Energy use for storage and cooking at consumer
- Raw-to-cook ratios at consumer
- Preparation techniques and cooking times at consumer
- Inedible fractions of food items (see section 4.10 - End-of-life and recycling)

- Food loss at the distribution centre, retail, and consumer (see section 4.10 - End-of-life and recycling)
- EoL scenarios per material per region (via landfill, incineration, recycling) (see section 4.10 - End-of-life and recycling)

The proposed approach suggests using default values included in PEF as much as possible and complementing the missing values with references to default values from the other methodology reports. A summary of the applied default values for the selected parameters is included in the tables below.

Table 3.8. Default values for transportation

Life cycle stage	Default item	Default data and reference
Raw material acquisition and pre-processing	Transport	For transportation of inputs (e.g., fertilizers, crop protection agents, manure, etc.), a default transportation distance of 50 km is selected. For transport of feed to livestock farms, the default transport scenario provided below is used: • Dairy, pig, and poultry farms: Transportation of compound feed to the animal farm is not included. Beef system: 100 km by truck (see Agrifootprint methodology document, Part 2, Chapter 7)[2].
Ingredients and food processing	Transport	Default values in PEF
Consumer packaging	Transport	Default values in PEF
Distribution	Transport to DC	Default values in PEF
Distribution	Transport from DC to retailer	Zero
Distribution	Transport from retail to consumer	Default values in PEF

Table 3.9. Default values for packaging (Material type, weight and reuse rate)

Parameter	Default data
Amount and type of packaging	The following hierarchy is proposed to identify default values: Use default values in PEFCR, if available. If no PEFCR is available for a specific product group, the default values calculated in the PACK_AGB project shall be used[3].

[2] Agri-footprint. (2022). Agri-footprint 6 methodology report – Part 2: Description of data.

[3] ADEME. (2023). PACK project report – Agribalyse® 3.2. Packaging section.

Reuse rate	Default values in PEF

Table 3.10. Default values for energy at distribution center and retail

Life cycle stage	Parameter	Default data based on PEF guidance
Distribution	Energy consumption cooling/freezing	Energy to maintain temperature - 40 kWh/m3*year
	Refrigerants	0.29 kg R-404a per m2 fridge or freezer, 2m high, 10% annual leakage
	Energy consumption (excl. cooling/freezing) - lighting	30 kWh/m2*year + 360 MJ bought (burnt in boiler) or: 10 Nm3 natural gas/m2 ·year
	Storage volume and time	A DC is assumed to store 60,000 m3 of product, out of which 48,000 m3 for ambient storage and 12,000 m3 for chilled or frozen storage. For 52 weeks of storage, a default total storage capacity of 3,120,000 m3*weeks/year shall be assumed.
Retail	Energy consumption cooling and freezing	Cooling - 1900 kWh/m2*year (219 kWh/m3) Freezing - 2700 kWh/m2*year (415 kWh/m3)
	Energy consumption (excl. cooling/freezing) - lighting and heating	400 kWh/m2*year
	Storage volume and time	A retail space is assumed to store 2,000 m3 of products (50% of the 2,000 m2 building area covered by shelves that are 2m high) over 52 weeks, i.e., 104,000 m3 * weeks/year.

Table 3.11. Default values for parameters at consumer

Parameter	Default data
Raw-to-cook ratios	Default values included in the Globodiet Methodology
Preparation techniques and energy consumption	Default values included in PEF-wise methodology (see table 3.12) [4].
Ratio electricity to Natural gas for cooking	Default values in PEF
Storage (Chilling, freezing, etc.) at the consumer level	Default values in PEF
Preparation time	Specific default values for pan frying and boiling from Foundation Earth methodology (see table 3.13) [5]. Default values for other preparation methods are included in the PEF-wise methodology (see table 3.14)[4].

[4] Wageningen University & Research (2024 draft - unpublished). PEF-wise methodology for food products consumed in the Netherlands.

[5] Foundation Earth. (2023). LCA methodology for environmental food labelling – 2023 beta version 1.0.

Added inputs and water for beverages prepared at the consumer level	Default values in Foundation Earth methodology (see table 3.15) [5]

Table 3.12 Default energy use per preparation technique at consumer [4]

Preparation technique	Energy source	Power (kWh/h)	Preparation time (min)	Comment
Deep frying	Always electric	2.3	Per product group	Power based on https://apparaatverbruik.nl/frituurpan/hoeveel-stroom-verbruikt-een-frituurpan/ 40 gram of sunflower oil added per kg product (= assumption)
Pan frying	Mix electric/ Natural gas	1	Per product group	Power based on PEF, 5 grams of sunflower oil added per kg product (= PEF default for meat, fish, eggs)
Boiling	Mix electric/ Natural gas	3	Per product group	Power based on PEF
Water cooker	Always electric	2.2	3	Assumption, based on https://apparaatverbruik.nl/waterkoker/hoeveel-stroom-verbruikt-een-waterkoker/
Oven	Always electric	1.23	Per product group	Power based on PEF
Microwave	Always electric	1	Per product group	Assumption
Chilled at consumer	Always electric	0.0777 kWh/L		PEF default
Freezing at consumer	Always electric	0.294 kWh/L		PEF default
No preparation	-			No energy use included

Table 3.13 – Default boiling time and added water per kg of product for "boiling" preparation at consumer [5]

Product category	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
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 3.14 - Default preparation times and water added for food categories at consumer [4]

Product Group	Deep Frying (min)	Oven (min)	Comment
Rice	N/A	-	Assumption
Pasta	N/A	-	PEF default
Potatoes	4	-	Assumption
Pulses	N/A	-	Assumption
Vegetables	N/A	-	Assumption
Meat	6	-	PEF default (pan frying)
Fish	6	-	PEF default (pan frying)
Eggs	N/A	-	PEF default (pan frying)
Frozen dishes	-	15	PEF default

Table 3.15 – Inputs and water added for beverages prepared at consumers [5]

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	

3.6 - Data gaps and proxies

When compiling the life cycle inventories for products in scope, data gaps might be encountered. The issue of addressing data gaps is not covered in the PEF method, but it is relevant when developing a harmonized database for the environmental footprint of food products using generic data. It is also relevant for ecolabeling, which uses partly generic data. When encountering data gaps, the approach is to either solve the data gaps by doing desk research or to use proxies or assumptions. The latter will be reflected in the Data Quality Rating (see Section 3.4 -

Data quality requirements). This section focuses on crop cultivation, animal production, processing of ingredients, and assembly of food products, where proxies need to be made, and no default values/ approaches are available. Other life cycle stages, such as distribution, retail, consumption, and packaging, are usually approached via default data when building a database/ executing ecolabeling. Default values are available from PEF in most cases (see Section 3.5 - Default values).

3.6.1 - Data gaps and proxies in crop cultivation and animal production

Data gaps often occur when information is lacking on crops and animal cultivation and production data, as well as their geographical location. For both kinds of data gaps, the approach is, in general, as follows. The FAO and Eurostat statistics are important sources of information on the origin of crops and animal products. Similarly, other sources of trade data can be used, such as TradeMap/ UN Comtrade, and FABIO model. An overview of these different data sources is presented in Table 3.13 (see Section 3.7 - Data sources for imported products). However, trade data for all crops and/ or animal products might not be available in these data sources, and therefore, the following proxy approach is suggested to fill these data gaps. The approach considers two main components: the type of trade data and the geographical location of the trade data. These two aspects should be considered in parallel by the LCA practitioner when selecting proxies.

Type of trade data

- Trade data is indirectly derived from the trade data of the co-product. For example, in FAOstat only the quantity of the cake of soya beans is given. By using a fixed soybean cake-to-soybean meal yield ratio, the amount of soybean meal production can be quantified.
- Trade data from a similar crop (same family) is used.
- Trade data on the commodity total or commodity group is used (e.g., trade data of refined coconut oil is based on coconut oil).

Geographical location

- When available, the EU country-specific consumption mix should be used.
- Alternatively, EU country-specific consumption mix can be based on imports only[2].
- Alternatively, no consumption mix is used, and therefore, the assumption is that the crop/ animal product is fully locally produced.
- If none of the previous alternatives is applicable, the consumption mix is based on the EU production mix (e.g., for beetroot, the EU production data are used as a proxy for the EU country-specific consumption mix).

Proxies' hierarchy

The approach to consistently dealing with crop cultivation and animal production data gaps follows the hierarchy described here. The priority is to use an EU-specific country consumption mix of a given crop and/ or animal product. Note that a minimum coverage of 70% of the consumption mix is required, following the approach proposed in the Eco Food Choice extrapolation method[6]. If the consumption mix coverage of 70% is not reached (e.g., no cultivation data for plums for the main importing countries: Spain, Costa Rica, and Turkey), proxies should be used depending on data availability, as follows:

- Crop cultivation and animal production data from another (neighbouring) country with similar climatic conditions on the same continent are used (e.g., if cultivation data for Turkey, a main importing country of plums in the EU, is lacking, cultivation data of Greece are used instead).
- Crop cultivation and animal production data of a similar crop or animal product, belonging to the same family, are used (e.g., apricot as a proxy for plums, or basil instead of mint).

If no proxies are available, the remaining data gaps are resolved via desk research.

3.6.2 - Data gaps and proxies in the processing of ingredients and food products

For the processing stage, the choice is to either solve the data gap using desk research or using proxies. The preference is to solve the data gap using desk research, but the choice will depend on the effort required to solve the data gap via desk research and the quality of the appropriateness of the available proxies for any given data gap.

3.7 - Data sources for imported products

The origin of food products consumed in each country is a critical factor influencing impact outcomes, emphasizing the importance of adjusting the consumption mix (the composition of products consumed in a country, both domestic and imported) for each product. However, obtaining accurate data on product origins can be challenging. To balance effort and accuracy, a cut-off point can be defined, simplifying the data collection process while ensuring that the information remains comprehensive and reliable. A 70% threshold is recommended for calculating the origins of the food product[7]. This threshold ensures that at least 70% of the total products consumed in the country are traced back to their specific sources, including the portion of domestic production intended for domestic use. The identified origins and their respective proportions, covering at least the 70% minimum threshold, can then be adjusted and normalised to 100% covering the total consumption mix. Thus, two critical data points

[6] Eco Food Choice. (2025). Extrapolation method: Methodological report on how to transpose a national LCA database on food to another country.

[7] ADEME. (2024). Agribalyse® 3.2 methodology for food products update.

need to be identified: the proportion of domestic production used for domestic consumption and the quantity and origin of imports.

To ensure accuracy and minimise uncertainty, the recommended hierarchy of data sources for this task is as follows:

- Well-documented public statistics from trusted national or international institutions. It is recommended to rely on international official databases such as FAOStat, EUROStat, Trade Map or FABIO, which provide comprehensive and standardised trade data, ensuring consistency and reliability in the analysis. If the user is aware that national data sources in their country are more accurate, it is recommended to prioritise them as the primary source of information over international data sources.
- Statistics with restricted-access or publicly accessible scientific literature
- Peer-reviewed, well-documented case study
- Published case study with limited supporting documentation
- Expert opinion
- Individual data and rough estimates

In studies related to environmental impacts, agricultural production and raw material trade, it is better to rely calculations on product weight than economic value, as it reflects better the physical scale of transportation, production and consumption, and eliminates the fluctuation factor of prices. Therefore, it is recommended to use product weight statistics as the basis for assessing import quantities and domestic consumption. Information on standards regarding the quality of data can be found in Section 3.4 - Data quality requirements.

Table 3.16. Recommended international databases.

Database	Data origin	Data scope
FAOStat	Food data is collected, processed and disseminated according to the standard International Merchandise Trade Statistics (IMTS) Methodology. The data is mainly provided by UNSD, Eurostat, and other national and international authorities. Trade partner data is used for non-reporting countries or missing cells, and data on food aid is added to consider total cross-border trade flows.	The trade database includes all food and agricultural products imported/exported annually by all the countries in the world, by country, region and economic country groups for about 600 individual food and agriculture commodities since 1961.
EUROStat	Eurostat processes international trade in goods statistics (ITGS) in line with the European business statistics (EBS) framework. Data is primarily sourced from EU member states.	It contains a wide range of statistics describing the economy in various ways, including international and European trade of food and manufactured products since 1995.
Trade Map	Trade Map sources its data from UN COMTRADE, maintained by the United Nations Statistics Division (UNSD), and integrates it with data collected by the International Trade Centre (ITC).	Trade Map provides indicators on export performance, international demand, markets and importing/exporting companies. It covers 220 countries and territories and 5,300 products of the Harmonised System. The monthly, quarterly and yearly trade flows are available from

		the most aggregated level to the tariff line level.
FABIO (Food and Agriculture Biomass Input-Output Model)	The work is based mostly on freely available data from FAOSTAT, IEA, EIA, and UN Comtrade/BACI. It also integrates sub-national production data.	FABIO provides a set of multi-regional physical supply-use and input-output tables covering global agriculture and forestry. FABIO currently covers 191 countries plus Rest-of-World, 121 processes and 130 commodities for 1986-2013.

3.8 – Secondary data

As part of the ecolabeling process, secondary or background data (i.e., generic datasets) are required. Three types of background data can be distinguished:

- Datasets specific to agriculture and food production
- Datasets not specific to agriculture and food production, such as electricity mixes, packaging materials, building materials, etc.
- Datasets specific to agriculture and food production but not related to on-farm operations or food processing/manufacturing stages, for example, the manufacture of fertilizers or pesticides, and the manufacture of agricultural equipment.

3.8.1 - Temporary need for a private database to fill current gaps

These types of background data (also referred to as "secondary datasets") should ideally be sourced from the public open-source Environmental Footprint (EF) database developed by the European Commission. However, at this stage, the use of the EF database is not possible due to the following limitations:

- The End User Licence Agreement (EULA) does not permit use of the EF database outside the official Product Environmental Footprint (PEF) framework.
- PEF Category Rules (PEFCRs) are not yet available for all product groups covered by this methodology.
- The EF database lacks transparency, as its results are aggregated.

