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Guidance for environmental footprint assessment of food products (Food-LCA)

Specification for external communicational purposes on the Finnish market

Hannele Heusala and Anniina Lehtilä (eds.)

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2nd edition compared with 1st edition:

- Chapter 5.2.3. Peat for bedding material and horticultural use: Data source suggestion removed
- Chapter 5.2.2. Animal modelling: Instructions to calculate nutrient content of fish material added
- Chapter order updated (within the Chapter 4)
- Minor text and value errors corrected
- Definitions and footnotes updated

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Esipuhe

Ohjeistus ruokatuotteiden ympäristöjalanjälkien arviointiin – tarkennus Suomen markkinoille ulkoista viestintää varten (= Ruoka-LCA-laskentaohjeistus) on kansallinen, elinkaariarviointiin (LCA) perustuva laskentaohjeistus, joka on tarkoitettu ruokatuotteiden ympäristöjalanjälkien vapaaehtoiseen arviointiin. Ohjeistus on tehty Euroopan komission Product Environmental Footprint (PEF) ohjeistuksen (EC 2021) pohjalta, mutta se pyrkii kattamaan laajasti koko ruokatuotekategorian ja se sisältää kansallisia tarkennuksia verrattuna PEF-ohjeistukseen. Näistä syistä ohjeistus ei ole täysin PEF-ohjeistusta vastaava.

Ruoka-LCA-laskentaohjeistuksen tavoitteena on yhdenmukaistaa ruokatuotteiden tuotekohtaisten ympäristöjalanjälkien elinkaariarviointia Suomessa, ja edistää siten ympäristöjalanjälkien vertailukelpoisuutta, luotettavuutta ja läpinäkyvyyttä. Ohjeistuksen ovat laatineet Luonnonvarakeskuksen (Luke) tutkijat osana LCAFoodPrint-projektia (2021–2025). Lisätietoja: https://www.luke.fi/fi/projektit/lcafoodprint. Ohjeistuksen kommentointiin ja kehittämiseen on osallistunut laajasti asiantuntijoita elintarvikealan yrityksistä, ministeriöistä, tutkimuslaitoksista ja muista sidosryhmistä.

Asiasanat: Elinkaariarviointi, ympäristöjalanjälki, ruokatuote

Preface

Guidance for environmental footprint assessment of food products (Food-LCA) - Specification for external communicational purposes on the Finnish market is a national guidance based on Life Cycle Assessment (LCA). It is targeted for conducting voluntary environmental footprints assessments for food products. The guidance is based on the European Commission's (EC) Product Environmental Footprint (PEF) method (EC 2021), but it aims to cover widely the whole food product category and it includes national specifications compared to the PEF. Therefore, this guidance is not fully corresponding with the PEF method.

Food-LCA guidance aims to harmonize the LCA of food products' environmental footprints in Finland, thereby promoting the comparability, reliability, and transparency of environmental footprints. This guidance has been prepared by researchers from the Natural Resources Institute Finland (Luke) as part of the LCAFoodPrint project (2021-2025). More information: https://www.luke.fi/en/projects/lcafoodprint. A wide group of professionals from the food sector including companies, ministries, research institutes, and other stakeholders were involved in commenting and development of this guidance.

Keywords: Life cycle assessment, Environmental footprint, Product Environmental Footprint, Food products

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Notifications

IMPORTANT NOTE

This document is based on the European Commission's Product Environmental Footprint (PEF) method. From now on, in this document:

All text marked in black is directly from the PEF document (EC 2021).

All text marked in green are modifications or additions made by the LCAFoodPrint project's research group.

Terminology: shall, should, may

This guidance uses precise terminology to indicate the requirements, the recommendations and options that could be chosen when an LCA study is conducted.

The term "shall" is used to indicate what is required in order for an LCA study to be in conformance with this guidance.

The term "should" is used to indicate a recommendation rather than a requirement. Any deviation from a "should" requirement has to be justified when developing the LCA study and made transparent.

The term "may" is used to indicate an option that is permissible.

Abbreviations

AF	allocation factor
AR	allocation ratio
BoM	bill of materials
BSI	British Standards Institution
CF	characterization factor
CFCs	chlorofluorocarbons
CPA	Classification of Products by Activity
DMI	dry matter intake
DNM	Data Needs Matrix
DQR	Data Quality Rating
EC	European Commission
EF	environmental footprint
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management Systems
EPD	Environmental Product Declaration
GE	gross energy intake
GHG	greenhouse gas
GR	geographical representativeness
GWP	global warming potential
ILCD-EL	International Reference Life Cycle Data System – Entry Level
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact assessment
NACE	Nomenclature Générale des Activités Economiques dans les Communautés Européennes
NMVOC	non-methane volatile compounds
P	precision
PEF	product environmental footprint
PEFCR	product environmental footprint category rules
TeR	technological representativeness
TiR	time representativeness

Definitions

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[1] and then combined to derive the environmental footprint associated with that process.

Examples of activity data include quantity of kilowatt-hours of electricity used, quantity of fuel used, output of a process (e.g. waste), number of hours equipment is operated, distance travelled, floor area of a building, etc.

Synonym of 'non-elementary flow'.

Acidification – EF 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 EF impact categories that is calculated and communicated alongside LCA results.

Additional technical information – non-environmental information that is calculated and communicated alongside LCA 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'.

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.

Bill of materials – a bill of materials or product structure (sometimes bill of material, BOM or associated list) is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts and the quantities of each needed to manufacture the product in scope of the LCA study. In some sectors it is equivalent to the bill of components.

Characterisation – calculation of the magnitude of the contribution of each classified input/output to their respective EF 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 EF impact category of concern. For example, with respect to the EF impact category 'climate change', the reference substance is CO2 and the reference unit is kg CO2-equivalents.

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 EF impact category indicator.

[1] Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute 2011).

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

Climate change – EF 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.

Commissioner of the LCA study - organisation (or group of organisations), such as a commercial company or non-profit organisation, that finances the LCA study in accordance with this guidance.

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.

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.

Declared unit - defines quantitative output (mass or volume) of the product being evaluated. The declared unit definition answers the question 'how much?'.

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.

Directly attributable – refers to a process, activity or impact occurring within the defined system boundary.

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 – EF 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.

LCA communication vehicles – all the possible ways that may be used to communicate the results of the LCA study to the stakeholders (e.g. labels, environmental product declarations, green claims, websites, infographics, etc.).

Electricity tracking[2] – the process of assigning electricity generation attributes to electricity consumption.

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, soil that are directly linked to the characterisation factors of the EF 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 of the LCA analysis 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.

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

Environmental footprint impact category indicator – quantifiable representation of an EF impact category.

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

Eutrophication – EF 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 EF impact categories are used: eutrophication, terrestrial; eutrophication, freshwater; eutrophication, marine.

External communication – communication to any interested party other than the commissioner or the practitioner of the study.

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.

[2] https://ec.europa.eu/energy/intelligent/projects/en/projects/e-track-ii

Foreground processes – those processes in the product life cycle for which direct access to information is available. For example, the producer's site and other processes operated by the producer or its contractors (e.g. goods transport, head-office services, etc.).

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).

By combining information on both radiative forcing (the energy flux caused by emission of the substance) and on the time it remains in the atmosphere, GWP gives a measure of a substance's capacity to influence the global average surface-air temperature and therefore subsequently influence various climate parameters and their effects, such as storm frequency and intensity, rainfall intensity and frequency of flooding, etc.

Horizontal averaging – the action of aggregating multiple unit process datasets or aggregated process datasets in which each provides the same reference flow, to create a new process dataset.

Human toxicity – cancer – EF 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 – EF 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.

Independent external expert – competent person, not employed in a full-time or part-time role by the commissioner of the LCA study or the user of this guidance, and not involved in defining the scope or conducting the LCA study.

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

Land use – EF 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).

Lead verifier – person taking part in a verification team with additional responsibilities, compared to the other verifiers in the team.

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.

Loading rate – ratio of actual load to the full load or capacity (e.g. mass or volume) that a vehicle carries per trip.

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 – EF 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. Partially disaggregated dataset at level-1 - a partially disaggregated dataset at level-1 contains elementary flows and activity data for one level down in the supply chain, while all complementing underlying datasets are in their aggregated form.

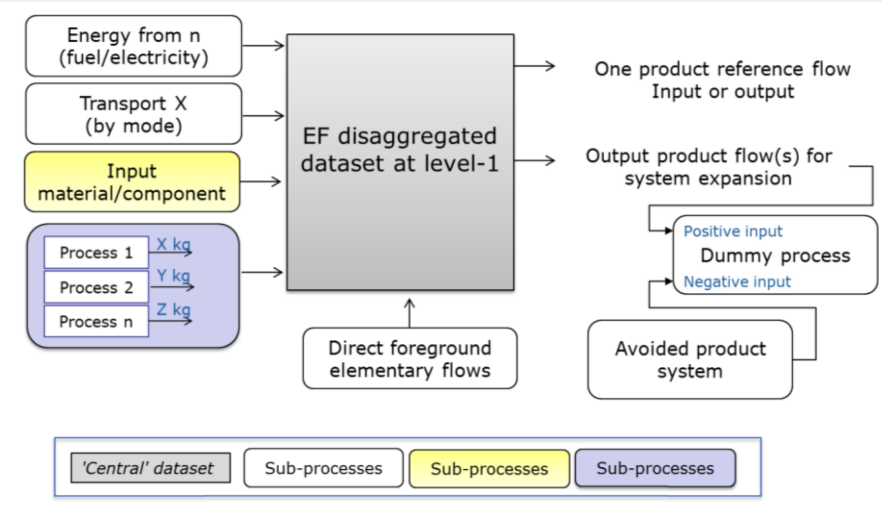

Figure 1. Example of dataset partially disaggregated at Level-1.

Particulate matter – EF 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 – EF 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.

High concentrations of ground-level tropospheric ozone damage vegetation, human respiratory tracts and manmade materials, by reacting with organic materials.

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 of the user of this guidance.

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 of the user of this guidance.

In this guidance, 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 category rules (PCRs) – set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories.

Product environmental footprint category rules (PEFCRs) – product category-specific, life cycle-based rules that complement general methodological guidance for PEF studies by providing further specification for a specific product category.

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

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

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 – data that is not from a specific process within the supply-chain of the company performing an LCA study.

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 of an LCA study.

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 LCA 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-population – any finite or infinite aggregation of individuals, not necessarily animate, subject to a statistical study that constitutes a homogenous sub-set of the whole population.

A synonym of ‘stratum’.

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).

Sub-sample - a sample of a sub-population.

Supply chain – all of the upstream and downstream activities associated with the operations of the user of this guidance, 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' EF 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 LCA 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.

Type III environmental declaration – an environmental declaration providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information.

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

Unit process, single operation - unit operation type unit process that cannot be further subdivided. Covers multi-functional processes of the unit operation type[3].

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

User of the LCA method – stakeholder producing an LCA study based on this guidance.

User of the LCA results – stakeholder using the LCA results for any internal or external purpose.

Validation – confirmation – by the environmental footprint verifier – that the information and data in the LCA study, LCA report and communication vehicles are reliable, credible and correct.

Validation statement – conclusive document aggregating the conclusions from the verifiers or the verification team regarding the EF study. This document is mandatory and shall carry the electronic or handwritten signature of the verifier or (where a verification panel is involved) the lead verifier.

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

Verification report – documentation of the verification process and findings, including detailed comments from the verifier(s), as well as the corresponding responses. This document is mandatory, but it may be confidential. The document shall carry the electronic or handwritten signature of the verifier or (where a verification panel is involved) the lead verifier.

Verification team – team of verifiers who will verify the LCA study, LCA report and LCA communication vehicles.

Verifier – independent external expert performing a verification of the LCA study and possibly taking part in a verification team.

Vertical aggregation – technical or engineering-based aggregation refers to vertical aggregation of unit processes that are directly linked within a single facility or process train. Vertical aggregation involves combining unit process datasets (or aggregated process datasets) together, linked by a flow.

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

Water scarcity footprint (Water use) – EF impact category that represents the relative available water remaining per area in a watershed, after demand from humans and aquatic ecosystems has been

[3] More details can be found in the Guide for EF-compliant datasets at https://eplca.jrc.ec.europa.eu/permalink/Guide_EF_DATA.pdf

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. In the PEF method (EC 2021), the impact category is called Water use. In here, it is called Water scarcity footprint, according to ISO 14046 definition.

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

1. Introduction

[Based on Chapter B.1. of Annex II in EC (2021)]

This national guidance provides detailed and comprehensive technical rules on how to conduct Life Cycle Assessment (LCA) studies on Finnish food products that are more reproducible, consistent, robust, verifiable, and comparable. Results of LCA studies are the basis for the provision of environmental footprint (EF) information and they may be used in a diverse number of potential fields of applications, including in-house management and participation in voluntary or mandatory programmes.

For all requirements not specified in this guidance, the user shall refer to the documents this guidance is in conformance with (see Chapter 7). Most importantly, this guidance follows the content, structure, and language of Product Environmental Footprint (PEF) guidance by the EC (2021) Annex II Part B: PEFCR TEMPLATE. This guidance also follows closely the requirements set in EC (2021) Annex I Product Environmental Footprint Method, also referred in this document as 'the EF method'.

The compliance with the present guidance is optional for in-house applications, whilst it is mandatory whenever the results of an LCA study or any of its content are intended to be communicated together with a reference to full alignment with this guidance.

This guidance aims to harmonize the assessment methods of environmental footprints of Finnish food products when the results are used for external communication. In addition, this guidance aims to help companies implement PEF-wise methodology. This guidance may be used when full compliance of an LCA study with the PEF method is not (yet) possible. If conducting a PEF study is possible, it is recommended. When performing a PEF study, this guidance may be used as a specification, especially regarding the modelling of agricultural emissions in Finland.

This guidance should be used together with communication guidance for the environmental footprints of food products (Lehtilä et al. 2024a; developed by Luke researchers within the LCAFoodPrint project).

Main exceptions to PEF terminology:

- in PEF: PEF study, in this guidance: LCA study
- in PEF: PEF Profile, in this guidance: LCA profile
- in PEF: PEF report, in this guidance: LCA report or report

Main exceptions, clarifications and additional guidance compared to PEF:

- Use of declared unit instead of functional unit (FU) as this guidance covers various food categories and FU, as defined in the EF method, cannot be defined[4].

[4] In the future improved, more robust functional units, such as those of Luke's NEPGa-project considering nutritional aspects of food products (nutritional functional units), should be developed as FU is crucial for the comparability of products the FU being the basis for comparison.

- Additional guidance for data collection requirements, in particularly for the screening step to define the most important processes (see Chapters 4)
- Additional guidance for modelling land use and land use change (LULUC) (see Chapter 4.8.1 and 4.8.2)
- Additional guidance for modelling of animal and plant production (see Chapters 5.2.1 and 5.2.2)
- Additional guidance for allocation for food production (see Chapter 4.6)
- Removal of system expansion and substitution in the allocation hierarchy (see Chapter 4.6).
- Removal of the Circular Footprint Formula in the modelling of the end of life (see Chapter 5.6).
- Removal of the possibility to use company-specific allocation factors in the farm module (see Chapter 4.6.2.1)
- A minor addition to the Data quality rating (DQR) criteria for datasets concerning water scarcity footprint (see Chapter 4.4.2, Table 4).

2. General information about the guidance

2.1. Research group behind this guidance

The document was prepared by the following authors:

Hannele Heusala, Sanna Hietala, Juha-Matti-Katajajuuri, Anniina Lehtilä, Ilkka Leinonen, Kim Lindfors, Frans Silvenius, Hanna L. Tuomisto and Kirsi Usva from the Natural Resources Institute Finland (Luke).

2.2. Consultations and stakeholders

[Based on Chapter B2.2. in Annex II of EC (2021)]

This guidance has been produced in LCAFoodPrint project (2021–2025). During the development phase, five workshops have been organized to receive comments from the food sector and its stakeholders involved in the project. The project group is thankful for all the comments received.

The funding organizations involved in the project were Apetit Oyj, Arla Oy, Atria Suomi Oy, Biocode Oy, Elintarviketeollisuusliitto Ry, Envitecpolis Oy, Gaia Consulting Oy, Hankkija Oy, Heino Group, HKScan Finland Oyj, Juustoportti Food Oy, Kauppapuutarhaliitto ry, Kesko Oyj, Lantmännen Agro Oy, LCA Consulting Oy, Leijona Catering Oy, Maa- ja metsätaloustuottajain Keskusliitto MTK ry, Maatilatalouden kehittämisrahasto (MAKERA), Matkailu- ja Ravintolapalvelut MaRa ry, Meira Oy, Nestle Finland, Olvi Oyj, Oy Gustav Paulig Ab, Oy Karl Fazer Ab, Oy Oatly Ab, Potwell Oy, Päivittäistavarakauppa ry, Raisio Oyj, Ruohonjuuri Oy, Saarioinen Oy, Satarehu Oy, SOK Liiketoiminta Oy, Valio Oy and Yara Suomi Oy.

The partners of the project included University of Helsinki, Finnish Environmental Institute (SYKE), LUT University, VTT Technical Research Centre of Finland, World Wide Fund For Nature (WWF Finland) and Ministry of Environment Finland.

2.3. Geographic validity

[Based on Chapter B2.5. in Annex II of EC (2021)]

This guidance is valid for food products in scope sold on the Finnish market.

2.4. Conformance to other documents

[Based on Chapter B2.7. in Annex II of EC (2021)]

This guidance has been prepared following the structure of PEF (2021) but modified for our more general scope to cover all food products. This guidance is not fully in conformance with the Product Environmental Footprint (PEF) method (EC 2021).

The chapters in this guidance that are either partly or fully corresponding to EC (2021) Annex I, Annex II Part A or Annex II Part B are marked under the Chapter titles.

An example: [Based on Chapter B2.7. in Annex II of EC (2021)]

3. Scope of the guidance

[Based on Chapter B.3 in Annex II of EC (2021)]

The scope of the guidance is food products that are sold on the Finnish market, and their product-level environmental footprints that are used for a basis of external communication[5]. The guidance gives more specific rules for products of Finnish origin, but it may be used for products from other countries than Finland.

Other than product-level environmental footprints and other uses than external communication (e.g., business-to-business communication or internal monitoring of environmental impacts within companies[6]) is out of the scope of this guidance. Also, management-specific LCA of food products intended for the internal development of production chains is outside the scope of this guidance. For the above-mentioned cases outside the scope of this guidance, this guidance may be used only where applicable without reference to full conformity.

This guidance is primarily targeted for the assessment of food products, and it takes into consideration all the most common food products, including plant, animal, and fish products. It is important to note that it is very likely that not all specific issues related to assessment, data collection, or modelling for all food production systems have been addressed. Therefore, this guidance may be utilized for other than most common food products where applicable without reference to full conformity.

Intermediate products and meals including different food products are out of the scope of this guidance. However, this guidance may be used for intermediate products and meals where applicable without reference to full conformity.

3.1. Declared unit

[Based on Chapter B.3.3 in Annex II of EC (2021)]

According to this guidance, declared unit (equal to reference flow) shall be used. Functional units (FU) shall not be used since food products can have different functions, and the scope of this guidance includes a wide range of different food products. Declared unit shall be mass or volume-based unit of edible food product to human consumption, delivered to the consumer considering also end of life[7]. All quantitative input and output data collected in the study shall be calculated in relation to this declared unit.

[5] For example, consumer communications in food products or product packages.
[6] For example, Science Based Targets Initiative (STBi)-related target setting including FLAG are outside the scope of this guidance. Therefore, the guidance is not in full conformance with STBi or FLAG requirements.
[7] In this guidance a mass or volume based declared unit is used as no functional unit suitable to cover all food products was readily available. In the future improved functional units, such as those considering nutritional aspects of food products (nutritional functional units), should be developed.

Regarding communication of the results and suitable unit of reference of an LCA study, more detailed recommendations are given in Ruoka-LCA communication guidance for environmental footprints of food products (Lehtilä et al. 2024a, *in Finnish*).

3.2. System boundary

[Based on Chapter B.3.4 in Annex II of EC (2021)]

The entire life cycle, from cradle to grave, shall be assessed. The following main life cycle stages and processes shall be included in the system boundary: 1) raw material acquisition and pre-processing (including production of parts and components, including packaging production); 2) manufacturing (production of the main product); 3) distribution (product distribution and storage); 4) use; 5) end of life (including packaging recovery or recycling). In Table 1, the life cycle phases and main areas/processes to be included are briefly described.

Table 1. Life cycle stages to be included in the assessment.

Life cycle stage	Short description of things to be included
Raw material acquisition and pre-processing	All plant and animal production, including production of inputs e.g. fertilisers and soil amendments, including relevant mining and extraction of resources; production of packaging materials and possible production of components and parts (such as pre-processing of agricultural raw materials) to be used in the manufacturing of the main product; transportation within and between extraction and pre-processing facilities, and transportation to the food industry manufacturing facility.
Manufacturing	The production stage begins when the product components enter the production site and ends when the finished product leaves the production facility.
Distribution	The distribution stage includes transport from the factory gate to the warehouse/retail, the storage at the warehouse/retail and transport from the warehouse/retail to the consumer's home.
Use	The use stage describes how the product is expected to be used by the end user (e.g. the consumer). This stage starts the moment the end user uses the product until it leaves its place of use and enters the end of life (EoL) stage (e.g., recycling, or final treatment).
End of life	The end of life stage begins when the product and its packaging are discarded by the user and ends when the product in scope is returned to nature as a waste product or enters another product's life cycle (i.e. as a recycled input). In general, this includes the waste from the product in scope, such as food waste and primary packaging. Waste generated during the manufacturing, distribution, retail or use stage or after use shall be included in the life cycle of the product and modelled at the life cycle stage where it occurs.

According to this guidance, the following processes may be excluded: Human urine and excreta and capital goods (including infrastructure) and their end of life (EoL) should be excluded, unless there is evidence from previous studies that they are relevant. Regarding more detailed system boundaries see also Chapter 4.2., 4.1, and 4.4.

Each LCA study done in accordance with this guidance shall provide in the LCA study a diagram indicating the activities falling in situation 1, 2 or 3 of the data needs matrix (DNM;

Chapter 4.3). Diagram shall clearly indicate the activities or processes that are included and those that are excluded from the analysis. The user of this guidance shall highlight in the diagram where company-specific data were used.