Open-source EF 4.0 datasets are expected to be released by the end of 2026 or early 2027; however, disaggregation of these datasets is still to be confirmed. The final version of the Eco Food Choice methodology will further consider how to integrate these datasets into the recommended background data hierarchy. Until EF 4.0 becomes available, non-public background databases must be used. Currently, the most suitable option is Agrifootprint, even though it is not open source. This choice is based on the following criteria:

- Completeness (worldwide scope, core food groups covered with 4,800 products, multi-stages scope going from cradle-to-farm or factory gate depending on products)

- Quality & transparency (documentation is available, peer reviewed, strong Data Quality Rating system in place, updated annually, detailed input/ output data with disaggregated data available, e.g., unit-level systems)
- Technological accuracy on agri-food systems (integration of country-specific food production practices)
- Interoperability with widely used software e.g., SimaPro, OpenLCA and widely used databases (reliance on Ecoinvent for non-agricultural/food-related data)
- Representativeness (modelling based on consistent representative data sources)

Compliance of the Agrifootprint database with the Eco Food Choice methodology requirements is to be reassessed with the release of the final method planned in 2026. Ecoinvent also meets most eligibility criteria for private databases and provides greater sectoral diversity (e.g., energy and electricity, transport, materials, waste and recycling). However, it lacks sufficient and comprehensive coverage of agricultural and food production data. In addition, Agrifootprint uses EcoInvent data to cover non-agri-food-related data, making it more aligned with Eco Food Choice's needs.

3.8.2 - Recommended hierarchy for background data

- For datasets not specific to agriculture and food production: Use Ecoinvent.
- For datasets specific to agriculture and food production but not related to on-farm or food processing/ manufacturing operations: Use Ecoinvent.
- For datasets specific to on-farm operations or food processing/ manufacturing:
  Follow the hierarchy below (in order of priority):
  - 1. Local open-source databases (e.g., Agribalyse, ILCIDAF, Dutch database, etc.), and pending they meet the eligibility criteria listed below.
  - 2. Locally extrapolated data as per the Eco Food Choice extrapolation guidelines[2], using the same prioritization approach as this report, and pending they meet the eligibility criteria listed below.
  - 3. Global open-source databases for imported products (e.g., Hestia.Earth)
  - 4. Private databases focused on agri-food (e.g., Agri-footprint) depending on the product assessed
  - 5. Private databases with broader sectoral coverage (e.g., Ecoinvent)

In the short term, although discrepancies and methodological misalignments are unavoidable, relying on available secondary data remains a pragmatic and necessary approach. This strategy allows for incremental improvement of the overall system over time. The long-term goal is the convergence of databases around shared methodological choices, ideally based on the consensus developed within the Eco Food Choice framework.

3.8.3 - Eligibility criteria for databases

Local open-source databases should be used only if they meet the following requirements:

- Completeness (coverage of core food groups, cradle-to-farm or factory gate at minimum)
- Quality & transparency (documentation available, peer reviewed, strong Data Quality Rating system in place, updated regularly, detailed input/ output data with disaggregated data available, e.g., unit-level systems)
- Technological accuracy on agri-food systems (integration of country-specific food production practices)
- Representativeness (modelling based on consistent representative data sources)
- Interoperability with widely used software e.g. SimaPro, OpenLCA and widely used databases e.g., EcoInvent
- Governance by non-profit, supported by local government organizations (e.g., ADEME, ENEA)

Private databases should be used only if they meet the following requirements:

- Completeness (worldwide scope, core food groups covered, cradle-to-farm or factory gate at minimum)
- Quality & transparency (documentation available, peer reviewed, strong Data Quality Rating system in place, updated regularly, detailed input/ output data with disaggregated data available, e.g., unit-level systems)
- Interoperability with widely used software, e.g., SimaPro, OpenLCA and widely used databases, e.g., EcoInvent
- Allows for filling gaps not covered by open-source databases, e.g., through a higher sectoral diversity
- Technological accuracy as much as possible on agrifood practices and important sectors (e.g., energy and electricity, transport)
- Representativeness (modelling based on consistent representative data sources)

3.8.4 - Guidance on the combination of data sources

It is advisable to limit the number of data sources used when compiling life cycle inventories, as excessive reliance on multiple databases can introduce methodological inconsistencies due to differing assumptions and modelling choices. No more than five databases should be used, given the current lack of comprehensive national databases. In the worst-case scenario, these five databases might include:

1) An open-source national database,
2) Extrapolated data from a local open-source database,
3) An open-source database covering imported products,
4) A food-specific private database, and
5) A general private database to address non-food data gaps.

Efforts should be made to streamline sources and prioritize consistency by striving for a maximum of three databases, including a robust national database.

Cut-off requirements can be found in Section 2.4 - Cut-off.

3.9 – Company-specific data

Product-specific data should be preferred over generic data when available, ensuring data consistency (e.g., one cannot use yield-specific data and fertilizer generic data, as yields and fertilizers are correlated). However, in many cases, the cost of collecting specific data overcomes the accuracy benefit and might prevent the scalability of ecolabeling. Also, more specific data induces more complex tools. It is important to focus on key primary data for environmental relevance and economic efficiency. As digitalization and data infrastructure progress, it should be easier to incorporate more primary data in ecolabel calculation in the future.

A certain level of company-specific data is needed for meaningful and trustworthy ecolabeling. From the start, the minimum data points that shall be filled with company-specific data are:

- Country of cultivation/ production per ingredient
- Production type (conventional or organic at least)
- Recipe (kg ingredients per kg final product)
- Country of processing (production of the (composed) food product)
- Processing operations (e.g., ambient, cooled, frozen, cooked, dehydrated, fried)
- Packaging materials and weight (kg per unit of packaging) or at least "packaging type"

Farm data on plant cultivation and animal husbandry, and processing of ingredients and food, will be targeted for company-specific data at a later stage. For farms, the focus can be on data that are relevant and relatively easy to collect, like yields, fertilizers used and amounts, pesticides used and amounts, energy use, fuel use, and feed compositions. Emissions will need to be remodeled using the company-specific data. For processing the data requirements are about mass balances, fuel use, energy use, water use, and waste streams. The remaining data points are either modelled or a default is being used.

Information from retailer databases might also be used to improve the assessment, for instance, by gaining more insight into the specific production circumstances using information on certification, labels, claims, seasonality, and nutritional information from these databases.

There can also be specific mitigation practices (e.g., tillage farming, cover cropping, rotational grazing, precision fertilization), particularly at farm and processing levels, of which the effects might be captured partially by the parameters mentioned above but might also partially be omitted using the above parameters. On the route to making ecolabeling more and more specific, the integration of such mitigation activities should be considered.

For electricity modelling, company-specific data or secondary data, or a mix of both may be used. Further guidance is included in Section 3.3.3 - Electricity use.

For the final life cycle stages (distribution, retail, consumer, end-of-life), it is recommended to stick to default scenarios. However, if accurate and representative quality company-specific data are available, they may be used, pending they follow the definitions prescribed in PEF.

4 – Life cycle stages

4.1 – Raw materials acquisition

This life cycle stage encompasses all activities related to the resource extraction, raw material production, pre-processing of materials and starting materials used as input for cultivation.

4.2 - Crop cultivation

4.2.1 - Pesticides

The pesticides applied to the field are modelled following the consensus LCI model development in the OLCA-Pest project, which improved the PestLCI 2.0 model (Dijkman and al., 2012[8]). The PestLCI Consensus Model is based on the emission quantification model PestLCI 2.0 (Nemecek and al., 2022[9]): pesticide types included are insecticide, herbicide, fungicide, plant growth regulator, and acaricide/ miticide. Default initial emission distribution fractions should be used (Tier 1A), which can be consulted in the OLCA-Pest project, particularly in the Excel file named "LCI results: Default life cycle inventory pesticide initial emission distribution fractions from the OLCA-Pest project"[10]. The emissions (including the crop compartment) are calculated by multiplying the mass applied by the respective emission fraction; all fractions sum up to 1.

To use the default emission fractions, the information needed are the crop and the target class. Split the fraction on the crop into the share of the products used for food and non-food purposes. If the share of food use is unknown, the default is 100% for crops that are generally used as food. As no crop compartment exists, this fraction is modelled in a separate emission to soil, mentioning that it corresponds to "crop compartment". It is recommended to change the modelling when the crop compartment is available in LCA software programs.

4.2.2 - Fertilisers

The application of synthetic, growing media, manure, crop residues, compost and other organic fertilisers leads to the emission of different pollutants to air, water, and soil. The following emissions are considered, according to PEF:

- NH_3 to air (from the use of N-fertiliser);

[8] Dijkman, T. J., Birkved, M., & Hauschild, M. Z. (2012). PestLCI 2.0: A second generation model for estimating emissions of pesticides from arable land in LCA. International Journal of Life Cycle Assessment, 17(8), 973–986.

[9] Nemecek, T., and al. (2022). Operationalising emission and toxicity modelling of pesticides in LCA: The OLCA-Pest project contribution. International Journal of Life Cycle Assessment, 27(4), 463–479.

[10] OLCA-Pest project. (2020). LCI results: Default life cycle inventory pesticide initial emission distribution fractions.

- N_2O to air (direct and indirect) (from the use of N-fertiliser);
- CO_2 to air (from the use of lime, urea, and urea compounds);
- NO_3 to water unspecified (leaching from the use of N-fertiliser);
- PO_4 to water unspecified or freshwater (leaching and run-off of soluble phosphate from the use of P-fertiliser); and
- P to water unspecified or freshwater (soil particles containing phosphorus, from the use of P-fertiliser).

The N_2O, NH_3, NO_3, and CO_2 emissions are modelled applying the IPCC 2019[11] Tier 2 approach, while Phosphorus emissions to water are modelled with the SALCA method (Nemecek and al., 2024[12]).

Table 4.1. Emissions flows and models

Emission	Compartment	Equation	Source
N_2O direct (synthetic and organic fertiliser)	Air	$kg\ N_2O = \sum(F_{SN} + F_{ON}) \times EF_{1i} + (F_{CR} + F_{SOM}) \times EF_1 + \times \frac{44}{28}$	IPCC 2019[11] Tier 2
N_2O indirect (synthetic and organic fertiliser)	Air	$kg\ N_2O_{deposition} = [(F_{SN} \times Frac_{GASF}) + ((F_{ON} + F_{prp}) \times Frac_{GASM})] \times EF_4 \times \frac{44}{28}$ $kg\ N_2O_{Leaching} = [(F_{SN} + F_{ON} + F_{CR} + F_{SOM}) \times Frac_{Leach}] \times EF_5 \times \frac{44}{28}$	
NH_3/NO volatilisation (synthetic fertilizer, sewage, other organic, manure, crop residues)	Air	$E_{fert\_NH_3} = \sum_{i=1}^{I} \sum_{j=1}^{2} (m_{fert_{i,j}} \times EF_{i,j})$ $E_{pollutant} = AR_{N\_applied} \times EF_{pollutant}$ $E_{applic\_} = (m_{applic_{slurry_{TAN}}} \times EF_{applic_{slurry}}) + (m_{applic_{solid\_TAN}} \times EF_{applic_{solid\_TAN}})$ $NH_{3_{cropresidues}} = \frac{17}{14} \times \sum(A_T \times Nload_T \times F_T) \times EF_{crop\ residues\ (T)}$	EEA, 2023[13]
NO_3 (synthetic and organic fertiliser)	Water	$kg\ NO_3 = (F_{SN} + F_{ON} + F_{prp} + F_{CR} + F_{SOM}) \times Frac_{Leach} \times \frac{62}{14}$	IPCC 2019[11] Tier 2
CO_2 (limestone, dolomite, urea)	Air	$kg\ CO_2 = ((kg_{Limestone} \times EF_{Lime}) + (kg_{Dolomite} \times EF_{dolomite}) + (kg\ urea \times EF_{urea})) \times \frac{44}{12}$	

[11] IPCC. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use. Intergovernmental Panel on Climate Change.

[12] Nemecek, T., and al. (2024). Swiss agricultural life cycle assessment: A method to assess the emissions and environmental impacts of agricultural systems and products.

[13] European Environment Agency. (2023). EMEP/EEA air pollutant emission inventory guidebook: Technical guidance to prepare national emission inventories. Publications Office of the European Union.

Phosphorus (P)	Water Soil erosion	$P_e = A \cdot m_{erod} \cdot P_{soil} \cdot r \cdot e$	SALCA Nemecek and al. (2024)[12]
	Water Runoff	$P_r = s \cdot k_r \cdot k_{s1} \cdot k_n \cdot k_t \left(1 + \frac{0.2}{80} \cdot f_m + \frac{0.7}{80} \cdot f_{ol} + \frac{0.4}{80} \cdot f_{os}\right)$	
	Water Leaching Groundwater	$P_g = k_l \cdot k_{s2} \cdot k_n \left(1 + \frac{0.2}{80} \cdot f_{ol}\right)$	
	Water Leaching Drainage	$P_d = P_g \cdot k_d$	

Table 4.2. Description of parameters – fertiliser emission model

Parameter	Description	Value
EF_1	Emission factor for direct N_2O emissions from Nitrogen inputs in kg N_2O-N, per kg N	0.01
EF_4	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces	0.01
EF_5	Emission factor for N_2O emissions from N leaching and runoff	0.011
F_{SN}	The amount of synthetic fertilizer N applied to soils, kg N	
F_{ON}	The amount of animal manure, compost, sewage sludge, and other organic N additions applied to soils, kg N	
F_{CR}	The amount of N in crop residues (above-ground and below-ground), kg N	
F_{SOM}	The amount of N in mineral soils that is mineralized, in association with loss of soil C from soil organic matter, kg N	
F_{prp}	Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N	
$Frac_{GASF}$	Fraction of synthetic fertiliser N that volatilises as NH_3 and NO_x, kg N volatilised	0.11
$Frac_{GASM}$	Fraction of applied organic N fertiliser materials (F_{ON}) and of urine and dung N deposited by grazing animals (FPRP) that volatilises as NH_3 and NO_x, kg N volatilised (kg of N applied or deposited)	0.21
$Frac_{Leach}$	Emission factor for N_2O emissions from Nitrogen leaching and runoff in kg N_2O-N per kg N leached and runoff	0.24
$EF_{dolomite}$	Emission factor for dolomite in kg C per kg dolomite	0.13
EF_{lime}	Emission factor for limestone in kg C per kg limestone	0.12
EF_{urea}	Emission factor for urea in kg C per kg urea	0.20
EF_{1i}	Emission factors developed for N_2O emissions from synthetic fertiliser and organic N application under conditions *i*, kg N_2O–N/kg N input (*i* = 1, …*n*)	
$E_{fert\_NH_3}$	The emission kg NH_3/year	
$EF_{i,j}$	The emission factor for fertiliser type *i* in pH region *j*	
$E_{pollutant}$	Amount of pollutant emitted (kg/year),	
$AR_{N\_applied}$	Amount of N applied in fertiliser, organic waste or crop residues, kg/year	
$EF_{pollutant}$	Emission factor of pollutant, kg/kg	
E_{applic}	The emission of NH_3-N during and immediately after field application	