3.3. List of EF impact categories

[Based on Chapter B.3.5 in Annex II of EC (2021)]

Each LCA study carried out in compliance with this guidance shall calculate the environmental footprint profile of a product including at least the EF impact category 'Climate change'. In addition, at least EF impact categories 'Eutrophication, freshwater' and water scarcity footprint should be assessed[8]. The other impact categories included in the EF method (EC 2021) are presented in Table 2.

Table 2. List of the impact categories to be used to calculate the LCA profile of a product.

EF Impact category	Impact category Indicator	Unit	Characterization model	Robustness
Climate change[9] - Climate change – biogenic - Climate change – land use and land use change	Global warming potential (GWP100)	kg CO_2 eq	Bern model - Global Warming Potentials (GWP) over a 100-year time horizon (Environmental Footprint (EF) method, version 3.1 or more recent; Andreasi Bassi et al. 2023).	I
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11 eq	EDIP model based on the ODPs of the World Meteorological Organisation (WMO) over an infinite time horizon (WMO 2014 + integrations)	I
Human toxicity, cancer	Comparative Toxic Unit for humans (CTU_h)	CTUh	Based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al. 2018	III
Human toxicity, non-cancer	Comparative Toxic Unit for humans (CTU_h)	CTUh	based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al. 2018	III
Particulate matter	Impact on human health	disease incidence	PM model (Fantke et al. 2016 in UNEP 2016)	I
Ionising radiation, human health	Human exposure efficiency relative to U^{235}	kBq U^{235} eq	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al. 2000)	II
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC eq	LOTOS-EUROS model (Van Zelm et al. 2008) as applied in ReCiPe 2008	II

[8] According to the EF method (EC 2021), all EF impact categories listed in Table 2 shall be assessed. This should be the future direction of environmental footprint assessments.

[9] The sub-categories '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.

EF Impact category	Impact category Indicator	Unit	Characterization model	Robustness
Acidification	Accumulated Exceed-ance (AE)	mol H+ eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al. 2008)	II
Eutrophication, ter-restrial	Accumulated Exceed-ance (AE)	mol N eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al. 2008)	II
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P eq	EUTREND model (Struijs et al. 2009) as applied in ReCiPe	II
Eutrophication, ma-rine	Fraction of nutrients reaching marine end compartment (N)	kg N eq	EUTREND model (Struijs et al. 2009) as applied in ReCiPe	II
Ecotoxicity, fresh-water	Comparative Toxic Unit for ecosystems (CTU_e)	CTUe	based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al. 2018	III
Land use[10]	Soil quality index[11]	Dimensionless (pt)	Soil quality index based on LANCA model (De Laurentiis et al. 2019) and on the LANCA CF version 2.5 (Horn and Maier 2018)	III
Water scarcity (Wa-ter use)	User deprivation po-tential (deprivation-weighted water con-sumption)	m^3 water eq of deprived water	Available WAter REmaining (AWARE) model (Boulay et al. 2018; UNEP 2016)	III
Resource use, min-erals and metals	Abiotic resource de-pletion (ADP ultimate reserves)	kg Sb eq	van Oers et al. 2002 as in CML 2002 method, v.4.8	III
Resource use, fos-sils	Abiotic resource de-pletion – fossil fuels (ADP-fossil)[12]	MJ	van Oers et al. 2002 as in CML 2002 method, v.4.8	III

Regarding the interpretation of results (see also Chapter 6): In case the LCA assessment covers all 16 environmental impact categories, the normalisation, and weighting factors of the latest available EF method shall be used. At time of publication of this guidance, the latest available factors of the EF v. 3.1 can be found at: https://eplca.jrc.ec.europa.eu/LCDN/developerEF.html.

[10] Refers to occupation and transformation.
[11] This index is the result of the aggregation, performed by JRC, of 4 indicators (biotic production, erosion resistance, mechanical filtration, and groundwater replenishment) provided by the LANCA model for assessing impacts due to land use as reported in De Laurentiis et al. 2019.
[12] In the EF flow list, and for the current recommendation, Uranium is included in the list of energy carriers, and it is measured in MJ.

3.4. Additional guidance for Climate Change: characterisation factors

The characterization factors (CF) of the Environmental Foodprint (EF) method shall be used, version 3.1 (Andreasi Bassi et al. 2023) or more recent. The latest version shall be used. The characterization factors can be found at https://eplca.jrc.ec.europa.eu/LCDN/developerEF.html.

3.5. Additional guidance for Eutrophication: freshwater characterisation factors

The characterization factors presented in the ReCiPe method (Huijbregts et al. 2016; based on CARMEN model) shall be used, version 2016 or more recent. The latest version shall be used. The global and country-specific characterization factors can be found at https://www.rivm.nl/en/documenten. Freshwater eutrophication shall be calculated as phosphorus equivalents.

3.6. Additional guidance for Eutrophication: marine water characterisation

The characterization factors presented in the ReCiPe method (Huijbregts et al. 2016; based on CARMEN model) shall be used, version 2016 or more recent. The latest version shall be used. The global characterization factors can be found at https://www.rivm.nl/en/documenten. Marine eutrophication shall be calculated as nitrogen equivalents.

3.7. Additional guidance for water scarcity footprint: characterization factors

The characterization factors recommended in the latest EF method should be used. The recommendation in EF 2.0 is to use the AWARE method (Boulay et al. 2018; UNEP 2016). The characterization factors for AWARE are available at https://wulca-waterlca.org/.

The original characterization factors are given in watershed and monthly levels, but aggregated factors exist at several other levels. There are regional, national, continent, and global level aggregated factors, and in addition, annual level aggregations.

At all aggregation levels, three types of characterization factors exist:

1. Agricultural factors to be used for irrigation water
2. Non-agricultural factors to be used for all other purposes (including other agricultural purposes)
3. Unknown factors in case the aimed purpose of the water flow is not known.

Unknown-type factors may be used but may be replaced by Agricultural and Non-Agricultural factors. Temporally aggregated characterization factors at the annual level may be used for characterization, but they may be replaced by monthly-level factors. Spatially aggregated characterization factors at the country level may be used for characterization, but they may be replaced by watershed-level factors. For secondary data, in case the origin country is not known, country-level characterization factors shall be replaced by continent and global-level factors, not factors representing other countries.

3.8. Additional environmental information

[Based on Chapter B.3.7 in Annex II of EC (2021)]

Biodiversity is considered relevant for the scope of this guidance, but currently, there is no robust method available that could take biodiversity aspects of Finnish agricultural production adequately into account. Thus, it is recommended that such a method is developed and used in the future.

Referring to Chapter 4.8.1: Net soil carbon uptake (i.e., soil carbon sequestration) may only be included in the LCA study as additional environmental information and if a proof is provided. In this guidance, we do not present a method for net soil carbon uptake. That is due to lack of methodological development and data limitations. In future, a recommended method for net soil carbon uptake will be published. Prior to this, great caution should be exercised.

Referring to Chapter 4.9: Offsets shall not be included in the impact assessment of an LCA study but may be reported separately as additional environmental information.

4. Life cycle inventory

4.1. Data types

4.1.1. Company-specific data

[Based on Chapter 4.6.1. in Annex I of EC (2021)]

This chapter describes company-specific LCI data, which are directly measured or collected at a specific facility or set of facilities, and representative of one or more activities or processes in the system boundary

The data shall include all known inputs and outputs for the processes. Examples for inputs: use of energy, water, land, materials. Examples of outputs: the products, co-products, emissions and waste generated. Emissions are divided into three compartments (emissions to air, to water and to soil).

There are several ways to collect company-specific emission data, for example, they can be based on direct measurements or calculated using company-specific activity data and related emission factors (e.g. litre of fuel consumption and emission factors for combustion in a vehicle or boiler). Whenever the sector of the product in scope is covered by EU ETS monitoring rules, the user of this guidance should follow quantification requirements as set out in Regulation (EU) 2018/2066 for the processes and GHGs covered therein. For carbon capture and storage, the requirements of this guidance prevail. The data may need scaling, aggregation or other forms of mathematical treatment to bring them in line with the reference flow of the process.

Typical specific sources of company-specific data are:

a. process- or plant-level consumption data;
b. bills and stock/inventory changes of consumables;
c. emission measurements (amounts and concentrations of emissions from flue gas and wastewater);
d. composition of products and waste;
e. procurement and sale department(s)/unit(s).

All new datasets created when conducting an LCA study shall be compliant with this guidance.

All company-specific data shall be modelled in company-specific datasets.

The bill of materials (BoM) has two parts: the list of materials/ingredients and the quantity used for each of them.

The activity data of the BoM shall be specific to the product in scope and modelled with company-specific data. For companies producing more than one product, the activity data used (including the BoM) shall be specific to the product covered by the study.

The modelling of the manufacturing processes shall be based on company-specific data (e.g. energy needed to assemble the materials/components of the product in scope).

4.1.2. Secondary data

[Based on Chapter 4.6.2. in Annex I of EC (2021)]

Secondary data refer to data not based on direct measurements or on calculation of the respective processes in the system boundary. Secondary data are either sector-specific, i.e. specific to the sector being considered for the LCA study, or multi-sector. Examples of secondary data include:

a. data from literature or scientific papers;
b. industry average life-cycle data from LCI databases, industry association reports, government statistics, etc.

All secondary data shall be modelled in secondary datasets which shall fulfil the quality requirements specified in Chapter 4.4. The sources of these data used shall be clearly documented and reported in the LCA report.

4.2. Cut-off and screening

[Based on Chapter A.4.4.3. and E.5.1. in Annex II of EC (2021)]

Any cut-off shall be avoided, unless under the following rules.

Processes and elementary flows may be excluded up to 3.0% (cumulatively) based on material and energy flows and the level of environmental significance (single overall score). The processes subject to a cut-off shall be made explicit and justified in the LCA report, in particular with reference to the environmental significance of the cut-off applied.

This cut-off has to 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 from the LCA study.

A screening study is recommended to identify processes that may be cut off.

Screening step

An initial screening of the life cycle inventory (LCI) – the 'screening step' – shall be performed because it helps focus data collection activities and data quality priorities. A screening step shall include the life cycle impact assessment (LCIA) phase and result in further, iterative refinements to the life cycle model for the product in scope, as more information becomes available. Within a screening step, no cut-off is allowed, and readily available primary or secondary data may be used, fulfilling the data quality requirements to the extent possible (as defined in Chapter 4.1). Once the screening is performed, the initial scope settings may be refined.

According to the PEF method (Annex I in EC 2021), processes that have a significant impact on the environmental footprint are those for which primary data must be collected. With a screening step, the relevant life cycle stages, processes, and material flows are to be identified for the product under investigation. As a result, from the screening step focus points can be identified. Also, data requirements are formed based on these relevant processes. Higher quality data (namely primary data i.e. company-specific data) shall be collected from more relevant processes, which contribute to the environmental impact the most, in comparison to less important processes. Independent of the life cycle stage, all stages and processes should be estimated.

Screening study may be performed with less accurate data (secondary data, expert opinion etc.), yet it is conducted for the whole life cycle, from cradle to grave, and relevant processes associated with the assessed impact category. Inventory processes may be modelled with available database processes such as Ecoinvent, Agri-footprint etc. Literature and expert opinions may be utilized in determining the quantities and details for the inventory.

From the screening study, for each assessed impact category, one must identify 1) company-specific processes with significant impact, 2) non-company-specific processes with significant impact and 3) remaining processes within the system boundary with less importance.

As the screening step is conducted with less accurate data, this might have an impact on the contributions of different processes and life cycle stages. After the initial screening step, iterative screening steps might be needed to refocus when more knowledge of the supply chain is available.

The perspective of the product-producing company is important as the mandatory data for the company's production chain must be collected from those processes associated with products that are managed by the company and have a significant impact (mandatory company-specific data). These processes need to be described separately for each product, as products and production chains vary.

Yet, when products of agricultural origin are considered, major contributions to environmental impacts originate in primary production, which is often not managed by the company responsible for the product of interest.

When these processes contribute significantly to 80% of the assessed impact category's result, it is mandatory to collect primary data from these processes.

All primary data must fulfil the data quality requirements set specifically for primary datasets.

4.3. Data collection requirements

[Based on Chapter A.4.4. in Annex II of EC (2021)]

The materiality principle

One of the main features of the this guidance is the 'materiality' approach, i.e. focusing where it really matters. In the context of this guidance, the materiality approach is developed around two main areas:

Impact categories (if multiple impact categories are assessed), life cycle stages, processes and direct elementary flows: the user of this guidance shall identify the most relevant ones (see Chapters 6.2-6.5). These are the environmental contributions on which companies, stakeholders, consumers, and policymakers should focus.

Data requirements: as the most relevant processes are those driving the environmental profile of a product, these shall be assessed by using data of higher quality compared to the less relevant processes, independently from where these processes happen in the life cycle of the product.

Once the screening of the environmental impacts of the studied product is conducted (Chapter 4.2), the user of this guidance shall address the following two questions:

a. (a) Which are the processes for which company-specific information is mandatory?
b. (b) Which are the processes that are driving the environmental profile of the product (most relevant processes, see Chapter 6.4)?

4.3.1. List of mandatory company-specific data

[Based on Chapter A.4.4.1 in Annex II of EC (2021)]

The list of mandatory company-specific data refers to the activity data, direct elementary flows and (unit) processes for which company-specific data shall be collected. This list defines the minimum data requirements to be fulfilled by the users of this guidance. The purpose is to avoid that a user without access to the relevant company-specific data is able to perform an LCA study and communicate its results by only applying default data and datasets. The user of this guidance shall define the list of mandatory company-specific data based on screening step (see Chapter 4.2).

For the selection of the mandatory company-specific data, the user of this guidance shall consider its relevance within the LCA profile, the level of effort needed to collect these data (especially for SMEs) and the overall quantity of data / time required to collect all mandatory company-specific data and existing legal requirements defined in EU law on measuring certain emissions. Based on this evaluation, the user of this guidance shall set the boundaries for the collection of company-specific data. A maximum of 50% of the data identified as high relevance may be substituted with high-quality secondary data based on a high level of effort and time needed for the collection of these data. For this data, data quality requirement criteria of primary data are to be used.

This decision has, in particular, the consequence that an LCA study may be performed only by searching for these data and default data is allowed for everything outside this list.

For each process for which company-specific data is mandatory, the user of this guidance shall provide the following information:

1. The list of the company-specific activity data to be declared together with the default secondary datasets to be used. The list of activity data shall be as specific as possible in terms of units of measure and any other characteristics that could help the user in conducting the calculations and in validation and verification of the LCA study.
2. The list of direct (i.e. foreground) elementary flows to be measured by the user of this guidance. This is the list of most relevant direct emissions and resources. For each emission and resource flow, the user of this guidance shall specify the frequency of measurements, the measurement methods and any other technical information necessary to

ensure comprehensive reporting that could help validation and verification of the LCA study.

For processes selected to be modelled mandatorily with company-specific data, the calculation shall follow the requirements set out in this chapter. For all other processes, the user of the guidance shall apply the Data Needs Matrix as explained in Chapter 4.4.4.

4.3.2. Assumptions and limitations

[Corresponds A.3.2.8. in the Annex II in EC (2021)]

In LCA studies, several limitations on carrying out the analysis may arise and therefore assumptions need to be made. All limitations and assumptions shall be transparently reported.

4.3.3. Data gaps and proxies

[Based on Chapter B.3.8.2 in Annex II of EC (2021)]

The following shall be included in the LCA study:

- The list of data gaps on the company-specific data is to be collected and how these data gaps are solved in the context of the LCA study;
- The list of processes excluded from the LCA study due to missing datasets;

4.4. Data quality requirements

[Based on Chapter B.5.3 in Annex II of EC (2021)]

Data collection for LCA includes the classification of data into primary and secondary sources data. Data and quality requirement is built to follow a materiality approach, focusing on the data, which has the major contributions to environmental impact. Basic principles in the data collection approach rely on the PEF method (EC 2021, Annex I).

4.4.1. DQR formula

[Based on Chapter 4.6.5.1 in Annex I of EC (2021)]

For the assessment, the data quality of each dataset and of the total LCA study shall be calculated and reported. The DQR values (for each criterion + total) for all the datasets used shall be reported.

The DQR calculation shall be based on four data quality criteria where TeR is the Technological Representativeness, GeR is the Geographical Representativeness, TiR is the Time Representativeness, and P is Precision (EC 2021, Annex I):

$$DQR = \frac{Te_R + Ti_R + G_R + P}{4} \quad \text{[Eq. 1]}$$

The representativeness (technological, geographical, and time-related) characterises the degree to which the processes and products selected for the modelling describe the system analysed, while the precision indicates the way the data are derived and the level of uncertainty.

Five quality levels can be reached according to the DQR. They are summarised in Table 3.

Table 3. Overall data quality level of used datasets, according to the achieved data quality rating, as in PEF method (EC 2021, Annex I).

Overall DQR	Overall data quality level
DQR ≤ 1.5	'Excellent quality'
1.5 < DQR ≤ 2.0	'Very good quality'
2.0 < DQR ≤ 3.0	'Good quality'
3 < DQR ≤ 4.0	'Fair quality'
DQR >4	'Poor quality'

The DQR formula is applicable to:

1. Company-specific datasets: the procedure for calculating the DQR of company-specific datasets is described in Chapter 4.4.2.
2. Secondary datasets: when using a secondary dataset in an LCA study (procedure described in Chapter 4.1.2)
3. Overall LCA study

The next chapters provide tables with the criteria to be used for the semi-quantitative assessment of each criterion.

4.4.2. Company-specific datasets

[Based on Chapter B.5.3.1. in Annex II of EC (2021)]

When creating a company-specific dataset, the data quality of

(i) the company-specific activity data and
(ii) the company-specific direct elementary flows (i.e. emission data) shall be assessed separately.

The DQR of the sub-processes linked to the activity data is evaluated through the requirements provided in the Data Needs Matrix.

A company-specific dataset is partially disaggregated: the DQR of the activity data and direct elementary flows shall be assessed. The DQR of the sub-processes shall be assessed through the Data Needs Matrix.

The DQR shall be calculated at the level-1 disaggregation before any aggregation of sub-processes or elementary flows is performed. The DQR of company-specific datasets shall be calculated as following:

1. Select the most relevant activity data and direct elementary flows: most relevant activity data are the ones linked to sub-processes (i.e. secondary datasets) that account for at least 80% of the total environmental impact of the company-specific dataset, listing them from the most contributing to the least contributing one. Most relevant direct elementary flows are defined as those direct elementary flows contributing cumulatively at least with 80% to the total impact of the direct elementary flows.

2. Calculate the DQR criteria TeR, TiR, GeR and P for each most relevant activity data and each most relevant direct elementary flow. The values of each criterion shall be assigned based on Table 4.
    a. Each most relevant direct elementary flow consists of the amount and elementary flow naming (e.g. 40 g carbon dioxide). For each most relevant elementary flow, the user of this guidance shall evaluate the 4 DQR criteria named TeR_{-EF}, TiR_{-EF}, GeR_{-EF}, P_{EF}. For example, the user of this guidance evaluates the timing of the flow measured, for which technology the flow was measured and in which geographical area.
    b. For each most relevant activity data, the 4 DQR criteria shall be evaluated (named TeR_{-AD} TiR_{-AD}, GeR_{-AD}, P_{AD}) by the user of this guidance.
    c. Considering that the data for the mandatory processes shall be company-specific, the score of P cannot be higher than 3, while the score for TiR, TeR, and GeR cannot be higher than 2 (The DQR score shall be ≤1.5).
3. Calculate the environmental contribution of each most relevant activity data (through linking to the appropriate sub-process) and each most relevant direct elementary flow to the total sum of the environmental impact of all most-relevant activity data and direct elementary flows, in % (weighted, using all EF impact categories). For example, the newly developed dataset has only two most relevant activity data, contributing in total to 80% of the total environmental impact of the dataset:
    a. Activity data 1 carries 30% of the total dataset environmental impact. The contribution of this process to the total of 80% is 37.5% (the latter is the weight to be used).
    b. Activity data 2 carries 50% of the total dataset environmental impact. The contribution of this process to the total of 80% is 62.5% (the latter is the weight to be used).
4. Calculate the TeR, TiR, GeR and P criteria of the newly developed dataset as the weighted average of each criteria of the most relevant activity data and direct elementary flows. The weight is the relative contribution (in %) of each most relevant activity data and direct elementary flow calculated in step 3.
5. The user of this guidance shall calculate the total DQR of the newly developed dataset using Eq. 2, where TeR, TiR, GeR and P are the weighted average calculated as specified in point (4).

Table 4. How to assess the value of the DQR criteria for datasets with company-specific information

Rating	P_{EF} and P_{AD}	TiR_{-EF} and TiR_{-AD}	TeR_{-EF} and TeR_{-AD}	GeR_{-EF} and GeR_{-AD}
1	Measured/calculated and externally verified	The data refers to the most recent annual administration period with respect to the LCA report publication date	The elementary flows and the activity data explicitly depict the technology of the newly developed dataset	The activity data and elementary flows reflect the exact geography (country) where the process modelled in the newly created dataset takes place
2	Measured/calculated and internally verified, plausibility checked by reviewer	The data refers to maximum 2 annual administration periods with respect to the LCA report publication date	The elementary flows and the activity data are a proxy of the technology of the newly developed dataset	The activity data and elementary flows partly reflect the geography (e.g., agricultural conditions) where the process modelled in the newly created dataset takes place. For water scarcity footprint, a wider geographical region is selected to represent the process for example a continent instead of a country.
3	Measured/calculated/literature and plausibility not checked by reviewer OR Qualified estimate based on calculations plausibility checked by reviewer	The data refers to maximum three annual administration periods with respect to the LCA report publication date	Not applicable	Not applicable
4–5	Not applicable	Not applicable	Not applicable	Not applicable

P_{EF}: Precision for elementary flows; P_{AD}: Precision for activity data; TiR_{-EF}: Time Representativeness for elementary flows; TiR_{-AD}: Time representativeness for activity data; TeR_{-EF}: Technology representativeness for elementary flows; TeR_{-AD}: Technology representativeness for activity data; GeR_{-EF}: Geographical representativeness for elementary flows; GeR_{-AD}: Geographical representativeness for activity data.