$m_{applic_{slurry_{TAN}}}$	The total amount of TAN	
$m_{applic_{solid\_TAN}}$	The total amount of TAN	
A_T	The area of the *T* th crop, ha	
$Nload_T$	the above-ground production of crop residues from the *T* th crop, kg N/ha.year	
F_T	The fraction of the crop residues from the *T* th crop that produce NH_3 emissions	
$EF_{crop\ residues\ (T)}$	The emission factor for crop *T*, kg NH_3-N/kg N_load	
44/12	CO_2-C to CO_2 conversion factor	
44/28	N_2O-N to N_2O conversion factor	
17/14	NH_3-N to NH_3 conversion factor	
62/14	NO_3-N to NO_3 conversion factor	
P_e	The mean amount of P transported into water bodies through soil erosion	
A	Area of plot, ha	
M_{erod}	Mass of eroded soil, t/ha	
P_{soil}	P concentration in soil, kg P/t	950 g P/t soil
r	Fraction of P loss reaching the aquatic environment	0.2
e	Enrichment factor	
P_r	P loss through runoff	
s	Dimensionless slope factor	
k_{s1}	Correction factor	0.8 – 1.2
k_n	Correction factor	0.8 – 1.4
k_t	Correction factor	
f_m, f_{ol} and f_{os}	The applied amounts of mineral fertiliser (*m*), liquid manure (slurry) (*ol*) and solid manure (*os*), kg P/ha	
P_g	Phosphorus leaching into groundwater	
K_l	The average annual P leaching into groundwater	
k_{s2}	Correction factor	
f_{ol}	The applied amount of slurry	
P_d	P leaching by drainage	
k_d	The drainage factor	

4.2.3 - Heavy metals

The heavy metals emissions modelling is based on the SALCA method (Nemecek and al., 2024[12]). Heavy metal emissions from field inputs are modelled as emissions to soil and/ or leaching or erosion to water, due to the application of fertilizers and manure, and due to deposition. This way, the inventory accounts for the final emissions (release) of the heavy metals in the environment, including the uptake of heavy metals by the crop. SALCA method considers the following:

- The agricultural inputs to a specific field are calculated. This includes mineral and organic fertilisers, pesticides, and seed.
- An allocation factor is calculated. This allocation factor is subsequently applied to the emissions from erosion and leaching and to exports from harvested goods.
- Emissions from leaching and erosion are determined, as well as metals exported with the crop.
- Emissions to agricultural soil are calculated as the difference of inputs and outputs (erosion, leaching, and harvest).

The metal concentrations in agricultural soils and the mean annual deposition rates data should be obtained according to the country and geographical context. The content of heavy metals (Cd, Cu, Zn, Pb, Ni, Cr and Hg) in mineral and organic fertilizers, biomass, pesticides, and for leaching can be consulted in the SALCA method (Nemecek and al., 2024)[12].

Table 4.3. Overview of the heavy metal emission model

	Equation
Total agricultural input	$\boldsymbol{M_{agro\,i} = \sum_j (M_{seed\,s} \times c_{seed\,s,i}) + \sum_j (M_{pesti\,e} \times c_{pesti\,e,i}) \times (1 - f_{air} - f_{OFS}) + \sum_j (M_{ferti\,t} \times c_{ferti\,t,i}) + \sum_j (M_{man\,m} \times c_{man\,m,i})}$
Allocation factor	$\boldsymbol{A_i = \frac{M_{agro\,i}}{(M_{agro\,i} + m_{depos\,i} \times F_a \times F_t)}}$
Harvest	$\boldsymbol{M_{harv,i} = \sum_j (M_{mainpr,j} \times c_{mainpr,j,i}) \times A_i + \sum_j (M_{copr,j} \times c_{copr\,j,i}) \times A_i + \sum_j (M_{pesti,j} \times c_{pesti\,j,i}) \times (1 - f_{air} - f_{OFS}) \times A_p}$
Leaching, to surface water	$\boldsymbol{M_{leach,i} = m_{leach,i} \times Fa \times Ft \times A_i \times f_{drain}}$
Leaching, to groundwater	$\boldsymbol{M_{leach,i} = m_{leach,i} \times Fa \times Ft \times A_i \times (1 - f_{drain})}$
Erosion	$\boldsymbol{M_{eros,i} = S_{eros} \times c_{soil,i} \times a \times f_{eros} \times Fa \times A_i}$
Agricultural soil balance	$\boldsymbol{M_{soil,i} = M_{agro,i} - M_{harv,i} - M_{leach,i} - M_{eros,i}}$

Table 4.4. Description of the parameters – heavy metal emission model

Parameter	Description
$M_{agro\ i}$	Total agricultural input
$M_{harv\ i}$	Harvest, kg
$M_{leach\ i}$	Leaching (to water and groundwater), kg
A_i	Allocation factor (emissions from deposition)
$M_{seed\ s}$	The amount of seed *s,* kg
$M_{pesti\ e}$	The metal-containing pesticides (e.g. copper fungicides) *e,* kg
$M_{ferti\ t}$	The mineral and purchased organic fertilisers *t,* kg
$M_{man\ m}$	The farmyard manure *m,* kg (when applicable)

$C_{seed\ s,i}$, $C_{pesti\ e,i}$, $C_{ferti\ t,i}$, $C_{man\ m,i}$	The respective concentrations of metal *i* in input *j*
f_{air} , f_{OFS}	The fractions of pesticide emitted after application to the air and off-field surfaces, respectively.
i	The type of metal
$m_{depos\ i}$	The total input of heavy metal from atmospheric deposition, kg/ha.year
F_a	The area of the field, ha
F_t	The duration of the occupation, year
$M_{mainpr\ j}$	The amount in kg of harvested main products
$M_{copr\ j}$	The amount of harvested co-products
$M_{pesti\ j}$	The amount of pesticides applied
$C_{mainpr\ j,i}$, $C_{copr\ j,i}$, $C_{pesti\ j,i}$	The respective concentrations
A_p	The fraction of metals in pesticides exported with the harvest (0.05). if $M_{agro\ i} = 0$, $A_i = 0$
f_{drain}	Fraction of the area with drainage
$m_{leach\ i}$	The average amount of metal leaching, kg/ha.year
S_{eros}	The amount of eroded soil, kg/ha. (see the SALCA erosion model)
$C_{soil\ i}$	The heavy metal concentration in the soil, kg/kg. (geographic specific)
a	The accumulation factor (1.86)

4.2.4 - Rice cultivation

The PEF method prescribes using the IPPC calculations for methane (CH_4) emissions from rice. The equations in Table 4.5 are used to estimate methane emissions from rice cultivation (IPCC, 2019[11]).

Table 4.5. Methane emission model from rice cultivation.

	Equation
Methane emissions	$EF_i = EF_c \times SF_w \times SF_p \times SF_o$
Adjusted CH_4 emission scaling factors for organic amendments	$SF_o = \left(1 + \sum_i ROA_i \times CFOA_i\right)^{0.59}$

Table 4.6. Description of parameters – rice cultivation

Parameter	Description
EF_i	Adjusted daily emission factor for a particular harvested area
EF_c	Baseline emission factor for continuous flooded fields without organic amendments.
SF_w	Scaling factor to account for the differences in water regime during the cultivation period.
SF_p	Scaling factor to account for the differences in water regime in the pre-season before the cultivation period.
SF_o	Scaling factor should vary for both type and amount of organic amendment applied.
SF_O	The adjusted CH_4 emission scaling factors for organic amendments
ROA_i	The application rate of organic amendment i in dry weight for straw and fresh weight for others, tonne/ha.

$CFOA_i$	The conversion factor for organic amendment i (in terms of its relative effect with respect to straw applied shortly before cultivation) that can be consulted in the corresponding table of the IPCC 2019 report.

4.2.5 - Peat soils

CO_2 emissions from organic (e.g., peat-derived) soils are modelled based on IPCC (IPCC, 2014[14]). It consists of assigning an annual emission factor that estimates the losses of C following drainage. Drainage stimulates oxidation of organic matter previously built up under a largely anoxic environment. Specifically, the area of drained and managed organic soils under each climate type is multiplied by the associated emission factor to derive an estimate of annual CO_2 emissions.

On the other hand, CH_4 emissions from the land surface are estimated using a simple emission factor approach, depending on climate and type of land use. The default methodology considers boreal, temperate, and tropical climate zones, and nutrient-rich/ nutrient-poor organic soils. Different land uses imply drainage to different depths. The CH_4 emission factors depend on gas flux measurements, either from closed chambers or (for land surface emissions) from eddy covariance.

Table 4.7. CO_2 and CH_4 emission model for drained organic soils

Carbon Dioxide (CO_2)	$L_{Organic} = \sum_{C} (A \times EF)_C$
Methane (CH_4)	$CH_{4\_Organic} = \sum_{C,n,p} \left(A_{c,n,p} \times ((1 - Frac_{ditch}) \times EF_{CH_{4\,land\,c,n}} + Frac_{ditch} \times EF_{CH_{4\,ditch\,c,p}})\right)$
$L_{Organic}$ is the annual carbon loss from drained organic soils (tonnes C/year) A is the land area of drained organic soils in climate type c (ha) EF is the mission factor for climate type c (tonnes C/ha.year) $A_{c,n,p}$ is the land area of drained organic soils in a land use category in climate zone c, nutrient status n and soil type p (ha) $EF_{CH4\text{-}land}$ is the emission factor for direct CH_4 emissions from drained organic soils by climate zone c and nutrient status n (kg CH_4/ha.year) $EF_{CH4\text{-}ditch}$ is the emission factor for CH_4 emissions from drainage ditches, by climate zone c and soil type p (kg CH_4/ha.year) $Frac_{ditch}$ is the fraction of the total area of drained organic soil that is occupied by ditches	

Table 4.8. CO_2 emission/removal factors for drained organic soils in all land use categories

Land-use category	Climate/vegetation zone	Mean Emission factor (tonnes C ha^{-1} $year^{-1}$)	Uncertainty	
Peatland managed for extraction	Boreal and temperate	2.8	1.1	4.2
	Tropical	2.0	0.06	7.0

[14] IPCC. (2014). 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Intergovernmental Panel on Climate Change.

- For more information, see 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands[14], and Table 7.4, Chapter 7, Volume 4, *2006 IPCC Guidelines*[15].
- For off-site CO2-C emissions from peat extracted for horticultural or energy use, see Chapter 7, Volume 4, *2006 IPCC Guidelines*[15].

4.3 - Animal production

Emissions modelling for animal farming systems shall include emissions from enteric fermentation, from manure handling in the stable, during on-farm manure storage, and pasture. Emissions from the application of manure are described in Section 4.2.2 - Fertilisers.

The inventory of the animal production system considers all the activities happening at the farms: herd handling, energy and other utilities utilisation, feed intake, excretion, and emissions. The output is the animal product itself when leaving the farm gate. Upstream systems to animal production are fully included in input inventories. Ruminants' farms are often mixed crop-livestock systems, in which animals are fed with crops cultivated on-farm or directly graze on pastureland. In this regard, manure released on pasture and pasture management is included in input pasture inventories. The following aspects of the animal production systems are considered in the modelling:

Feed

- Ration/ compound feed formulation
- Feed ingredient inbound transportation
- Compound feed energy and water use
- Ration/ compound feed nutritional characteristics
- Estimation of uneaten feed

Animal herd and animal performances

- Number of incoming and outgoing animals (or biomass)
- Amount of animal product output and characteristics
- Weight or age of incoming and outgoing animals
- Mortality and escape rates
- Feed intake, and feed conversion ratio
- Time spent outside, or in housing
- Manure management system type (based on IPCC and EMEP/EEA definitions)

Other inputs

[15] IPCC. (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Vols. 1–5). Intergovernmental Panel on Climate Change.

- Energy use (on farm, on ship/boats);
- Water use;
- Material requirements for aquaculture infrastructure and cages (capital goods are only included in fish systems)
- Refrigerants use on and emissions on farm, ship/boats;
- Other materials use (e.g., bedding, chemicals for cleaning, lice treatment).

The modelling of emissions is mainly based on IPCC (2019[11]) guidelines for national greenhouse gas inventory (agriculture, forestry and other land use) and complemented with the EMEP/EEA air pollutant emission inventory Guidebook 2023[13]. The emissions included are:

- Methane (CH4) from enteric fermentation and manure management;
- Ammonia (NH3) and nitric oxide (NO) from manure management;
- Nitrous oxide (N2O) from manure management, direct emissions and indirect emissions (leaching and volatilization);
- Non-methane volatile organic compounds (NMVOC), from manure management: storage, feeding, grazing and housing;
- Particulate matter (PM2.5 and PM10), from manure management).

Leaching of phosphorus (P) and emissions of heavy metals (e.g., Cu, Zn) are not modelled at the animal husbandry handling and manure management, but only at manure application on the farm.