4.4.3. DQR of secondary datasets used in LCA studies

[Based on Chapter 4.6.5.3. in Annex I of EC (2021)]

This chapter describes the procedure for calculating the DQR of secondary datasets used in an LCA study. If guidance compliant datasets are used, this involves re-calculating the DQR of the secondary dataset when it is used in the modelling of most-relevant processes (see Chapter 4.4.4), to allow the user of this guidance to assess the context-specific DQR criteria (i.e. TeR, TiR and GeR of most-relevant processes). The TeR, TiR and GeR criteria shall be re-evaluated based on 5. The total DQR of the dataset shall be recalculated using Eq. 1 from the Chapter 4.4.

Table 5. How to assess the value of the DQR criteria when secondary datasets are used.

	TiR	TeR	GeR
1	The LCA report publication date happens within the time validity of the dataset	The technology used in the LCA study is exactly the same as the one in scope of the dataset	The process modelled in the LCA study takes place in the country the dataset is valid for.
2	The LCA report publication date happens not later than 2 years beyond the time validity of the dataset	The technologies used in the LCA study are included in the mix of technologies in scope of the dataset	The process modelled in the LCA study takes place in the geographical region (e.g. Europe) the dataset is valid for.
3	The LCA report publication date happens not later than 4 years beyond the time validity of the dataset	The technologies used in the LCA study are only partly included in the scope of the dataset	The process modelled in the LCA study takes place in one of the geographical regions the dataset is valid for.
4	The LCA report publication date happens not later than 6 years beyond the time validity of the dataset	The technologies used in the LCA study are similar to those included in the scope of the dataset	The process modelled in the LCA study takes place in a country that is not included in the geographical region(s) the dataset is valid for, but sufficient similarities are estimated based on expert judgement.
5	The LCA report publication date happens later than 6 years after the time validity of the dataset	The technologies used in the LCA study are different from those included in the scope of the dataset	The process modelled in the LCA study takes place in a different country than the one the dataset is valid for. Not applicable for water scarcity footprint.

4.4.4. Data needs matrix (DNM)

[Based on Chapter B.5.4 in Annex II of EC (2021)]

Besides the mandatory company-specific data, other non-mandatory data and secondary data shall be defined. For evaluation of other than mandatory company-specific data, a Data Needs Matrix is provided (DNM; Table 5) and shall be used to model the product in scope. DNM categorises different types of data sources and instructs how to proceed with data collection. It provides details on which processes company-specific data or secondary data shall be used. The provided data source categories are:

- **Situation 1**: A company-managed process for which the company has primary data available;
- **Situation 2:** The process is not managed by the company, but primary data is available;
- **Situation 3:** The process is not managed by the company and no primary data is available.

The user of this guidance shall do the following (as in EC 2021 Annex I):

1. Determine how much influence (Situation 1, 2 or 3) the company has over each process in its supply chain. This decision determines which of the options in DNM table is valid to each process.
2. Provide a table in the LCA report listing all processes and their situation according to the DNM.
3. Follow the data requirements indicated in Table 6.

Table 6. Data Needs Matrix (DNM). *Disaggregated datasets shall be used.

	Data requirements	
Situation 1: process run by the company	Option 1	Provide company-specific data (both activity data and direct emissions) and create a company-specific dataset (DQR≤1.5). Calculate DQR of the dataset following the rules in Chapter 4.4.2.
Situation 2: process not run by the company but with access to company-specific information	Option 1	Provide company-specific data and create a company-specific dataset (DQR≤1.5). Calculate DQR of the dataset following the rules in Chapter 4.4.2.
	Option 2	Use compliant secondary dataset and apply company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific compliant datasets (DQR≤3.0). Recalculate DQR of the dataset used (see Chapter 4.4.3).
Situation 3: process not run by the company and without access to company-specific information	Option 1	Use compliant secondary dataset in aggregated form (DQR≤3.0). Recalculate DQR of the dataset if the process is most relevant (see Chapter 4.4.3).

4.4.4.1. Processes in situation 1

[Based on Chapter B.5.4.1 in Annex II of EC (2021)]

For each process in situation 1 there are two possible options:

1. The process is in the list of most relevant processes as specified in this guidance or is not in the list of most relevant process, but still the company wants to provide company-specific data (option 1);
2. The process is not in the list of most relevant processes and the company prefers to use a secondary dataset (option 2).

Situation 1/Option 1

For all processes run by the company and where the user of this guidance applies company-specific data. The DQR of the newly developed dataset shall be evaluated as described in Chapter 4.4.3.

Situation 1/Option 2

For the non-most relevant processes only, if the user of this guidance decides to model the process without collecting company-specific data, then the user shall use the secondary dataset in compliance with this guidance together with its available default DQR values.

If the DQR of default dataset to be used for the process is not available, the user of this guidance shall take the DQR values from the metadata of the original dataset or re-evaluating P, TeR, TiR and GeR, using the Table 4.

4.4.4.2. Processes in situation 2

[Based on Chapter B.5.4.1 in Annex II of EC (2021)]

When a process is not run by the user of the guidance, but there is access to company-specific data, then there are three possible options:

1. The user of the guidance has access to extensive supplier-specific information and wants to create a new compliant dataset (Option 1);
2. The company has some supplier-specific information and want to make some minimum changes (Option 2);
3. The process is not in the list of most relevant processes and the company wants to make some minimum changes (Option 3).

Situation 2/Option 1

For all processes not run by the company and where the user of this guidance applies company-specific data, the DQR of the newly developed dataset shall be evaluated as described in Chapter 4.4.3.

Situation 2/Option 2

The user of the guidance shall use company-specific activity data for transport and shall substitute the sub-processes used for electricity mix and transport with supply-chain specific, guidance compliant datasets.

The user of the guidance shall make the available DQR context-specific by re-evaluating TeR and TiR using the Table 4 in Chapter 4.1.1. The criteria GeR shall be lowered by 30%[13] and the criteria P shall keep the original value.

Situation 2/Option 3

The user of this guidance shall apply company-specific activity data for transport and shall substitute the sub-processes used for electricity mix and transport with supply-chain specific, guidance compliant datasets.

[13] In situation 2, option 2 it is proposed to lower the parameter GeR by 30% in order to incentivise the use of company-specific information and reward the efforts of the company in increasing the geographic representativeness of a secondary dataset through the substitution of the electricity mixes and of the distance and means of transportation.

4.4.4.3. Processes in situation 3

[Based on Chapter B.5.4.2. in Annex II of EC (2021)]

If a process is not run by the company using this guidance and the company does not have access to company-specific data, there are two possible options:

1. It is in the list of most relevant processes (situation 3, option 1);
2. It is not in the list of most relevant processes (situation 3, option 2).

Situation 3/Option 1

In this case, the user of this guidance shall make the available DQR values of the dataset used context-specific by re-evaluating TeR, TiR and GeR, using the Table 6. The criteria P shall keep the original value, if available.

Situation 3/Option 2

For the non-most relevant processes, the user of this guidance may apply secondary dataset with its DQR values when available, or re-evaluate P, TeR, TiR and GeR, using the Table 4.

4.4.5. How to calculate the average DQR of the study

[Based on Chapter B.5.6. Annex II of EC (2021)]

To calculate the average DQR of the LCA study, the user of this guidance shall calculate separately the TeR, TiR, GeR and P for the LCA study as the weighted average of all most relevant processes, based on their relative environmental contribution to each assessed environmental impact category separately. The calculation rules explained in Chapter 4.4.1 shall be used.

4.5. Sampling procedure

[Based on Chapter 4.4.6. in Annex I and A.4.2.5. in Annex II of EC (2021)]

In some cases, a sampling procedure is needed to limit the data collection only to a representative sample of plants/ farms etc. Examples of cases when the sampling procedure may be needed are in case multiple production sites are involved in the production of the same Stock Keeping Unit (SKU); e.g., in case the same raw material/ input material comes from multiple sites or in case the same process is outsourced to more than one subcontractor/supplier.

A stratified sample shall be used, 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. With this type of sampling, it is guaranteed that subjects from each sub-population are included in the final sample, whereas simple random sampling does not ensure that sub-populations are represented equally or proportionately within the sample.

In case sampling is needed, it shall be conducted as specified in this guidance. However, sampling is not mandatory and any user of this guidance may decide to collect the data from all the plants or farms, without performing any sampling.’

The population and the selected sample used for the LCA study shall be clearly described in the LCA report (e.g., the % of the total production or % of number of sites, following the requirements stated in this guidance).

In some cases, the user of this guidance needs a sampling procedure to limit the data collection to only a representative sample of plants, farms etc. The user of this guidance shall:

(i) specify in the LCA report if sampling was applied,
(ii) follow the requirements described in this chapter and
(iii) indicate which approach was used.

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 in order to select a representative sample as a stratified sample:

(iv) define the population;
(v) define homogeneous sub-populations (stratification);
(vi) define the sub-samples at the sub-population level;
(vii) define the sample for the population starting from the definition of sub-samples at the sub-population level.

4.5.1. How to define homogeneous sub-populations (stratification)

[Based on Chapter 4.4.6.1. in Annex I of EC (2021)]

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.

Additional aspects to be taken into consideration may be added.

The number of sub-populations shall be calculated as follows:

$$Nsp = g * t * c \quad \text{[Eq. 2]}$$

- Nsp: number of sub-populations;
- g: number of countries in which the sites/plants/farms are located;
- t: number of technologies/farming practices;
- c: 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 with the numbers of classes identified for each additional aspect (e.g. those sites which have an environmental management or reporting system in place).

4.5.2. How to define sub-sample size at sub-population level

[Based on Chapter 4.4.6.2. in Annex I of EC (2021)]

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

i) **Based on the total production of the sub-population.**

The user of this guidance 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.

ii) **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.

$$nSS = \sqrt{nSP} \qquad \text{[Eq. 3]}$$

- nSS: required sub-sample size
- 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.

4.5.3. Sampling regarding former land use[14]

PAS 2050:2011: "where neither the country of production nor the former land use is known, the greenhouse gas (GHG) emissions arising from land use change shall be the weighted average of the average land use change emissions of that commodity in the countries in which it is grown.

Knowledge of the prior land use can be demonstrated using a number of sources of information, such as satellite imagery and land survey data. Where records are not available, local knowledge of prior land use can be used. Countries in which a crop is grown can be determined from import statistics, and a cut-off threshold of not less than 90% of the weight of imports may be applied. Data sources, location and timing of land use change associated with inputs to products shall be reported."

[14] Moved here from the Chapter 7.9.3. "Sub-category 3: Climate change – land use and land transformation" in PEF (EC 2021 Annex 1).

4.6. Allocation rules

[Based on Chapter 4.5. in Annex I of EC (2021)]

If a process or facility provides more than one function, i.e. it delivers several goods and/or services ('co-products'), it is 'multifunctional'. In these situations, all inputs and emissions linked to the process shall be partitioned between the product of interest and the other co-products in a principled manner. Systems involving multi-functionality of processes shall be modelled in line with the following decision hierarchy. Specific allocation requirements in Chapters 4.6.2-4.6.7 of this guidance always prevail over the ones available in this Chapter.

Decision hierarchy

1) Subdivision

As per EN ISO 14044:2006, wherever possible, subdivision should be used to avoid allocation. Subdivision refers to disaggregating multifunctional processes or facilities to isolate the input flows directly associated with each process or facility output. It shall be investigated first whether it is possible to subdivide the analysed process. Where subdivision is possible, inventory data shall be collected only for those unit processes directly attributable[15] to the goods/services of concern.

2) Allocation based on a relevant underlying physical relationship

Where it is not possible to apply subdivision, allocation should be applied: the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects relevant underlying physical relationships between them (EN ISO 14044:2006). Allocation based on a relevant underlying physical relationship refers to partitioning the input and output flows of a multi-functional process or facility in line with a relevant, quantifiable physical relationship between the process inputs and co-product outputs (for example, a physical property of the inputs and outputs that is relevant to the function provided by the co-product of interest).[16]

Or to allocate input/output based on some other relevant underlying physical relationship that relates the inputs and outputs to the function provided by the system, the user of the this guidance shall demonstrate that it is possible to define a relevant physical relationship by which to allocate the flows attributable to the provision of the defined function of the product system: if this condition is fulfilled, the user of the this guidance may allocate based on this physical relationship.

[15] Directly attributable refers to a process, activity or impact occurring within the defined system boundary.

[16] In the PEF method (EC 2021), allocation based on a physical relationship may be modelled using direct substitution, if it is possible to identify a product that is directly substituted. However, this guidance (Food-LCA) deviates from the PEF method in this regard, and no substitutions shall be used in LCA studies according to this guidance.

3) Allocation based on some other relationship

Allocation based on some other relationship may be possible. For example, 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. In any case, to ensure the physical representativeness of the LCA results as far as possible a clear justification for having discarded 1) and 2) and for having selected a certain allocation rule in step 3) shall be provided.

Allocation based on some other relationship may be approached by analysing is it possible to allocate the input/output flows between the products and functions on the basis of some other relationship (e.g. the relative economic value of the co-products)? If yes, allocate products and functions based on the relationship identified.

4.6.1. Specification for economic allocation

For the allocation of multifunctional processes, the decision hierarchy described above shall be used. When the decision hierarchy leads to the use of economic allocation, then any co-product output (including compost, anaerobic digestion/sewage treatment, bottom ashes/slag or any input to the biogas plant) shall be allocated according to the same principles as manure in the EF method (see Chapter 4.6.2.1) and the thereof derived classification below. The circular footprint formula (CFF) of the PEF method (EC 2021) shall not be used[17].

Classification of outputs:

- **Co-product:** If a co-product output does have an economic value (market price), it is regarded as a product or co-product. The inputs and outputs associated with multi-functional processes are allocated 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.
- **Residual:** If a co-product output does not have an economic value (market price) in the stage in which it is produced, but has a utilization value (e.g. fertilization value, energy is recovered in its incineration), it is regarded as a residual. Zero upstream burden shall be allocated to the user of the output. The emissions related to the production of the output are allocated to the other co-product outputs of the process producing the output. Further, no burdens nor credits from downstream are allocated to the producer of the output. If the producer of the output is responsible (pays) the transportation to the user of the output, also the burden of transport is allocated to the producer.

[17] In the PEF method (EC 2021), the end of life is modelled through the Circular Footprint Formula (CFF). This guidance deviates from the PEF method in this regard, and no CFF shall be used in LCA studies according to this guidance. Regarding the end of life of packaging materials, in the coming years PlastLife/SCORE – project will produce an EF method-based Product Category Rules (PCR) for food packaging. In case there is an interest to communicate the environmental footprint of food packaging or to compare different food packaging options, we recommend following the project's outcomes.

- **Waste:** If a co-product output does not have an economic value (no market price) nor a utilization value, it is regarded as waste (e.g. landfilled). The upstream burden and the end of life or waste treatment of such output shall be allocated to the producer of the output. If the producer of the output is responsible (pays) the transportation to the end of life treatment, also the burden of transport is allocated to the producer.

4.6.2. Allocation in animal husbandry

[Based on Chapter 4.5.1. in Annex I of EC (2021)]

This chapter provides instructions on how to address specific issues related to the modelling of farm, slaughterhouse and rendering for cattle, swine, and sheep. In particular, instructions are provided on:

1. allocation of upstream burdens at farm level among outputs leaving the farm
2. allocation of upstream burdens (linked to live animals) at slaughterhouse level among outputs leaving the slaughterhouse.

4.6.2.1. Allocation within the farm module

[Based on Chapter 4.5.1.1. in Annex I of EC (2021)]

At farm module, subdivision shall be used for processes that are directly allocated to certain outputs (e.g. energy use and emissions related to milking processes). If the processes cannot be subdivided due to the lack of separate data or because it is technically impossible, the upstream burden, e.g. feed production, shall be allocated to farm outputs using either a biophysical or economic allocation method as defined by the default values provided in the following chapters for cattle, swine, sheep and fish[18]. For poultry and reindeer, economic allocation shall be applied for farm outputs produced for different purpose for example broiler eggs and other products from broiler parent farms and reindeers for meat and recreational services (e.g. tourism).

Manure exported to another farm shall be considered as one of the following[19]:

(a) Residual (default option): if manure does not have an economic value at the farm gate, it is regarded as residual without allocation of an upstream burden. The emissions related to manure management up to the farm gate are allocated to the other farm outputs where manure is produced.

(b) Co-product: when exported manure has an economic value at the farm gate, an economic allocation of the upstream burden shall be used for manure by using the relative economic value of manure compared to milk, live animals, eggs and other animal products at the

[18] The EF method (EC 2021) also allows changing these allocation factors if company-specific data are collected and used for the farm module. However, this guidance (Food-LCA) deviates from the PEF method in this regard, and no changes shall be made in LCA studies according to this guidance.
[19] In the PEF method (EC 2021), the classification applies to manure at cattle farm. This guidance applies the same rules for manure of all animals.

farm gate. However, biophysical allocation based on IDF rules shall be applied to allocate the remaining emissions between milk and live animals.

(c) Manure as waste: when manure is treated as waste (e.g. landfilled), the end of life guidance (Chapter 5.6) shall be applied[20].

4.6.2.2. Allocation within the farm module for dairy cattle

[Based on Chapter 4.5.1.2. in Annex I of EC (2021)]

The International Dairy Federation (IDF) (2015) allocation method between milk, cull cows and surplus calves shall be used. The end of life guidance (Chapter 5.6) shall be applied for dead animals (see Chapter 4.6.1).

The allocation factor (AF) for milk shall be calculated using the following equation:

$$AF = 1 - 6.04 \times M_{meat} / M_{milk} \quad [Eq. 4]$$

M_{meat} is the mass of live weight of all animals sold including bull calves and culled mature animals per year and M_{milk} is the mass of fat and protein corrected milk (FPCM) sold per year (corrected to 4% fat and 3.3% protein). The constant 6.04 describes the causal relationship between the energy content in feed in relation to the milk and live weight of animals produced. The constant is determined based on a study that collected data from 536 US dairy farms[21]. Although based on US farms, the IDF considers that the approach is applicable to European farming systems.

The FPCM (corrected to 4% fat and 3.3% protein) shall be calculated by using the following formula:

$$FPCM\ (kg/yr) = Production(kg/yr) \times (0.1226 \times TrueFat\% + 0.0776 \times TrueProtein\% + 0.2534) \quad [Eq. 5]$$

In cases where a default value of 0.02 kg meat/kg milk for the ratio of live weight of animals and milk produced in Equation 4 is used, the equation yields default allocation factors of 12% to live weight of animals and 88% to milk (Table 7). These values shall be used as default values used for allocating the upstream burdens to milk and live weight of animals for cattle when secondary datasets are used. If company-specific data are collected for the farming stage, the allocation factors shall be changed using the equations included in this chapter.

Table 7. Default allocation factors for cattle at farming.

Co-product	Allocation factor
Animals, live weight	12%
Milk	88%

[20] In the PEF method (EC 2021), the end of life of waste is modelled through the Circular Footprint Formula (CFF). This guidance deviates from the PEF method in this regard, and no CFF shall be used in LCA studies according to this guidance.
[21] Thoma et al. 2013

4.6.2.3. Allocation within the farm module for sheep

[Based on Chapter 4.5.1.3. in Annex I of EC (2021)]

A biophysical approach shall be used for allocating upstream burdens to the different co-products for sheep. The 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines for national GHG inventories (IPCC 2006b) contain a model for calculating energy requirements that shall be used for sheep. This model is applied in this document.

Dead animals and all the products from dead animals shall be regarded as waste and end of life guidance (Chapter 5.6) shall be applied. In this case, however, the tracing of products from dead animals shall be allowed so this aspect can be taken into consideration in LCA studies.

It is mandatory to use the default allocation factors included in this document whenever secondary datasets are used for the life-cycle stage of farming for sheep. If company-specific data are used for this life-cycle stage, the allocation factors shall be calculated with the company-specific data using the equations provided.

The allocation factors shall be calculated as follows[22]:

% **wool** = [**Energy for wool** ($\mathbf{NE_{wool}}$)] / [(**Energy for wool** ($\mathbf{NE_{wool}}$)+ **Energy for milk** ($\mathbf{NE_{l}}$) + **Energy for meat** ($\mathbf{NE_{g}}$)] [Eq. 6]

% **milk** = [**Energy for milk** ($\mathbf{NE_{l}}$)] / [(**Energy for wool** ($\mathbf{NE_{wool}}$)+ **Energy for milk** ($\mathbf{NE_{l}}$) + **Energy for meat** ($\mathbf{NE_{g}}$) [Eq. 7]

% **meat** = [**Energy for meat** ($\mathbf{NE_{g}}$)] / [(**Energy for wool** ($\mathbf{NE_{wool}}$)+ **Energy for milk** ($\mathbf{NE_{l}}$) + **Energy for meat** ($\mathbf{NE_{g}}$)] [Eq. 8]

To calculate the energy for wool (NE_{wool}), energy for milk (NE_{l}) and energy for meat (NE_{g}) with company-specific data, the equations included in IPPC (2006), and reported below, shall be used. In case secondary data are used instead, the default values for the allocation factors provided in this document shall be used.

Energy for wool, NE_{wool}

$$\mathbf{NE_{wool} = (EV_{wool} \times Production_{wool}) \times 365} \qquad \text{[Eq. 9]}$$

NE_{wool} = net energy required to produce wool, MJ/day.
EV_{wool} = the energy value of each kg of wool produced (weighed after drying but before scouring), MJ/kg. A default value of 157 MJ/kg (NRC 2007) shall be used for this estimate[23].
$Production_{wool}$ = annual wool production per sheep, kg/yr.

[22] The same naming as used in IPCC (2006b) is used.
[23] The default value of 24 MJ/kg originally included in the IPPC document was modified into 157 MJ/kg following the indication of FAO - Greenhouse gas emissions and fossil energy demand from small ruminant supply chains Guidelines for assessment (2016).

Default values to be used for calculating NE_{wool} and the resulting net energy required are reported in Table 8.

Table 8. Default values to be used in calculating NE_{wool} for sheep.

Parameter	Value	Source
EV_{wool} - sheep	157 MJ/kg	NRC 2007
$Production_{wool}$ - sheep	7.121 kg	Average of the four values provided in Table 1 of 'Application of LCA to sheep production systems: investigating co-production of wool and meat using case studies from major global producers[24].
NE_{wool} - sheep	3.063 MJ/d	Calculated using Eq. 9

Energy for milk, NE_l

$$NE_l = Milk \times EV_{milk} \qquad [Eq.\ 10]$$

NE_l = net energy for lactation, MJ/day.
Milk = amount of milk produced, kg of milk/day.
EV_{milk} = the net energy required to produce 1 kg of milk. A default value of 4.6 MJ/kg (AFRC 1993) shall be used which corresponds to a milk fat content of 7% by weight.