Table 4.9. Overview of the modelled emissions in animal systems

Excretions and emissions	Emission Source	Comment
Methane (CH_4), enteric fermentation	IPCC Tier 2	Excluding poultry
Methane (CH_4), manure	IPCC Tier 2	
Volatile Solids (VS) excretion	IPCC, Tier 2	
Nitrogen (N) excretion	IPCC, Tier 2	
Total Ammoniacal Nitrogen (TAN) excretion	EMEP/EEA, Tier 2	
Ammonia (NH_3) emissions	EMEP/EEA, Tier 2	
Nitric Oxide (NO) emissions	EMEP/EEA, Tier 2	
Direct Nitrous Dioxide (N_2O) emissions	IPCC, Tier 2	
Indirect Nitrous Dioxide (N_2O), leaching	IPCC, Tier 2	NH_3 and NO_x emissions based on EMEP/EEA
Indirect Nitrous Dioxide (N_2O), volatilization	IPCC, Tier 2	
Non-Methane Volatile Organic Compounds (NMVOC) emissions	EMEP/EEA, Tier 2	
Particulate Matter ($PM_{2.5/10}$) emissions	EMEP/EEA, Tier 1	

4.3.1 - Enteric fermentation

The modelling follows the IPCC 2019[11], Tier 2 approach. In the Tier 2 method, emission factors are calculated based on disaggregated livestock population categories. The key considerations for the Tier 2 method are the development of emission factors and the collection of detailed activity data. The enteric emissions from the livestock category and the total methane (CH_4) emissions from enteric fermentation are calculated as indicated in the table below. See Section 3.9 – Company-specific data for guidance on data gathering, adaptation, and application.

Table 4.10. Methane enteric fermentation emission modelling

	Equation	Source
Total enteric CH_4 emissions	$Total\ CH_{4-enteric} = \sum_{i,P} E_{i,P}$	IPCC, Tier 2
Enteric CH_4 emissions	$E_T = \sum_{(P)} EF_{(T,P)} \times \left(\frac{N_{(T,P)}}{10^6}\right)$	
Emission factor	$EF = \frac{GE \times \left(\frac{Y_m}{100}\right) \times 365}{55.65}$	
Gross Energy intake	$GE = \left[\frac{\left(\frac{NE_m + NE_a + NE_l + NE_{work} + NE_p}{REM}\right) + \left(\frac{NE_g + NE_{wool}}{REG}\right)}{DE}\right]$	

Table 4.11. Description of the parameters – enteric fermentation

Parameter	Description
T	Species/category of livestock
P	Productivity system
E_T	Methane emissions from enteric fermentation in animal category *T,* in Gg CH_4/year
EF	emission factor for the defined livestock population *T* and the productivity system *P*, in kg CH_4/head.year
N	The number of head of livestock species / category *T* in the country classified as productivity system P
E	The emissions for the *i*th livestock categories and subcategories based on production systems (*P*)
EF	Emission factor, kg CH4/head*year
GE	Gross energy intake, MJ/head*day
Y_m	Methane conversion factor, per cent of gross energy in feed converted to methane (values for cattle, buffalo, sheep and goats can be consulted in the IPCC (2019) report)
NE_m	Net energy required by the animal for maintenance, MJ/day
NE_a	Net energy for animal activity, MJ/day
NE_l	Net energy for lactation, MJ/day
NE_{work}	Net energy for work, MJ/day
NE_p	Net energy required for pregnancy, MJ/day
REM	Ratio of net energy available in a diet for maintenance to digestible energy
NE_g	Net energy needed for growth, MJ/day

REG	Ratio of net energy available for growth in a diet to digestible energy consumed
NE_{wool}	Net energy required to produce a year of wool, MJ/day
DE	Digestibility of feed expressed as a fraction of gross energy

4.3.2 - Manure management

Emissions modelling of manure management system includes Methane (CH_4), Nitrogen (N), Nitrous Oxide (N_2O), Ammonia (NH_3), Nitric Oxide (NO), Non-methane Volatile Organic Compounds (NMVOC), and Particulate Matter (PM). The modelling is based on IPCC (2019[11]) and EEA Air Pollutant Emission Inventory Guidebook [13], mainly Tier 2 otherwise specified, as indicated in the table below.

Methane (CH_4)

The Tier 2 is based on country-specific estimates of volatile solids and the impact of interactions between manure management systems and animal categories on total CH_4 emissions during excretion and storage, including manure treatments such as the production of biogas. The Tier 2 method relies on two primary types of inputs that affect the calculation of methane emission factors from manure: manure characteristics and animal waste management characteristics (AWMS).

N_2O

N_2O is produced, directly and indirectly, during the storage and treatment of manure before it is applied to land or otherwise used for feed, fuel, or construction purposes. The approach is based on N excretion, emission factors for N_2O emissions, as well as volatilization and leaching factors. As for direct N_2O emission from manure management, a Tier 2 method would follow the same calculation equation as Tier 1 but include the use of country-specific data for some or all the variables.

NH_3

The Tier 2 approach ensures consistency between the N species reported. It estimates the mineralisation of N and the immobilisation of TAN during manure management, and estimates other losses of N, e.g., as NO, to more accurately estimate the TAN available at each stage of manure management. The adoption of a consistent N-flow model, based on proportional transfers of TAN, allows different options or pathways to be incorporated to account for differences among real-world systems. The kg N mass balance can be used to check for errors.

NMVOC

NMVOC emissions arise from six different sources: silage stores, the feeding table if silage is used for feeding, livestock housing, outdoor manure stores, manure application, and grazing animals. NMVOC emissions from manure stores and manure application are estimated as a fraction of those from livestock housing. This fraction is assumed to be the same ratio as for NH_3 emissions.

PM

Emissions of PM occur from both housed and free-range or grazing livestock. However, emission measurements have focused on housed livestock, and a general lack of available information in the scientific literature means that *EFs* that are specific to free-range or grazing livestock are not available.

Table 4.12. Emission flows and modelling of manure management systems.

Animal	Emission flow	Equations	Source
Dairy Beef Pigs Goat Sheep Poultry	Methane (CH_4)	$CH_{4(mm)} = \left[\sum_{T,S,P} \frac{(N_{T,P} \times VS_{T,P} \times AWMS_{T,S,P} \times EF_{T,S,P})}{1000}\right]$ $EF_T = (VS_T \times 365) \times \left[B_{0(T)} \times 0.67 \times \sum_{S,k} \frac{MCF_{S,k}}{100} \times AWMS_{T,S,k}\right]$	IPCC 2019 Tier 2[11]
Dairy Beef Pigs Goat Sheep Poultry	Volatile Solids	$VS = \left[GE \times \left(1 - \frac{DE}{100}\right) + (UE \times GE)\right] \times \left[\left(\frac{1 - ASH}{18.45}\right)\right]$	IPCC 2019 Tier 2[11]
Dairy Beef Pigs Goat Sheep Poultry	Nitrogen (N) excretion	$Nex_T = N_{intake\,(T)} \times \left(1 - N_{retention_{frac(T)}}\right) \times 365 \frac{days}{year}$	IPCC 2019 Tier 2[11]
Dairy Beef Goat Sheep	Nitrogen (N) intake	$N_{intake(T)} = \frac{GE}{18.45} \times \left(\frac{\frac{CP\%}{100}}{6.25}\right)$	IPCC 2019 Tier 2[11]
Swine Poultry		$N_{intake(T)} = DMI_i \times \left(\frac{\frac{CP\%}{100}}{6.25}\right)$	
Dairy Beef Pigs Poultry Goat Sheep	Nitrous oxide (N_2O) (Direct)	$N_2O_{D(mm)} = \left[\sum_S \left[\sum_{T,P} \left(\left(N_{(T,P)} \times Nex_{(T,P)}\right) \times AWMS_{(T,S,P)}\right) + N_{cdg(S)}\right] \times EF_{3(S)}\right] \times \frac{44}{28}$	IPCC 2019 Tier 2[11]
	Nitrous oxide (N_2O) (Indirect)	1 $N_2O_{G(mm)} = \left(N_{volatilization-MMS)} \times EF_4\right) \times \frac{44}{28}$ 2 $N_2O_{L(mm)} = \left(N_{Leaching-MMS)} \times EF_5\right) \times \frac{44}{28}$	IPCC 2019 Tier 2[11]
Dairy Beef Pigs Poultry Goat Sheep	Ammonia (NH_3) Nitric Oxide (NO) (House, storage, Yard)	$EMMS_{NH_3} = \left(E_{yard} + E_{h\_slurry} + E_{h\_solid} + E_{str\_slurry} + E_{str\_solid}\right) \times \frac{17}{14}$ $EMMS_{NO_2} = \left(E_{str\_slurry\_NO} + E_{str\_solid\_NO}\right) \times \frac{46}{14}$	EMEP/EEA 2023 Tier 2[13]
	Ammonia (NH_3) Nitric Oxide (NO) (Field application)	$E_{applic\_slurry} = m_{applic\_slurry\_TAN} \times EF_{applic\_slurry}$ $E_{applic\_solid} = m_{applic\_solid\_TAN} \times EF_{applic\_solid}$	EMEP/EEA 2023 Tier 2[13]

Dairy Beef	Non-methane volatile compounds (NMVOC) Total	$E_{NMVOC} = AAP_{animal} \times (E_{NMVOC,slg\_str} + E_{NMVOC,slg\_fdg} + E_{NMVOC,h} + E_{NMVOC,str} + E_{NMVOC,applic} + E_{NMVOC,graz})$	EMEP/EEA 2023 Tier 2[13]
	Non-methane volatile compounds (NMVOC) (Storage, housing, feeding, grazing, manure)	$E_{NMVOC,slg\_str} = MJ \times X_h \times (EF_{NMVOC,slg\_fdg} \times Frac\_max_{slg}) \times Frac_{slg\_str}$ $E_{NMVOC,slg_{fdg}} = MJ \times X_h \times \left(EF_{NMVOC,slg_{fdg}} \times Frac\_max_{slg}\right)$ $E_{NMVOC,h} = MJ \times X_h \times EF_{NMVOC,h}$ $E_{NMVOC,graz} = MJ \times (1 - X_h) \times EF_{NMVOC,graz}$ $E_{NMVOC,manure\_str} = EF_{NMVOC,h} \times \left(\frac{E_{NH3,str}}{E_{NH3,h}}\right)$	
Pigs Poultry Goat Sheep	Non-methane volatile compounds (NMVOC)	$E_{NMVOC,slg\_str} = VS \times X_h \times (EF_{NMVOC,slg\_fdg} \times Frac\_max_{slg}) \times Frac_{slg\_str}$ $E_{NMVOC,slg_{fdg}} = VS \times X_h \times \left(EF_{NMVOC,slg_{fdg}} \times Frac\_max_{slg}\right)$ $E_{NMVOC,h} = VS \times X_h \times EF_{NMVOC,h}$ $E_{NMVOC,graz} = VS \times (1 - X_h) \times EF_{NMVOC,graz}$ $E_{NMVOC,manure\_str} = EF_{NMVOC,h} \times \left(\frac{E_{NH3,str}}{E_{NH3,h}}\right)$	EMEP/EEA 2023 Tier 2[13]
Dairy Beef Pigs Poultry Goat Sheep	Particulate matter (PM)	$Em_{PM_{2.5}} = \sum_i EF_{PM_{2.5_i}} * AAP_i$ $Em_{PM_{10}} = \sum_i EF_{PM_{10_i}} * AAP_i$ $APP = n_{places} \times \left(1 - \frac{t_{empty}}{365}\right)$	EMEP/EEA 2023 Tier 1[13]

Table 4.13. Description of the parameters – manure management systems

Parameter	Description
T	Species/category of livestock
P	Productivity class of the system
N	The number of head of livestock species/category *T* in the country classified as productivity system P
S	Manure management system
VS	Volatile solids
MCF	Methane conversion factors for each manure management system *S* by climate region *k*, percent
GE	Gross energy intake, MJ/day
DE	Digestibility of the feed in percent
EUxGE	Urinary energy expressed as fraction of GE.
ASH	The ash content of feed calculated as a fraction of the dry matter feed intake.
DMI	Dry Matter Intake
CP	Percent crude protein in dry matter for growth stage "i"

$N_2O_{D(mm)}$	Direct N_2O emissions from manure management in the country (kg N_2O/year)
Nex	Annual average N excretion per head of species/category *T* in the country, for productivity system *P* in kg N/animal.year
$N_{cgd(S)}$	Annual nitrogen input via co-digestate in the country, in kg N/year, where the system *S* refers exclusively to anaerobic digestion.
AWMS	Fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country.
EF_3	Emission factor for direct N_2O emissions from manure management system *S* in the country, kg N_2O -N/kg N in manure management system *S*
$N_{volatilization\text{-}MMS}$	Amount of manure nitrogen that is lost due to volatilisation of NH_3 and NO_x, kg N/year
$N_{leaching\text{-}MMS}$	Amount of manure nitrogen that is lost due to leaching, kg N/year
$N_2O_{L(mm)}$	Indirect N_2O emissions due to leaching and runoff from Manure Management in the country, kg N_2O/year
$N_2O_{G(mm)}$	Indirect N_2O emissions due to volatilization of N from Manure Management in the country, kg N_2O/year
EF_4	Emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O-N/(kg NH_3-N+NO_x-N volatilised)
EF_5	Emission factor for N_2O emissions from nitrogen leaching and runoff, kg N_2O-N/kg N leached and runoff
AAP	Average annual population
Slg	Silage
Fdg	Feeding
Str	Storage
h	House
EMMS	Emissions (NH_3, NO) Manure Management System
X_h	The proportion of the year the animals are housed
$E_{house,yard,\ store}$	The emissions (NH_3-N, N_2O-N, NO-N, N_2) from the livestock housing, yard and storage from the slurry and solid manure
$E_{applic,slurry/solid}$	The N emissions from the slurry and solid manure storage after field application
$EF_{appl,slurry/solid}$	Emission factor for slurry and solid manure application
E_{NMVOC}	The total NMVOC emissions from different sources
MJ	Feed intake in energy units
EF_{NMVOC}	Emission factor for house, grazing, storage and silage-feeding
$Frac\_max_{slg}$	The feed in dry matter during housing that is silage, expressed as a fraction of the maximum proportion of silage possible in the feed composition
$Frac_{slg\_str}$	The proportion of the emissions from the silage store compared with the emissions from the feeding table in the building
Em_{PM}	Particulate Matter emissions (2.5, 10)
$EF_{PM2.5/10}$	Particles 2.5/10 emission factor, animal *i*
N_{places}	Average capacity for a housed livestock category that is usually occupied
T_{empty}	The average duration during the year when the animal place is empty (in d)

4.3.3 - Aquaculture (marine fish)

The fish production systems calculate the emissions correlated to aquaculture and live catch systems. The emissions modelled in the fish production system are:

- Total nitrogen (N) emitted to the ocean,
- Total phosphorus (P) emitted to the ocean,
- Dinitrogen monoxide (nitrous oxide) (N2O) emitted to air from nitrogen emitted to ocean,
- Methane (CH4) emitted to air from carbon emitted to ocean.