The default values to be used for calculating NE_l and the resulting net energy required are provided in Table 9.

Table 9. Default values to be used in calculating NE_l for sheep.

Parameter	Value	Source
EV_{milk} – sheep	4.6 MJ/kg	AFRC (1993)
Milk - sheep	2.08 kg/d	Estimated milk production 550 lbs of sheep milk per year (average value), milk production estimated for 120 days in one year.
NE_l - sheep	9.568 MJ/d	Calculated using Eq. 10.

Energy for meat, NE_g

$$Ne_g = WG_{lamb} \times (a+0.5b(BW_i+BW_f)) / 365 \qquad [Eq.\ 11]$$

Ne_g = net energy needed for growth, MJ/day.
WG_{lamb} = the weight gain (BW_f – BW_i), kg/yr.
BW_i = the live body weight at weaning, kg.
BW_f = the live body weight at 1-year old or at slaughter (live weight) if slaughtered prior to 1 year of age, kg.
a, b = constants as described in Table 10.

[24] Wiedemann et al. Int J. of LCA 2015.

Note that lambs will be weaned over several weeks as they supplement a milk diet with pasture feed or supplied feed. The time of weaning should be taken as the time at which they depend on milk for half their energy supply. The NE_g equation used for sheep includes two empirical constants ('a' and 'b') that vary by animal species/category (Table 10).

Table 10. Constants for use in calculating NE_g for sheep[25]

Animal species/category	a ($MJ\ kg^{-1}$)	b ($MJ\ kg^{-2}$)
Intact males	2.5	0.35
Castrates	4.4	0.32
Females	2.1	0.45

In case company-specific data are used for the farming stage, the allocation factors shall be recalculated. In this case, the parameter 'a' and 'b' shall be calculated as weighted average if more than one animal category is present.

Default values to be used in calculating NE_g are reported in Table 11.

Table 11. Default values to be used in calculating NE_g for sheep.

Parameter	Value	Source
WG_{lamb} - sheep	26.2 – 15 = 11.2 kg	Calculated
BW_i - sheep	15 kg	It is assumed that the weaning happens at 6 weeks. Weight at 6 weeks as stated from Figure 1 in 'A generic model of growth, energy metabolism and body composition for cattle and sheep', Johnson et al. 2015 – Journal of Animal Science.
BW_f - sheep	26.2 kg	Average of the weight values for sheep at slaughter, as provided in Appendix 5 of FAO (2016b), GHG emissions and fossil energy demand from small ruminant supply chains, (FAO 2016b).
a - sheep	3	Average of the three values provided in Table 10.
b - sheep	0.37	Average of the three values provided in Table 10.
NE_g - sheep	0.326 MJ/d	Calculated using Eq. 11.

The default allocation factors to be used in LCA studies for sheep are provided in Table 12 together with the calculations.

Table 12. Default allocation factors to be used in LCA studies for sheep at farming stage, equations[26]

Allocation factor, meat	% **meat**= [(NEg)] / [(NEwool)+ (NEl) + (NEg)] = 2.52%
Allocation factor, milk	% **milk**= [(NEl)] / [(NEwool)+ (NEl) + (NEg)] = 73.84%
Allocation factor, wool	% **wool**= [(NEwool)] / [(NEwool)+ (NEl) + (NEg)] = 23.64%

[25] This table corresponds to Table 10.6 in IPCC (2006b).
[26] Page 10.24 of IPCC (2006b).

4.6.2.4. Allocation within the farm module for swine

[Based on Chapter 4.5.1.4. in Annex I of EC (2021)]

Allocation at farming stage between piglets and sows shall be made applying economic allocation. The default allocation factors to be used are reported in Table 13.

Table 13. Allocation at farming stage between piglets and sows

	Unit	Price	Allocation factors
Piglets*	24.8 p	40.80 €/animal	92.63%
Sow to slaughter**	84.8 kg	0.95 €/kg live weight	7.37%

* Corresponds with "market swine – growing" of "breeding swine – growing"
** Corresponds with "breeding swine – adult"

4.6.2.5. Allocation within the slaughterhouse

[Based on Chapter 4.5.1.5. in Annex I of EC (2021)]

Slaughterhouse and rendering processes produce multiple outputs going to the food and feed chain or to other non-food or feed value chains (e.g. the leather industry or chemical or energy recovery chains).

At the slaughterhouse and rendering module stage, subdivision shall be used for those process flows that are directly attributable to certain outputs. If it is not possible to subdivide the processes, the remaining flows (e.g. excluding those already allocated to milk for milk producing systems or to wool for wool producing systems) shall be allocated to the slaughterhouse and rendering outputs using economic allocation. Default allocation factors are provided in the following chapters for cattle, swine, and sheep. These default values shall be used in LCA studies. Changes to the allocation factors are not allowed.

4.6.2.6. Allocation within the slaughterhouse for cattle

[Based on Chapter 4.5.1.6. in Annex I of EC (2021)]

At the slaughterhouse, the allocation factors are established for the five product categories described in Table 14. If allocation factors used for subdividing the impact of the carcass among the different cuts are preferred, they shall be defined and justified in the LCA study.

The by-products that originate from the slaughterhouse and rendering are classified in three categories.

Category 1: Risk materials, e.g. infected/contaminated animals or animal by-products:

- disposal and use: incineration, co-incineration, landfill, used as biofuel for combustion, manufacture of derived products.

Category 2: Manure and digestive tract content, products of animal origin unfit for human consumption:

- disposal and use: incineration, co-incineration, landfill, fertilisers, compost, used as biofuel for combustion, manufacture of derived products.

Category 3: Carcasses and parts of animals slaughtered which are fit for human consumption but are not intended to be used for this purpose for commercial reasons, including skins and hides going to the leather industry (note that hides and skins may also belong to other categories depending on the condition and nature that is determined by the accompanying sanitary documentation):

- disposal and use: incineration, co-incineration, landfill, feed, pet food, fertilisers, compost, used as biofuel for combustion, manufacture of derived products (e.g. leather), oleo-chemicals and chemicals.

The upstream burdens to slaughterhouse and rendering outputs shall be allocated as follows:

Food grade materials: product with allocation of upstream burdens.

Category 1 material: by default, upstream burdens are not allocated. Apply the output classification of Chapter 4.6.1.

Category 2 material: by default, upstream burdens are not allocated. Apply the output classification of Chapter 4.6.1.

Category 3 material has the same fate as that of Category 1 and 2 (for fat – to be burned, or bone and meat meal) and does not have an economic value at the slaughterhouse gate: by default, upstream burdens are not allocated. Apply the output classification of Chapter 4.6.1.

Category 3 skins and hides (unless they are classified as residual or waste and/or follow the same way as Category 1 and Category 2): product with allocation of upstream burdens.

Category 3 materials, not included in previous categories: product with upstream burdens allocated.

The default values in Table 14 shall be used in LCA studies. Changes to the allocation factors are not allowed.

Table 14. Economic allocation ratios for beef[27]

	Mass fraction	Price	Economic allocation (EA)	Allocation ratio* (AR)
	%	€/kg	%	
a) Fresh meat and edible offal	49.0	3.00	92.957	1.90
b) Food grade bones	8.0	0.19	1.0	0.12
c) Food grade fat	7.0	0.40	1.8	0.25
d) Category 3 slaughter by-products	7.0	0.18	0.8	0.11
e) Hides and skins	7.0	0.80	3.5	0.51
f) Category 1/2 material and waste	22.0	0.00	0.0	0.00

* AR have been calculated as 'Economic allocation' divided by 'Mass fraction'

[27] Based on the PEF screening study (v 1.0, November 2015) of the pilot PEFCR on meat (bovine, pigs and sheep), available at https://webgate.ec.europa.eu/fpfis/wikis/pages/viewpage.action?pageId=81474527. ECAS registration needed to access the website.

AR shall be used to calculate the environmental impact of a unit of product by using the equation below:

$EI_i = E_{lw} * AR_i$ [Eq. 12]

EI_i = environmental impact per mass unit of product *i*, (*i* = a slaughterhouse output listed in Table 14)
EI_w = environmental impact of the whole animal divided by live weight mass of the animal
AR_i = allocation ratio for product *i* (calculated as economic value of *i* divided by mass fraction of *i*).

EI_w shall include upstream impacts, slaughterhouse impacts that are not directly attributable to any specific product and impact from the management of slaughterhouse waste (cat. 1 and 2 material and waste in Table 14)

The default values for AR_i as shown in Table 14 shall be used for the EF studies to represent the European average situation.

4.6.2.7. Allocation within the slaughterhouse for swine

[Based on Chapter 4.5.1.7. in Annex I of EC (2021)]

The default values in Table 15 shall be used in LCA studies dealing with allocation within the slaughterhouse for swine. Changing allocation factors based on company-specific data is not allowed.

Table 15. Economic allocation ratios for swine[28].

	Mass fraction	Price	Economic allocation (EA)	Allocation ratio* (AR)
	%	€/kg	%	
a) Fresh meat and edible offal	67.0	1.08	98.67	1.54
b) Food grade bones	11.0	0.03	0.47	0.04
c) Food grade fat	3.0	0.02	0.09	0.03
d) Category 3 slaughter by-products	19.0	0.03	0.77	0.04
e) Hides and skins (categorised in Category 3 products)	0.0	0.00	0	0
Total	100.0		100.0	

4.6.2.8. Allocation within the slaughterhouse for sheep

[Based on Chapter 4.5.1.8. in Annex I of EC (2021)]

The default values in Table 16 shall be used in LCA studies that deal with allocation within the slaughterhouse for sheep. Changes to allocation factors based on company-specific data are not allowed.

[28] Based on the PEF screening study (v 1.0, November 2015) of the meat pilot, available at https://webgate.ec.europa.eu/fpfis/wikis/pages/viewpage.action?pageId=81474527

Table 16. Economic allocation ratios for sheep[29]

	Mass fraction	Price	Economic allocation (EA)	Allocation ratio* (AR)
	%	€/kg	%	
a) Fresh meat and edible offal	44.0	7	97.860	2.22
b) Food grade bones	4.0	0.01	0.0127	0.0032
c) Food grade fat	6.0	0.01	0.0190	0.0032
d) Category 3 slaughter by-products	13.0	0.15	0.618	0.05
e) Hides and skins (categorised in Category 3 products)	14.0	0.35	1.6	0.11
f) Category 1 / 2 material and waste	19	0	0	0
Total	100		100	

4.6.2.9. Allocation of fish

If allocation cannot be avoided by subdivision (see Chapter 4.6), allocation between different parts of fish in aquaculture shall be made by applying economic allocation. The classification of outputs in Chapter 4.6.14.6.2.1 shall be applied. If the co-products have the same basic functionality[30], physical-based (e.g. mass, or volume, if volume is the limiting factor) allocation can be used for simplification (e.g. all edible parts for human consumption).

If allocation cannot be avoided by subdivision (see Chapter 4.6), allocation between different fish species in fisheries shall be made by applying economic allocation. The classification of outputs in Chapter 4.6.14.6.2.1 shall be applied.