Table 4.14. Emission flows and modelling of marine fish farming

Emission flow	Equation	Source
Total Nitrogen (N) emitted to water	$Ex_{N\,water} = Ex_N - Em_{N_2O,w} * \frac{Mw_{N_2}}{Mw_{N_2O}}$	
Phosphorus (P) intake	$C_{intake} = FI_{DM} * P$	
Phosphorus (P) retention	$P_{retention} = WG \times \sum_{i\,E\,age\,range} \frac{P_{content\,i}}{1000}$	
Total Phosphorus (P) emitted to water	$Em_P = P_{intake} - P_{retention}$	PEFCR Marine fish Tier 2[16]
Nitrous Oxide (N_2O) emitted to air from Nitrogen (N) emitted to water	$Em_{N_2O,w} = Ex_N * EF_{N_2O,w} * \frac{Mw_{N_2O}}{Mw_{N_2}}$	
Methane (CH_4) emitted to air from Carbon (C) emitted to water	$Em_{CH_4,w} = Ex_C * EF_{CH_4,w} * \frac{Mw_{CH_4}}{Mw_C}$	
Carbon (C) excretion	$Ex_C = C_{intake} - C_{retention}$	

Table 4.15. Description of the parameters – marine fish farming

Parameter	Description
C	Carbon content in the feed in a dry matter basis, based on country-specific data sources
P	Phosphorus content in the feed in a dry matter basis, based on country-specific data sources
WG	Weight gain, based on country-specific data sources
FI_{DM}	Feed intake in a dry matter basis, based on country-specific data sources
Mw_x	Molecular weight of molecule x
$EF_{N2O,\,W}$	N_2O indirect emission factor from N emitted in water, based on draft PEFCR for marine fish
$EF_{CH4,\,W}$	CH_4 emission factor from carbon excreted in water, based on draft PEFCR for marine fish

4.4 - Feed production

This life cycle stage encompasses all activities related to the (pre-)processing of dry feed ingredients, feed additives, and minerals into (compound) feeds, namely, transport, processing of crops and other raw materials into feed.

[16] European Commission. (2025). Product Environmental Footprint Category Rules (PEFCR) for unprocessed marine fish products. Publications Office of the European Union.

4.5 - Food and ingredients processing

This life cycle stage encompasses all activities related to the processing of crops into food ingredients and food ingredients into final food products.

4.6 - Packaging production

This life cycle stage encompasses activities related to the production of packaging materials for consumer packaging, transport of packaging materials to the packing location, and packing the food into the consumer packaging. For waste and recycling, refer to Section 4.10 - End-of-life and recycling.

4.7 - Distribution

The distribution stage includes transport from food processing locations to distribution centres, storage at distribution centres, which include energy for heating, cooling, and lighting, refrigerant consumption and losses, transport from distribution centres to retail, and from retail to consumer. The default values used can be consulted in section 3.5 - Default values. For waste and recycling, refer to Section 4.10 - End-of-life and recycling.

4.8 - Retail

The retail stage includes storage activities that consume energy. Also, food waste that is generated during storage at retail is included in the modelling of the retail life-cycle stage. Refer to Section 3.5 - Default values to consult the defaults values that apply.

4.9 - Use and preparation

The consumption stage includes food storage and food preparation at the homes of consumers. Unavoidable food losses generated during the preparation of the food is also included in this stage. However, avoidable food waste and its primary packaging are excluded from the consumption stage and are part of the end-of-life stage of the food product (see Section 4.10 - End-of-life and recycling).

4.10 - End-of-life and recycling

The end of life of products used during the manufacturing, distribution, retail, the use stage, or after use, shall be included in the overall modelling of the life cycle of the product. Overall, this should be modelled and reported at the life cycle stage where waste occurs. The Circular Footprint Formula (CFF) is used to model the end of life of products as well as the recycled content, and is a combination of 'material + energy + disposal', i.e.:

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

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

Disposal $$(1 - R_2 - R_3) \times E_D$$

$$(1 - R_1)E_V$$

$$R_1 \times \left(AE_{recycled} + (1 - A)E_V \times \frac{Q_{sin}}{Q_p}\right)$$

$$(1 - A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$

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

$$(1 - R_2 - R_3) \times E_D$$

Table 4.16. Description of parameters – circular footprint formula

Parameter	Description
A	allocation factor of burdens and credits between the supplier and user of recycled materials.
B	allocation factor of energy recovery processes. It applies both to burdens and credits. It shall be set to zero for all PEF studies.
Q_{sin}	quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.
Q_{sout}	quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.
Q_p	quality of the primary material, i.e. quality of the virgin material.
R1	proportion of material in the input to the production that has been recycled from a previous system.
R2	proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.
R3	proportion of the material in the product that is used for energy recovery at EoL.
Erec	specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including the collection, sorting, and transportation processes.
ErecEoL	specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process.
Ev	specific emissions and resources consumed (per functional unit) arising from the acquisition and preprocessing of virgin material.

E*v	specific emissions and resources consumed (per functional unit) arising from the acquisition and preprocessing of virgin material assumed to be substituted by recyclable materials.
EER	specific emissions and resources consumed (per functional unit) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, etc.).
ESE,heat and ESE,elec:	specific emissions and resources consumed (per functional unit) that would have arisen from the specific substituted energy source, heat and electricity respectively.
ED	specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery.
XER,heat and XER,elec:	the efficiency of the energy recovery process for both heat and electricity.
LHV	lower heating value of the material in the product that is used for energy recovery.

The CFF can be represented as in Figure 4.1, where the blue boxes describe the material section of the CFF, the orange box describes the energy recovery processes (e.g., incineration), and the yellow box describes the disposal (e.g., landfill).

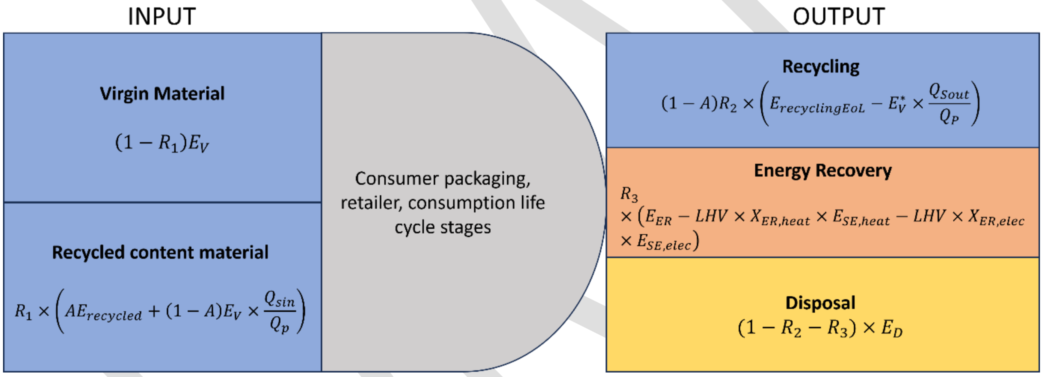


Figure 4.1. Graphical representation of the CFF

4.10.1 - Parameter selection for CFF

The default parameters to use in modelling the circular footprint formula are provided in Annex C Transition Phase (https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml) method.

The A factor

Annex C Transition Phase provides values for factor A at two levels – material (e.g., aluminum) and application (e.g., aluminum for automotive or building). The following hierarchy shall be followed:

- Check in Annex C Transition Phase the availability of an application-specific A value;
- If an application-specific A value is not available, the material-specific A value in Annex C Transition Phase shall be used;

- If a material-specific A value is not available, the A value shall be set equal to 0.5.

Recycled content (R1)

The following procedure shall be applied (in hierarchical order) to select the value of R1 to be used.

- Company-specific values may be used either when the process is run by the company conducting the PEF study or when the process is not run by the company conducting the PEF study, but that company has access to (company-) specific information. It is recommended to stick to default scenarios except if accurate and representative quality company-specific data are available, pending they follow the definitions prescribed in PEF.
- If no accurate and representative company-specific values are available, country-specific values shall be applied. See example of the Agribalyse Database within the PACK-AGB project[3].
- If no country-specific values, default R1 values of Annex C Transition Phase (application-specific) shall be applied[17].
- When no application-specific value is available in Annex C Transition Phase, R1 shall be set to 0%.

Recycling output rate (R2)

The following procedure shall be followed to select the R2 value to be used.

- Company-specific values shall be used when available, after recyclability has been evaluated (see PEF guidance chapter 4.4.8.9[1]). It is recommended to stick to default scenarios except if accurate and representative quality company-specific data are available, pending they follow the definitions prescribed in PEF.
- If no accurate and representative company-specific values are available, country-specific values shall be applied. See example of the Agribalyse Database in the PACK-AGB project, Section 5.2.1 - Table 10)[3].
- If no country-specific values are available and the criteria used for evaluating recyclability are fulfilled (see PEF guidance chapter 4.4.8.9[1]), application-specific R2 values shall be used selecting the appropriate value available in Annex C Transition Phase[17]:
- if an R2 value is not available for a specific country, then the European average shall be used.
- if an R2 value is not available for a specific application, the R2 values of the material shall be used (e.g. materials' average).
- in case no R2 values are available, R2 shall be set equal to 0.

The R3 value

The following procedure shall be applied (in hierarchical order) to select the R3 value to be used.

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[17] European Commission (Last update 2022). European Platform on LCA (EPLCA), from https://eplca.jrc.ec.europa.eu/LCDN/developerEF.html.

- Company-specific values shall be used when the process is run by the company conducting the PEF study or when the process is not run by the company conducting the PEF study but that company has access to (company-)specific information. It is recommended to stick to default scenarios except if accurate and representative quality company-specific data are available, pending they follow the definitions prescribed in PEF.
- If no accurate and representative company-specific values are available, country-specific values shall be applied. See example of the Agribalyse Database within the PACK-AGB project in its Section 5.2.1 - Table 10)[3].
- When no country-specific values are available, the default secondary R3 values of Annex C Transition Phase shall be applied[2].
- When no value is available in Annex C Transition Phase, new values can be used for R3 (using statistics or other data sources) or shall be set to 0%.

The quality ratios: Qsin/Qp and Qsout/Qp

In the case of packaging materials, the following procedure shall be applied to select Qsin/Qp and Qsout/Qp values.

- Company-specific values shall be used when the process is run by the company conducting the PEF study. It is recommended to stick to default scenarios except if accurate and representative quality company-specific data are available, pending they follow the definitions prescribed in PEF.
- When no accurate and representative company-specific values are available, default values of the Annex C Transition Phase shall be applied[2].

Energy-related parameters (LHV, XER,heat and XER,elec)

The following procedure shall be applied (in hierarchical order) to select the LHV value to be used.

- Material-specific values shall be used. If the process is not run by the company conducting the PEF study, the company should request access to (company-)specific information. It is recommended to stick to default scenarios except if accurate and representative quality company-specific data are available, pending they follow the definitions prescribed in PEF.
- When no accurate and representative company-specific values are available, country-specific values shall be applied. See the example of the Agribalyse Database in the PACK-AGB project report, in its Section 5.2.5 - Table 40[3];
- If no country-specific values available, the default values in Table 4.17 shall be used for LHV.

Table 4.17. LHV for different packaging materials

Packaging material	LHV (MJ/kg)
Glass	0
Steel	0

Aluminum	0
Other metals	0
Paper and cardboard	10
PET	25.7
PP	42.1
PE	42.1

The following procedure shall be applied (in hierarchical order) to select the XER,heat and XER,ele values to be used.

- Country-specific values shall be applied. See the example of the Agribalyse Database in the PACK-AGB project report, in its Section 5.2.5 - Table 38[3];
- If no country-specific values are available, default values in Table 2 reported by CEWEP Energy Report III[18] on the energy recovery rates for municipal solid waste in Europe shall be used.

Table 4.18. Default values for XER,heat and XER,ele

Parameter	Value
XER,heat	0.35
XER,ele	0.15

4.10.2 - Waste scenarios

This section describes the sources that should be used for defining the values for food loss and waste scenarios in selected life cycle stages. It focuses mainly on processing, packaging, distribution, retail, consumption, and end-of-life stages. Other stages, such as raw material production, crop cultivation, feed production, and animal production stages, are not considered since PEF does not provide any reference or information on accounting for food loss in these stages. *Note: Waste at any stage shall be considered using the Circular Footprint formula (CFF).*

Ingredient- and food- processing

The following hierarchy should be applied for selecting the food loss values in this life cycle stage.

- Company-specific data on food loss from processing. It is recommended to stick to default scenarios except if accurate and representative quality company-specific data are available, pending they follow the definitions prescribed in PEF.
- If accurate and representative company-specific data is not available, food loss values can be obtained from available PEFCRs (e.g., Dairy, Pasta, Beer, etc.)
- If information is not available in PEFCRs, the default values listed in Table below shall be used.

[18] CEWEP. (2015). Energy Report III: Status 2007–2010.

Table 4.19. Default values for food loss at the processing stage

Product group	Food loss (%)	Reference
Cereals	5	FAO 2011[19]
Roots and tubers	15	FAO 2011
Oilseeds and pulses	5	FAO 2011
Fruits and vegetables	2	FAO 2011
Meat products	5	FAO 2011
Fish and seafood	6	FAO 2011
Dairy products	1.2	FAO 2011
Eggs	0.5	(Bräutigam and al., 2014)

- If no value for food loss is available in the previous table for a specific product, a default value of 2%[20] of food loss at the processing stage shall be used.

Consumer packaging

No food losses are assumed for the packaging stage, due to the lack of consistent data on this topic.

Distribution, storage and retail

Food loss values should be taken from PEF guidance Appendix F (see Table 4).

Table 4.20. PEF default values of food loss for distribution, storage and retail phase

Product group	Food loss (in %)
Fruit and vegetables	10
Meat and meat alternatives	4
Dairy products	0.5
Cheese (assumed same as dairy products)	0.5
Grain products	2
Rice (assumed same as grain product)	2
Pasta (assumed same as grain product)	2
Roots and tubers (e.g. potatoes)	7
Pulses (assumed same as oils and fats)	1
Fish	9

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[19] FAO. (2011). Global food losses and food waste – Extent, causes and prevention. Food and Agriculture Organization of the United Nations.

[20] Eurostat. (2024). Food waste and food waste prevention – estimates.

Eggs (assumed same as meat)	4
Oils and fats	1
Prepared/processed meals (ambient)	10
Prepared/processed meals (chilled)	5
Prepared/processed meals (frozen)	0.6
Confectionery	5
Other foods	1
Coffee and tea	1
Alcoholic beverages	1
Other beverages	1

Consumption

The following hierarchy should be considered to estimate the food loss values in this stage:

- Country-specific values of food loss after use (e.g., consumer's bins). National statistics of waste produced per product group can be used for this purpose.
- If country-specific values are not available, the default food loss values reported in the PEF guidance Appendix F should be used (see Table 4.21).

Table 4.21. PEF default values for food losses at the end-of-life stage

Product group	Food loss (in %)
Fruit and vegetables	19
Meat and meat alternatives	11
Dairy products	7
Cheese (assumed same as dairy products)	7
Grain products	25
Rice (assumed same as grain product)	25
Pasta (assumed same as grain product)	25
Roots and tubers (e.g., potatoes)	30[21]
Pulses (assumed same as oils and fats)	4
Fish	12[5]
Eggs (assumed same as meat)	11
Oils and fats	4
Prepared/processed meals (ambient)	10

[21] Caldeira, C., and al. (2019). Quantification of food waste per product group along the food supply chain in the European Union: A mass flow analysis. Resources, Conservation and Recycling, 149, 479–488.

Prepared/processed meals (chilled)	5
Prepared/processed meals (frozen)	0.5
Confectionery	2
Other foods	2
Coffee and tea	5
Alcoholic beverages	5
Other beverages	5

End-of-life

Food waste from the ingredient and food processing stage shall be modelled as waste and/or biowaste. No waste scenario shall be considered in the consumer packaging stage, as no food loss is assumed from this stage.
Waste scenario for food losses at the distribution, storage, and retail (consolidated level) and at the consumer should be taken from PEF guidance Appendix F, considering that food waste is 50% trashed (incinerated and landfilled), 25% composted, and 25% methanised. In the case of liquid food, waste is treated via a wastewater treatment plant.

5-Life cycle impact assessment

5.1 - Method and environmental indicators

For the beta version of the EFC methodology, as introduced in Section 1.1 - General, the arguments of PEF-compliance and the current level of operationalization support the use of the LCIA method EF 3.1. This ensures methodological alignment with European policy initiatives, which is particularly relevant for any work feeding into policy or market-facing instruments. It consists of the following, midpoint-based impact categories presented in the table below.

Table 5.1. Impact categories with respective impact category indicators

Impact category	Unit	Impact category indicator
Acidification	mol H^+ equivalents	Accumulated Exceedance of buffer capacity – AE
Climate change	kg CO_2 Equivalents	Radiative forcing as global warming potential over 100 years – GWP100
Ecotoxicity, freshwater	CTU_e	Comparative Toxic Unit for ecosystems
Particulate Matter	disease incidence	Impact on human health
Eutrophication, marine	kg N equivalents	Fraction of nutrients reaching marine end compartment
Eutrophication, freshwater	kg P equivalents	Fraction of nutrients reaching freshwater end compartment
Eutrophication, terrestrial	mol N equivalents	Accumulated Exceedance – AE
Human toxicity, cancer	CTU_h	Comparative Toxic Unit for humans
Human toxicity, non-cancer	CTU_h	Comparative Toxic Unit for humans
Ionising radiation, human health	kBq U235 equivalents	Human exposure efficiency relative to U-235
Land use	dimensionless (pt)	Soil quality index, representing the aggregated impact of land use on: Biotic production; Erosion resistance; Mechanical filtration; Groundwater replenishment
Ozone depletion	kg CFC11 equivalents	Ozone Depletion Potential – ODP
Photochemical ozone formation - human health	kg NMVOC equivalents	Tropospheric ozone concentration increase
Resource use, fossils	MJ	Abiotic resource depletion, fossil fuels – ADP-fossil
Resource use, minerals and metals	kg Sb equivalents	Abiotic resource depletion – ADP ultimate reserves
Water use	m^3-world equivalents	Weighted user deprivation potential

As detailed in Section 8.2 - Weighting, the Eco Food Choice method provisionally remove the human toxicity indicators from the core results and integrate their weight into a broader “toxicity” category, using the existing “freshwater ecotoxicity” impact category as a proxy.

As detailed in Section 6-Biodiversity impacts, Eco Food Choice provisionally adopts the BioMAPS approach for assessing land use-related biodiversity impacts. This will serve as the 17th indicator. Alternative methods will be investigated. The effects of changes in normalisation and weighting on biodiversity outcomes will also be explored in future iterations.

5.2 - Hotspot analysis

Once the user of the method has ensured that the LCA system is robust and aligned with all aspects defined in the goal and scope definition phases, the next step is to identify the main contributing elements to the LCA results, also referred to as '*hotspot' analysis*. The user of the method should identify (together with the % contribution) the most relevant:

- Impact categories: classes of resource use or environmental impacts to which the life cycle inventory data are related.
- Life-cycle stages: consecutive and interlinked phases of a product system.
- Processes: specific activities or operations within a life cycle stage.
- Elementary flows: exchanges between a product system and the environment, such as material or energy inputs like water or emissions released like CO2.

Despite all categories being important, it must be noted that there is an operational difference between them. impact categories and life-cycle stages are more relevant for communicating the results, highlighting the environmental areas where the organisation should focus their attention. In contrast, processes and elementary flows are more important for engineers and designers to improve the overall footprint through process changes, optimization, or pollution control, particularly in internal studies aimed at enhancing a product's environmental performance.

Most relevant impact categories

The identification of the most relevant impact categories must be based on the results of the LCA analysis, after normalisation and weighting. The most relevant impact categories will be all of those that contribute to at least 80% of the total single score calculated (see Sections 5-Life cycle impact assessment and 8-Aggregation), starting from the largest to the smallest contributions. At least three relevant impact categories should be identified as the most relevant ones. More impact categories can be added to the list, but none shall be deleted.

Most-relevant life-cycle stages

The most relevant life-cycle stages are those that together contribute more than 80% to any of the most relevant impact categories identified, starting from the largest to the smallest contributions. As a starting point, the 10 life-cycle stages described in Section 4 - Life cycle stages of this method should be considered. More life-cycle stages may be added or split to the list under justification, but none shall be deleted. A minimum level of standardization of the life-cycle stages to be included in the LCA should be achieved to ensure the comparability of the results, and should be reached in consensus among key stakeholders and market participants of the food sector. If the use stage (the consumption of the product at the consumer's house in the case of food products) accounts for more than 50% of the total impact of a most-relevant impact category, the procedure should be re-run excluding the use stage. In this case, the final list of the most relevant life-cycle stages will include those identified in the revised procedure, in addition to the use stage. While this is uncommon in LCAs for most food products, it can be significant for certain items, such as coffee, where the use phase often involves energy-intensive preparation or a high food-to-waste ratio.

Most-relevant processes

The most relevant processes are those that together contribute more than 80% to any of the most relevant impact categories identified. More processes may be added to the list of the most relevant ones, but none shall be deleted. The identification of the most relevant processes must be carried out according to Table 3.1. Overview of the activities included in the life cycle stages.

Identical processes (meaning two processes that have the same Universally Unique Identifier) taking place in different life-cycle stages (e.g., transportation, electricity use) shall be accounted for separately. Identical processes taking place within the same life-cycle stage shall be accounted for together. The list of most-relevant processes and their % contribution must be reported together with the respective life-cycle stage (or multiple life-cycle stages if relevant) but reported separately for each most-relevant impact category.

In the case that the contribution of the use stage to the total impact of a most-relevant impact category exceeds 50%, as discussed in Section 4 - Life cycle stages, the most relevant processes should be identified by analysing the entire life cycle excluding the use stage, on one hand, and focusing solely on the use stage, on the other.

Most-relevant elementary flows

The most relevant elementary flows are those that together contribute at least 80% to the impact for each most relevant process for every specific impact category, starting from those that contribute the most to those that contribute the least. More elementary flows may be added to the list of most-relevant ones, but none shall be deleted. They should be reported separately for each most-relevant impact category.

Direct elementary flows

Elementary flows belonging to the background system of the most relevant process may dominate the impact. Therefore, if disaggregated datasets are available, the most relevant direct elementary flows for each most relevant process should also be identified.

Most relevant direct elementary flows are the direct elementary flows that together contribute at least 80% to the total impact of the direct elementary flows of the process, within each most-relevant impact category. The analysis shall be limited to the direct emissions of level-1 disaggregated datasets (definition can be found in the European Platform on LCA[17] and the Guide for EF compliant datasets[22]), datasets with a specific level of granularity where the

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[22] Fazio, S., Zampori, L., De Schryver, A., Kusche, O., & Diaconu, E. (2020). *Guide for EF compliant data sets: Version 2.0* (EUR 30175 EN). Publications Office of the European Union.

most-relevant processes of the system are disaggregated while leaving less critical processes aggregated. This means the 80% cumulative contribution shall be calculated based only on the impact caused by the direct emissions, and not the total impact of the process.

Dealing with negative numbers

When determining the percentage impact contribution, there may be rare instances where negative values occur in processes or elementary flows. A negative process indicates an avoided burden, representing the removal, reuse, or recycling of materials that benefit the technosphere (e.g., recycling). A negative flow occurs when a substance is removed from the environment, benefiting the ecosphere (e.g., a treatment removing a heavy metal from water). In such cases, it is recommended to exclude these values to ensure that the associated positive credits are not considered in the final calculation. This procedure does not apply when identifying the most relevant life-cycle stages.

6-Biodiversity impacts

Assessing biodiversity impacts in globalized production chains is highly complex, depending on pedoclimatic contexts, the essential biodiversity variables (EBVs) considered, the taxa considered, and so on. It is data-intensive, requiring advanced, spatially explicit models. Currently, data are incomplete and uneven, making endpoint indicators highly uncertain due to the lack of sufficiently comprehensive models. As a result, midpoint indicators are considered more operationally robust in the short term for environmental labelling, offering a pragmatic but partial solution.

At first glance, the PEF indicators (EF 3.1) reflect biodiversity impact by covering 4 of the 5 pressures identified by the IPBES. However, these pressures are only partially covered as far as the terrestrial agricultural sector is concerned. For the beta version of EFC, we chose PEF as our first approach, mainly because of its operational maturity and the fact that the GLAM/ endpoint methodology has not yet been finalized, tested, or integrated into LCA software. It was nevertheless specified that the framework should remain compatible with GLAM to facilitate a possible convergence in the future.

To develop a biodiversity indicator that reflects agroecological practices while maintaining consistency with established European Commission recommendations and LCA principles, a dual approach is followed as described in the following subsections.

6.1 - BioMAPS

This beta version aligns with the European Commission recommendation by using LANCA BioMAPS by default as the methodological basis to add a 17th indicator: **"Land use – Biodiversity."** BioMAPS provides a multi-scale assessment framework (global, regional, and local), offering an LCA-based approach that aligns with the broader LCA methodology. It incorporates several key biodiversity components that are often missing from traditional LCA models: agricultural practices; concept of vulnerability, irreplaceability, number of threatened species and rarefied species richness; expanded taxonomic coverage including data on numerous taxa ranging from invertebrates to vertebrates; and consideration of different biodiversity levels, from species to ecosystems. It is also quickly operational as the country-specific characterization factors (CFs) have already been shared, a key requirement for the beta version of the Eco Food Choice method. While its implementation is proposed at this stage, it is nonetheless essential to acknowledge that several methodological limitations persist and should be explicitly considered.

6.2 - BVI

Biodiversity Value Indicator (BVI) is a promising candidate to serve as a 17th biodiversity indicator:

- It is consistent with the overall LCA framework and captures biodiversity impacts at local, regional, and global scales.
- It will include both terrestrial and marine ecosystems in a single methodology. For now, only the terrestrial ecosystem is available. Concerning the marine ecosystems, the author informed us that a scientific

publication on direct exploitation is in the writing process; another publication on marine eutrophication is planned next.

- It is implementable with the newly released characterization factors in LCA software.
- It incorporates agricultural management parameters for which data are already normally available. Characterization factors are already available for 152 major crops.

Nonetheless, methodological limitations persist for BVI and should be explicitly considered. Given these uncertainties, the Eco Food Choice consortium proposes pilot testing the BVI method on a selection of products to assess its applicability and relevance. This testing phase is critical, as further evidence would be required to justify any transition from BioMAPS to BVI in future iterations of the methodology.

6.3 - Additional non-LCA biodiversity indicators

Non-LCA biodiversity indicators may offer complementary insights, particularly in capturing agroecological practices. This approach has been developed in France and is currently under consultation. Five complementary indicators based on agricultural practices have been proposed. In this method, the combined weight of all additional indicators should not exceed 30% of the total score.

This approach allows for the identification of agricultural practices beneficial to biodiversity, including agroecological production systems. However, several concerns remain, particularly around data availability in other European countries, the objective quantification of benefits, and the inconsistency of this “non-LCA” approach compared to LCA-based indicators. These concerns include the method of weighing and the potential variability in the choice of indicators in different countries.

A similar approach could be tested at the European level. A preliminary assessment of data availability is required to evaluate feasibility. If deemed feasible, the consortium will conduct pilot testing on a selection of products to refine the recommendation to be included in the final version of the Eco Food Choice method.

6.4 – Impact of normalisation

The choice of normalisation factors can significantly influence the visibility of agroecological benefits within the biodiversity indicator. In both the BioMAPS and BVI methodologies, concerns persist that normalisation may dampen or obscure biodiversity impacts. Testing alternative normalisation schemes is therefore recommended. This includes evaluating whether using the global population as a normalisation baseline is appropriate, or if alternative factors could better reflect agroecological impacts.

7-Operationalisation

7.1 - Sampling

The user of the method shall (i) specify in the report if sampling was applied, (ii) follow the requirements described in this section, and (iii) indicate which approach was used. Examples of cases where the sampling procedure may be needed are those where multiple production sites are involved in producing the same product, e.g., if the same raw material/input material comes from multiple sites or if the same process is outsourced to more than one subcontractor/supplier.

The representative sample shall be derived via a stratified sample, i.e., one that ensures that sub-populations (strata) of a given population are each adequately represented within the whole sample of a research study. Using a stratified sample allows for more precision than a simple random sample, provided that the sub-populations have been chosen so that the items of the same sub-population are as similar as possible in terms of the characteristics of interest. In addition, a stratified sample guarantees better coverage of the population. The following procedure shall be applied to select a representative sample as a stratified sample:

- Define the population
- Define homogeneous sub-populations (stratification)
- Define the sub-samples at the sub-population level
- Define the sample for the population starting from the definition of sub-samples at the sub-population level.

Stratification is the process of dividing members of the population into homogeneous subgroups (sub-populations) before sampling. The sub-populations should be mutually exclusive: every element in the population shall be assigned to only one sub-population. The following aspects need to be taken into consideration in identifying the sub-populations:

a. geographical distribution of sites
b. technologies/ farming practices involved
c. production capacity of the companies/sites taken into consideration.
d. Time consideration (to capture annual variability on yield, for instance)

Additional aspects to be taken into consideration may be added. The number of sub-populations shall be calculated as follows:

$Nsp = g * t * c$

Where:

Nsp is the number of sub-populations; g, the number of countries in which the sites/plants/farms are located; t, the number of technologies/farming practices; and c, the number of classes of capacity of companies.

In case additional aspects are taken into account, the number of sub-populations is calculated using the above formula and multiplying the result by the number of classes identified for each additional aspect (e.g., those sites that have an environmental management or reporting system in place).

Once the sub-populations have been identified, the sample size of each shall be calculated (the sub-sample size). Two alternative approaches are possible:

- Based on the total production of the sub-population. The user of the method shall identify the percentage of production that each sub-population will cover. It shall not be lower than 50%, expressed in the relevant unit. This percentage determines the sample size within the sub-population.
- Based on the number of sites/farms/plants involved in the sub-population. The required sub-sample size shall be calculated using the square root of the sub-population size.

$nSS = \sqrt{nSP}$

Where nSS is required sub-sample size and nSP: sub-population size. The chosen approach shall be specified in the report. The same approach shall be used for all the sub-populations selected. The representative sample of the population corresponds to the sum of the sub-samples at the sub-population level. If rounding is necessary, the general rule used in mathematics shall be applied:

- If the number you are rounding is followed by 5, 6, 7, 8, or 9, round the number up.
- If the number you are rounding is followed by 0, 1, 2, 3, or 4, round the number down.

7.2 - Reporting and data declaration

One possible way to operationalize and verify the correct use of the EFC method for consumer products labelled in stores is through the development of a centralized product register platform. Alternative approaches to operationalization and verification may also be considered.

7.2.1 – Product register platform: objectives and features

This platform concept could serve the following objectives, among others:

- Labelling authorization: Act as a centralized register to support labelling authorization under the EFC method for a defined period. The main idea is for companies wanting to use the Eco Food Choice logo to register the products to be labelled on the platform (one by one or in bulk), to ensure they are using a validated scoring tool that has correctly implemented the Eco Food Choice method. The product would need to be registered before market entry. If a product composition changes, a new registration would be done and the label must be updated before market entry, as is specified in the regulation EU 1169/2011 that information provided to consumers shall not be misleading, accurate, clear, and easy to understand. If the EFC method is updated, a new registration would be mandatory within a defined period (24 months is suggested).

- Compliance verification: Enable controlled access to relevant product data for authorized verifiers to assess compliance.
- Harmonization: Contribute to the harmonization of data and labelling requirements across European countries.
- Statistics: Facilitate the generation of statistics and market insights on the adoption of the EFC method and label.
- Public information: A simplified, open-access version of the register could potentially be developed to inform end consumers (not currently a priority).
- Support to secondary databases: Product-level scores could be collected to improve the quality of secondary databases. The potential use of such data will be further explored during the finalization of the method.

The platform would have the following features:

- API integration: Seamless integration with existing scoring tools.
- Data protection: Secure handling and storage of sensitive data.
- Export and import in .csv / .xls formats: import can be very useful for bulk registrations. For example, a large producer or a retailer may plan to register several products at once.
- Role-Based Access Control (RBAC) via Single Sign On (SSO): This can be made official via an authorization register where all data providers provide explicit consent to share specific data for specific purposes by specific users.

Data owners (e.g. producers, manufacturers): full access to their own product data.
Retailers and large producers should also be able to easily access the scores of all their products (and download large amounts of information in an Excel format).
Producers should sign the authorisation register if they agree to allow retailers to access their data.
Public verifiers: unrestricted access to all data.
Private auditors: conditional access to all data, subject to authorization from data owners or public authorities.
Platform administrators: access to infrastructure settings without visibility on proprietary data.
General public/ consumers: access to public data only (e.g., product score), in a second development step.
In order to have a scalable model, some considerations can be taken into account:

- Bulk submissions: It should be facilitated through an API connecting to the scoring platform, and the possibility of importing data in an Excel format. This should be possible for retailers and large manufacturers.
- Public-facing Platform: In a second phase, a consumer-facing platform could be launched. This will enhance transparency and enable informed consumer choice, reinforcing the EFC methodology's public utility. It could be displaying the following information: Product identification, Single environmental score, Sub-scores (e.g., PEF and additional indicators), Company name, Brand name, Product name, Product

category, Certifications and labels, Data Quality Rating (DQR), List of ingredients (without quantities), Net weight, Packaging materials.

7.2.2 - Data points needed

Most of the following information is not meant to be entered directly by data owners, but to be searched for in "validated scoring tools" with an API. However, scoring tools would need to be able to provide these data points, given that they are essential to calculate the single score.

Metadata

- Date of data entry
- Verification signatures (to monitor validity period)

From Data Owners

- Product identification (EAN code)
- Legal representative contact details
- Scoring tool used

Via API from Scoring Tool

To be validated, a scoring tool must implement the Eco Food Choice method and be audited by a public authority or a private auditor. It also must include the following information, linked with an EAN. The objective is to keep this process as easy as possible to encourage companies to register their products. Companies would fill the information only once in the scoring tools, and the product register platform would access data via API.

- Company name
- Brand name
- Product name
- Product category
- Certifications and other labels (e.g, organic)
- Product single score
- Sub-scores (LCA PEF-based indicators + additional indicators e.g. biodiversity)
- Matrix of sub-scores x Life cycle stages
- Data Quality Rating (DQR)
- Country of consumption
- Calculation parameters:
  - Countries of processing for each production step
  - Country of origin for all ingredients and sub-ingredients
  - Detailed recipe (ingredient weights per kg final product)

- Packaging materials and weights (kg/unit),
- Packaging volume
- Net weight
- Storage conditions (ambient, cooled, frozen)
- Preparation (cooking, baking, etc)

7.2.3 - Roles and responsibilities

While implementation strategies may be adjusted to different countries' contexts, our preferred model is an EU-led, publicly managed product register platform to ensure long-term governance, consistency, and fairness. We also envision public-private partnerships to operationalise it efficiently.

- Tool development: The European Commission would ideally develop and manage the platform, modelled on existing mechanisms (e.g. EU energy labels for appliances), and leveraging existing national initiatives (e.g. Ecobalyse in France) for cost-effectiveness and to build on existing knowledge. It could be managed by a suitable Directorate-General (e.g. DG ENV) or an EU-funded non-private entity.
- Tool maintenance: The European Commission would designate a structure to ensure ongoing platform functionality and updates. Similarly, as above, several non-private entities can be considered, including DG or EU-funded entities, but private entities could also be considered as long as the product register platform remains free to use for all stakeholders.
- Note: In case a scoring tool is leading the market in a monopoly situation, this private player could develop a public-private partnership to support implementation and innovation. However, such a register database must remain open to any other private players that need to register a product.

Following this recommendation issued with the beta version of the method, discussions should be started with EC and other relevant points of contact.

7.2.4 - Verification

As a general concept, no ex-ante verification at the product level is recommended due to cost and scalability considerations. Companies will commit to data veracity and submit legally binding declarations when registering. However, in countries where the ecolabelling initiative is led by governments, or in the scenario where the European Commission would like to verify that a product with the Eco Food Choice label meets the requirements of the method, randomised compliance audits may be conducted.

Randomised compliance audits: Audits may be conducted to check whether a product in store with the EFC logo is using a validated scoring platform to issue its label. Such audits could be led:

by national authorities in countries where feasible, or by EU authorities.

by private certification bodies (e.g., Bureau Veritas, Blonk (Mérieux NutriSciences)) if requested by a national government or the European Union.

Sanctions could be similar to Nutri-Score in France, which lays three levels of sanctions:

Request to take corrective action

Suspension of the right to use the Logo until compliance is reached

Withdrawal of the right to use the logo for a set period

Certification of scoring tools: Private tools (e.g., Mondra, InoQo) would need to be certified to ensure correct implementation of the Eco Food Choice method. Certification may be handled by third-party entities or public authorities. The goal is to ensure that any company using the EFC label is effectively following the EFC methodology. Therefore, to be EFC-compliant, both private and public scoring tools would be capable of:

- Providing the data detailed above.
- Linking the EAN code directly to this dataset via API, to get all data points listed in Section 7.2.2 - Data points needed. Excel files exported from the platform should also be able to be imported to the product register platform if they contain all relevant information.
- Implementing the EFC method. This can include the following considerations: The scoring tool should also be able to link ingredient producers to the right secondary LCA data, split up ingredients into sub-ingredients, be able to deal with missing information (countries, ingredients, packaging), create a quality score, etc. These steps should also be harmonized between tools. In the second phase, the tool should also give producers the opportunity to provide additional primary information in a user-friendly way, providing all the necessary guidance and definitions, and potentially develop specific guidance to other (e.g., farm level) tools.
- Plausibility checks should be embedded in the certified scoring tools. Only data entries that trigger plausibility alerts (based on predefined thresholds or inconsistencies) will be flagged during submission. These flags will appear in the declaration platform and be accessible to verifiers and competent authorities to guide audits or follow-up requests. Plausibility check procedures may be suggested after the release of the beta version of the Eco Food Choice method, in the testing phase, towards the release of the refined finalised version.

Further details on verification procedures are to be shared with the final version of this methodology, informed by the testing phase. Compliance with PEF will be sought.

8-Aggregation

8.1 - Normalisation

For the normalisation step, we propose to follow the recommendations of the Product PEF guidelines. Specifically, normalisation factors are calculated by dividing the global total environmental impacts by the global population. This approach enables consistent comparison across impact categories and supports the integration of the EFC method with established European and international practices.

8.2 - Weighting

We propose to remove robustness adjustment factors. The EFC methodology prioritises potential environmental impacts importance, over knowledge gaps. Since robustness factors from PEF were issued, several improvements have been made, particularly for the ecotoxicity indicator. Given that food systems are a major contributor to ecotoxic emissions, and that pesticide-related impacts represent a key hotspot for human and ecosystem health, the current PEF weighting, assigning only 2% to freshwater ecotoxicity, appears misaligned with the environmental significance of this issue.

Toxicity

Current indicators for human toxicity (cancer and non-cancer) are subject to methodological limitations that distort results. These include:

- Pesticide Residues: The OLCA-Pest model has been recommended by the consortium to better capture human exposure to pesticides through crop emissions. However, current LCA databases do not yet include a dedicated compartment for pesticide residues on food products. As a temporary solution, we propose to follow the PEF approach and model 100% of these emissions as entering the soil compartment, as further described in Section 4.2.1 - Pesticides.
- Heavy Metals: Toxicity impacts from heavy metals tend to outweigh others due to temporal aggregation methods, leading to a disproportionate influence on overall toxicity scores.
- Organic and Agroecological Products: These products often receive higher toxicity scores, which is inconsistent with scientific consensus. This misalignment partly arises from the dominance of heavy metals in aggregated toxicity indicators.

To address these concerns, the EFC consortium proposes a dual strategy:

- Short-term recommendation (beta version): Remove the human toxicity indicators from the core results and integrate their weight into a broader "toxicity" category, using the existing "freshwater ecotoxicity" impact category as a proxy.
- Sensitivity analyses: Test an alternative approach by distributing the weight of human toxicity evenly across all impact categories.

This approach does not dismiss the importance of human toxicity but rather acknowledges the current limitations and imbalance of the indicators available. Ecotoxicity is considered a more reliable proxy for total toxicity (encompassing both human and environmental dimensions) and allows for the inclusion of impacts across the full value chain, regardless of geographical location (e.g Europe, Brazil, etc). In the context of the beta version, this solution offers a pragmatic way to reflect toxicity while more robust human-specific indicators are under development.

The compromise proposed through the dual strategy ensures short-term usability while allowing for ongoing methodological improvements.

	PEF	Step 1	Step 2	Step 3
Toxicity (Proxy: Ecotoxicity Freshwater)	**2**	**6**	**19**	**17**
Climate Change	21	13	13	11
Water use	9	10	10	9
Land use	8	9	9	8
Resource use, fossils	8	7	7	7
Resource use, minerals and metals	8	7	7	6
Ionising radiation	5	6	6	5
Ozone depletion	6	6	6	5
Particulate matter	9	5	5	5
Photochemical ozone formation	5	5	5	4
Acidification	5	5	5	4
Eutrophication, terrestrial	4	3	3	3
Eutrophication, freshwater	3	3	3	3
Eutrophication, marine	3	3	3	3
Human toxicity, cancer effects	**2**	**7**	**x**	**x**
Human toxicity, non-cancer effects	**2**	**6**	**x**	**x**
Land use biodiversity	/	/	/	**11**

Figure 4: Aggregation strategy – beta version of Eco Food Choice

"Land use biodiversity" weighting

As detailed in section 6 on biodiversity, Eco Food Choice provisionally adopts the BioMAPS approach for assessing land use-related biodiversity impacts. This will serve as the 17^{th} indicator. Alternative methods will be investigated. The effects of changes in normalisation and weighting on biodiversity outcomes will also be explored in future iterations.

The integration of any new indicator should follow the same approach originally used by the European Commission to define weighting factors, combining expert judgement and public opinion. This would help ensure methodological consistency with the existing indicators.

However, the initial weighting method used by the Commission was based on an online questionnaire distributed at the community level, combined with complementary analyses. Reproducing this process would require reassessing the weightings of all indicators, which represents a heavy and complex task that is difficult to undertake in the short term.

Such a revision could be more appropriately addressed during the development of the final version.

For now, there is no consensus on how to weight the impact category "Land use biodiversity." While an equal-weighting scheme would assign it 1/17th of the total impact score by default, this does not reflect the ecological significance of biodiversity loss driven by agricultural activities. Indeed, agriculture is one of the sectors with the greatest impact on biodiversity in Europe[1]. It has a particular impact on several of the key drivers of biodiversity loss: changes in land use and direct exploitation[2].

We propose assigning a greater relative weight to this category. We recommend allocating 2/17ths of the total weight to "Land Use – Biodiversity," a level comparable to that assigned to the climate change impact.

This is a temporary solution for the beta version. It will be tested and can be re-evaluated later.

8.3 - Grading

This research led to a preliminary proposal for the grading approach. It was found that normative choices are inevitable, which can either be de-emphasized in a technocratic approach or structured in a stakeholder process. Considering a preference for the stakeholder consultation, simplicity and transparency are recommended.

Relative grading is preferred over absolute grading.

Differentiation of food products can be improved by applying an unequal quantile distribution for grade allocation rather than equal quantiles. The distribution could be as follows, pending the number of grades to be derived is 8: A band (best performers): 25%; H band (lower performers): 15%; Intermediate bands (B–G): 10% each.

This configuration provides several advantages to foster product improvement:

- The broader A band rewards good and moderately good performers, requiring less motivation for further improvement.
- The narrower middle bands (B–G) create stronger incentives for average and moderate performers to improve and move up one grade.
- The medium-sized H band identifies products with the greatest potential for improvement.

The main drawback is the normative and novel nature of this approach, which may require further justification and testing on real products.

The impact population for the proposed unequal quantile approach should consider:

- The grading will initially be derived from a proxy impact population, i.e., Agribalyse, or upcoming larger food databases at EU level.
- The relative frequency of an impact should be according to consumption level (by citizens in real or recommended diets, or from retail). This requires further research previous to implementation. The EFC consortium proposes that it is later informed with the "actual" impact population, i.e., from the database that is being built from primary and new secondary data provision and improved modelling.
- No other normative aspects should be introduced to the impact population to avoid complexification.

The number of grades to be derived is still to be defined, depending on the results of the testing conducted by the Work Package 4 of the EFC project:

- More research is needed, and alignment with interpretation aids should be pursued.
- A certain level of uncertainty in the grading is acceptable.
- Data quality and its requirements may need to be increased over time to reduce uncertainty, while there are many other reasons to do so.

An interpretation aid (e.g., a numeric score) is recommended. Some key considerations include:

- More research is needed, and alignment with the number of grades should be pursued. It may be an option not to provide an interpretation aid if the colour-letter-grades suffice.
- It should be based on a single score, like the grading.
- It can follow a grading approach that differentiates another part of the impact population.

9-Assumptions, limitations, and future development

9.1 - Assumptions and Limitations

The EFC methodology presents the following assumptions and limitations:

- The crop compartment is still missing when modelling pesticide emissions in LCA software. It was assumed that the crop compartment emissions fraction goes into the soil.
- Methane emissions modelling in marine aquaculture is based on man-made wastewater treatment processes, which leads to higher uncertainty.
- The DQR cannot be applied to aggregated datasets, nor is it feasible for assessing large datasets. The DRQ guide for input datasets is missing.
- Unavoidable food loss at the processing and consumption stages is excluded.
- The biodiversity impact of seafood is not covered.
- Uncertainty analyses guidelines have not yet been developed.

9.2 - Roadmap towards the final version of the EFC method

The final version of the EFC methodology (target release: November 2026) will build on the beta version while incorporating new scientific and data developments, and feedback from pilot testing and stakeholder consultation. This section outlines the main areas where refinements are being considered.

9.2.1 - Functional unit

- Evaluation of nutritional FUs (e.g., caloric content, nutrient density such as Nutrient Rich Food Index, serving size) to better reflect the primary function of food.
- Challenges to address:
- multifunctionality of food: macro- and micronutrients with importance varying by consumer characteristics (e.g., age, health status, dietary needs), potential bias toward nutrient-dense foods
- non-nutritional benefits not easily quantifiable: taste, texture, emotional satisfaction
- consumer understanding: intuitive meaning could be limited, risk of overlap with nutrition-focused tools (e.g., Nutri-Score)
- Requirement for robust nutrient composition databases before implementation; current absence makes short-term application unlikely.

9.2.2 – Greenhouse gases modelling

- Biogenic carbon modelling: Adoption of the −1/+1 accounting approach, in line with GLAM recommendations and anticipated EF 4.0 guidance (2026), which is likely to ask for the tracking of biogenic carbon flows, with a −1/+1 approach in foreground modelling and a 0/0 approach for background datasets.
- LULUC: Integration of spatially explicit conversion data and linear discounting (aligned with SBTi). Hedge removal will be better assessed. Strategies to improve data availability for crop-specific regionalized modelling need further discussion.

9.2.3 - Data quality requirements

- Exploration of minimum DQR thresholds as eligibility criteria for labelling.
- Methods to manage variable quality of large-scale input datasets under assessment.

9.2.4 – Default values

- Preparation at consumer values could be more exhaustive and aligned. A second literature review will be conducted.

9.2.5 - Secondary data

- Anticipated release of open-source EF 4.0 datasets (2026–2027) and reassessment of their integration into the EFC hierarchy. Their ranking in the hierarchy may depend on their disaggregated nature, which is preferred.
- Review of Agrifootprint compatibility with EFC in light of updated requirements.
- Refinement of eligibility criteria for secondary datasets, in particular, whether they shall be EF and/ or EFC compliant, and how this can be implemented and verified.

9.2.6 - Company-specific data

- Strategy development to incentivize provision and use of company-specific data.
- Further specification of required data for processing operations depending on the default data available.
- Exploration of the availability of retailer data (e.g., certifications/ labels, production systems/ techniques) to improve the quality and the precision of the assessment.
- If necessary, pathways to progressively enhance assessments with more detailed farm-level data, while starting with the minimum required datasets. A feasibility assessment will be conducted.
- Development of more specific guidance on company-specific data calculation and the desired frequency of updates. There might be a link to be made with the sampling procedure.

- Farm data on plant cultivation and animal husbandry, and processing of ingredients and food, will be targeted for company-specific data at a later stage.
- There can also be specific mitigation practices (e.g., tillage farming, cover cropping, rotational grazing, precision fertilization), particularly at farm and processing levels, of which the effects might be captured partially by the parameters mentioned above, but might also partially be omitted using the above parameters. On the route to making ecolabeling more and more specific, the integration of such mitigation activities should be considered.

9.2.7 – Crop cultivation and animal production

- Pesticides: Integration of a crop compartment in pesticide emission modelling.
- Aquaculture: Revision of phosphorus (P) and nitrogen (N) emissions modelling for marine aquaculture.
- Water: Addition of water consumption impacts in livestock systems.

9.2.8 - End-of-life and recycling

- Literature review to define default food loss values at the consumption stage.
- Development of proxies for products lacking clear categorization at the processing stage.

9.2.9 – Method and environmental indicators

Shift from midpoint to endpoint characterisation is to be assessed to solve several problems, including:

- Improving biodiversity impact assessment through broader and more integrated modelling beyond land use alone,
- Normalization may no longer be needed (except perhaps for aggregating the 3 to 4 areas of protection into a single score),
- Weighting may no longer be needed as individual indicator results within each area of protection can simply be summed up (which does not imply equal weighting, they simply are additive), which would strongly improve ISO 14044 compliance for a comparative assertion,
- It would open the way to apply the latest state-of-the-art LCIA methods GLAM and ImpactWorld+ (all other LCIA methods are at least 10 years old, most even 15 to 20 years and largely outdated from a scientific perspective), which also cover relevant, emerging impact categories like microplastics or ecosystem services,
- EF might eventually move to endpoint characterisation (2030), and EFC should provide "future-proof" recommendations. Alternatively, two sets of recommendations could be an option: 1) immediate implementation (time horizon 2026/27), and 2) progressive implementation (time horizon 2029/30).

Time horizon and toxicity assessment

- Consider limiting the time horizon of CFs to 100 years (and include CFs for >100 years for a sensitivity study), particularly for human and ecotoxicity, in order to limit the strong bias of metals with long-term impacts (tens of thousands of years) when using CFs with an infinite time horizon.
- Possible separation of organic and inorganic toxicity results if limiting the time horizon is not sufficient to limit metal bias.
- Consider the application of "shortcuts" for essential metals limiting their toxicity (e.g. zinc, which is only toxic to certain ecosystems (spatially defined) and certain fractions of the human population).
- Addressing missing exposure pathways: Consideration of recommending the inclusion of direct pesticide exposure of humans through pesticide residues. While current LCIA methods already allow the characterisation of this exposure pathway (the dominating one for health impacts from food products), it requires a new emission compartment "emission to plant", which is currently not available in LCI databases or software, although this can be expected to change.

LCIA method

The final EFC methodology will not recommend the use of the EF 3.1 method, due to its foreseeable obsolescence, as recommended in its beta version. Potential candidates for the recommended LCIA method for the final version of the EFC methodology are:

- EF 4.0 - next-generation EF method with potential enhancements
- GLAM - developed under UNEP with broad coverage and updated science
- ImpactWorld+ - comprehensive and future-oriented
- ReCiPe - widely used and well-documented, though somewhat dated
- LC-IMPACT - limited impact category coverage, making it a less likely candidate

Consideration of shortening the list of impact categories

The consortium underscores that removing certain impact categories at this stage would provide limited practical benefit. While such exclusions might marginally reduce life cycle inventory (LCI) data requirements, the drawbacks are significant:

- Reduced differentiation and comparability: Excluding categories diminishes the ability to capture meaningful differences between production systems and undermines comparability across products.
- Risk of burden shifting and greenwashing: Omissions could incentivize stakeholders to shift impacts toward unmeasured categories, deliberately or unintentionally. This may enable products with high impacts in excluded categories to appear environmentally preferable, thereby "hiding" relevant burdens.
- Minimal data efficiency gain: The potential reduction in LCI data demand is negligible. Categories with low contributions are unlikely to require primary data; adequate secondary data should already be available in established databases.

For these reasons, the beta version of the EFC methodology retains the full set of impact category indicators from EF 3.1. At present, no changes are foreseen to this approach. However, a sensitivity test may be conducted to quantify potential gains from omitting very low-contribution categories, ensuring that such a decision, if ever considered, remains evidence-based.

9.2.10 – Hotspot analysis

- Negative numbers, (environmental savings/credits) are excluded from the current results. A more detailed discussion is planned for the second version of the report.

9.2.11 - Biodiversity impacts

- Assessment of agricultural practices: The Eco Food Choice methodology should ensure fair comparisons across all types of farms and production systems. While organic farming has been shown to deliver positive outcomes for biodiversity[23], is equally important to recognize that other agricultural practices - not necessarily covered by organic certification (e.g., high precision agricultural practices)- can also contribute significantly to biodiversity preservation. They should be acknowledged and valued by the assessment framework.
- An analysis grid mapping the pros and cons of the different options detailed in section 6, complemented by the results of pilot testing, will be instrumental in informing the second version of the EFC methodology. Particular attention will be paid to upcoming developments from the European Commission, notably the release of PEF 4.0.
- Seafood products, currently excluded from the beta version, should be integrated into the scope of the final methodology.
- In the longer term, the scientific consensus supports a shift toward endpoint approaches like GLAM. Efforts to operationalize these should continue, with pilot testing to evaluate their effect. The Eco Food Choice framework should remain compatible with endpoint approaches to enable future integration.

9.2.12 - Reporting and data declaration

An assessment of how data collected in the product register can be used to improve secondary databases will be conducted.

Plausibility checks may be developed during the testing phase of the beta version of the Eco Food Choice methodology towards the release of the refined finalised version. However, the verification of the scoring tool is likely

[23] Ulrich, C., and al. (2025). *Agriculture, aquaculture and fishing: Impact of food standards on biodiversity. Summary of the scientific report of the study*. INRAE; Ifremer.

sufficient to authorise the Eco Food Choice label use, and these platforms will implement their own plausibility checks.

Scalability considerations will be furtherly discussed and enriched.

Scenario in countries where the ecolabelling initiative is not publicly led are also to be furtherly described.

Following this recommendation issued with the beta version of the methodology, discussions should be started with EC and other relevant points of contact.

9.2.13 – Weighting

- Placing greater emphasis on toxicity has raised concern because it would have significant effects on certain specific sectors. Indeed, highlighting toxicity may enhance the distinction between organic and conventional agriculture in some cases, but it will not always work in favor of organic systems (particularly in sectors like viticulture, which could emerge with less favorable impact scores).
- The weight of heavy metals in the normalization process has emerged as a key concern, as their significant contribution (particularly from agricultural systems) distorts the final weighting. Their underrepresentation in other sectors creates a bias that should be corrected. The targeted exclusion of the impacts of these heavy metals (in human toxicity and/or ecotoxicity) was discussed.
- The targeted redistribution of human toxicity weight toward indicators with a demonstrated link to human health could also be an option to be explored.

9.1.13 - Grading

- Alternative LCA metric: single score per mass of product within diet context could be explored.
- More material and more consideration are needed on how to derive grades.
- Some consideration is needed on how to derive the impact population. It should be assessed how much work should be invested in adjusting the impact population, and a thorough discussion on which methodological starting points should be taken. Testing the effect of removal of duplicates or adjustment of frequency of products should be done, but in a smart and efficient way, considering prior work.
- Expected results inform the number of grades and interpretation aid (choices 4 and 5). Currently, using 8 grades is recommended, together with a numerical score, on a 100-point scale. This depends on the upcoming consumer testing activities planned by the Work Package 4 of Eco Food Choice, and consultation of other stakeholders.

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