If allocation cannot be avoided by subdivision (see Chapter 4.6), allocation between different fish oil and fish meal shall be made by applying either mass or economic allocation. The classification of outputs in Chapter 4.6.14.6.2.1 shall be applied if economic allocation is used.

4.6.2.10. Allocation of reindeer

If allocation cannot be avoided by subdivision (see Chapter 4.6), allocation between meat and different recreational services from reindeer shall be made by applying economic allocation.

4.6.3. Allocation in plant production

4.6.3.1. Allocation of plant products at farm

If allocation cannot be avoided by subdivision (see Chapter 4.6), allocation between parts of plants used for human consumption and parts of plants for other uses shall be made by default applying economic allocation. The classification of outputs in Chapter 4.6.14.6.2.1 shall

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[29] Based on the PEF screening study (v 1.0, November 2015) of the meat pilot, available at https://webgate.ec.europa.eu/fpfis/wikis/pages/viewpage.action?pageId=81474527

[30] All edible parts with the same basic functionality (e.g. nutritional functionality) shall be allocated the same share of burdens. For example, the PEF method on allocation within the slaughterhouse considers fresh meat and edible offal as one edible group (Annex I: 4.5.1.5 in EC 2021). Also, the feed PEFCR refers to LEAP guidelines on feeds (FAO 2016) which states "*it is recommended not to differentiate beyond a level that exceeds basic functionality and a level that is related exclusively to consumer preferences*".

be applied. If the co-products have the same basic functionality[31], physical-based (e.g. mass, or volume, if volume is the limiting factor) allocation can be used for simplification (e.g. all edible parts for human consumption from vegetable production).

4.6.3.2. Allocation of crop rotations

In the cultivation of crop sequences, organic fertilisers such as animal manure, peat products, and compost enhance not only the growth of the crops they are applied to but also that of the following crops in the rotation. To account for the greenhouse gas emissions generated during the production and use of organic fertilisers fairly, the emissions should be allocated across all crops in the rotation.

Currently, the PEF method (EC 2021) does not consider the allocation of organic fertilisers. Yet, European Commission (EC) expert groups under Technical Advisory Board, particularly Agricultural Modelling Working Group Milestone 2 have suggested the inclusion of the allocation of organic fertilisers into the next update of the PEF method. This approach considers crop rotations and organic manure through assessing nitrogen balance, nitrogen inputs as crop residues and organic fertiliser and time of application. The suggested approach, however, considers only the emissions generated from the use of organic fertilisers.

While the current PEF method lacks guidance for accounting for organic fertilisers separately from synthetic fertilisers, PAS 2050:2012 (BSI 2012) has included an approach for allocation. According to this approach,

- Emissions which are generated in the same year that organic fertilizer is applied should be entirely attributed to the crop receiving the application.
- Emissions occurring beyond the first year after organic fertilizer application should be distributed among all crops in the crop rotation plan, proportionate to their area coverage in the application year.
- Nitrous oxide (N_2O) emissions resulting from nitrogen in green manure crop residues should be allocated across all crops in the crop rotation plan, based on their respective area coverage during the year of application.

In the PAS 2050:2012 approach, the basis for allocation arises from the crop needs, when the input benefits all crops in a multiple-crop production system. If applied input benefits only the following crop, area basis is used instead.

For this current guideline, no specific recommendation for the approach to be used for crop rotations is made. The allocation may be conducted following the PAS 2050:2012 approach.

[31] All edible parts with the same basic functionality (e.g. nutritional functionality) shall be allocated the same share of burdens. For example, the PEF method on allocation within the slaughterhouse considers fresh meat and edible offal as one edible group (Annex I: 4.5.1.5 in EC 2021). Also, the feed PEFCR refers to LEAP guidelines on feeds (FAO 2016) which states "*it is recommended not to differentiate beyond a level that exceeds basic functionality and a level that is related exclusively to consumer preferences*".

4.6.4. Allocation in biogas plant

The allocation between produced energy and digestate shall be made applying economic allocation The classification of outputs in Chapter 4.6.1 shall be applied. The CFF of the EF method (EC 2021) shall not be used.

4.6.5. Allocation within manufacturing

If allocation cannot be avoided by subdivision (see Chapter 4.6), the allocation between different co-products in manufacturing shall be made by default applying economic allocation (e.g. the allocation between soy meal and soy oil). The classification of outputs in Chapter 4.6.14.6.2.1 shall be applied. If the co-products have the same basic functionality[32], physical-based (e.g. mass or volume, if the volume is the limiting factor) allocation can be used for simplification (e.g. all edible parts for human consumption from a mill).

4.6.6. Allocation rules for electricity

[Based on Chapter B.5.8. in Annex II of EC (2021)]

A physical relationship shall be used to subdivide the electricity consumption among multiple products for each process (e.g. mass, number of pieces, volume).

In case a product is produced in different locations or sold in different countries, the electricity mix shall reflect the ratios of production or ratios of sales between EU countries/regions. To determine the ratio, a physical unit shall be used (e.g. number of pieces or kg of product). For LCA studies where such data are not available, the average EU residual consumption mix (EU+EFTA), or region-representative residual mix, shall be used.

If the consumed electricity comes from more than one electricity mix, each mix source shall be used in terms of its proportion in the total kWh consumed. For example, if a fraction of this total kWh consumed is coming from a specific supplier a supplier-specific electricity mix shall be used for this part. See below for on-site electricity use.

A specific electricity type may be allocated to one specific product in the following conditions:

(a) If the production (and related electricity consumption) of a product occurs in a separate site (building), the energy type physical related to this separated site may be used.
(b) If the production (and related electricity consumption) of a product occurs in a shared space with specific energy metering or purchase records or electricity bills, the product-specific information (measure, record, bill) may be used.

[32] All edible parts with the same basic functionality (e.g. nutritional functionality) shall be allocated the same share of burdens. For example, the PEF method on allocation within the slaughterhouse considers fresh meat and edible offal as one edible group (Annex I: 4.5.1.5 in EC 2021). Also, the feed PEFCR refers to LEAP guidelines on feeds (FAO 2016) which states "*it is recommended not to differentiate beyond a level that exceeds basic functionality and a level that is related exclusively to consumer preferences*".

(c) If all the products produced in the specific plant are supplied with a publicly available LCA study, the company wanting to make the claim shall make all LCA studies available. The allocation rule applied shall be described in the LCA study, consistently applied in all LCA studies connected to the site and verified. An example is the 100% allocation of a greener electricity mix to a specific product.

On-site electricity generation:

If on-site electricity production is equal to the site own consumption, two situations apply:

1) No contractual instruments have been sold to a third party: the own electricity mix (combined with LCI datasets) shall be modelled.
2) Contractual instruments have been sold to a third party: the 'country-specific residual grid mix, consumption mix' (combined with LCI datasets) shall be used.

If electricity is produced in excess of the amount consumed on-site within the defined system boundary and is sold to, for example, the electricity grid, this system may be seen as a multi-functional situation. The system will provide two functions (e.g. product + electricity) and the following rules shall be followed:

1) If possible, apply subdivision. Subdivision applies both to separate electricity productions or to a common electricity production where you may allocate based on electricity amounts the upstream and direct emissions to your own consumption and to the share you sell out of your company (e.g. if a company has a windmill on its production site and exports 30% of the produced electricity, emissions related to 70% of produced electricity should be accounted in the LCA study).
2) If not possible, direct substitution shall be used. The country-specific residual consumption electricity mix shall be used as substitution[33].

Subdivision is considered as not possible when upstream impacts or direct emissions are closely related to the product itself.

4.6.7. Allocation rules for distribution

Allocation of transport emissions to transported products shall be done based on physical causality, such as mass or volume. Mass-based allocation is recommended for heavy products and liquids, and volume for products with lower density than liquids.

[33] For some countries, this option is a best case rather than a worst case.

4.7. Electricity modelling

[Based on Chapter B.5.8. in Annex II of EC (2021)]

The guidelines in this chapter shall only be used for the processes where company-specific information is collected (situation 1 / Option 1 & 2 / Option 1 of the DNM).

The following electricity mix shall be used in hierarchical order:

(a) Supplier-specific electricity product shall be used if for a country there is a 100% tracking system in place, or if:

(i) available, and
(ii) the set of minimum criteria to ensure the contractual instruments are reliable is met.

This is the default option in Finland. If not available, then typically option (c) is to be used. This applies to all electricity products with a guarantee of origin, verifiable via contract or certification, whether renewable, nuclear, or fossil.

(b) The supplier-specific total electricity mix shall be used if:

(i) available, and
(ii) the set of minimum criteria to ensure the contractual instruments are reliable is met.

This option applies when suppliers do not provide several electricity products with a guarantee of origin, but only one average electricity product with a guarantee of origin.

(c) The 'country-specific residual grid mix, consumption mix' shall be used. Country-specific means the country in which the life cycle stage or activity occurs. This may be an EU country or non-EU country. The residual grid mix prevents double counting with the use of supplier-specific electricity mixes in (a) and (b).

This applies to exchange-traded electricity and when suppliers provide electricity products without a guarantee of origin.

The most up-to-date consumption mix and the greenhouse gas emission factor for Finnish 'country-specific residual grid mix, consumption mix' can be found on the website of the Finnish Energy Authority. The emission factor does not include emissions from infrastructure and fuel procurement. These and other environmental impact categories shall be assessed (for example with the help of commercial databases, such as Ecoinvent).

(d) As a last option, the average EU residual grid mix, consumption mix (EU+EFTA), or region representative residual grid mix, consumption mix, shall be used. Note: for the use stage, the consumption grid mix shall be used.

The environmental integrity of the use of supplier-specific electricity mix depends on ensuring that contractual instruments (for tracking) reliably and uniquely convey claims to consumers. Without this, the LCA study lacks the accuracy and consistency necessary to drive product/ corporate electricity procurement decisions and accurate consumer (buyer of electricity) claims. Therefore, a set of minimum criteria that relate to the integrity of the contractual instruments as reliable conveyers of environmental footprint information has been identified. They represent the minimum features necessary to use supplier-specific mix within LCA studies.

Set of minimum criteria to ensure contractual instruments from suppliers

A supplier-specific electricity product/ mix may only be used if the user of this guidance ensures that the contractual instrument meets the criteria specified below. If contractual instruments do not meet the criteria, then country-specific residual electricity consumption-mix shall be used in the modelling.

A contractual instrument used for electricity modelling shall:

Criterion 1 – Convey attributes

1) Convey the energy type mix associated with the unit of electricity produced.
2) The energy type mix shall be calculated based on delivered electricity, incorporating certificates sourced and retired (obtained or acquired or withdrawn) on behalf of its customers. Electricity from facilities for which the attributes have been sold off (via contracts or certificates) shall be characterized as having the environmental attributes of the country residual consumption mix where the facility is located.

Criterion 2 – Be a unique claim

1) Be the only instruments that carry the environmental attribute claim associated with that quantity of electricity generated.
2) Be tracked and redeemed, retired, or cancelled by or on behalf of the company (e.g. by an audit of contracts, third party certification, or may be handled automatically through other disclosure registries, systems, or mechanisms).

Criterion 3 – Be as close as possible to the period to which the contractual instrument is applied

Modelling 'country-specific residual grid mix, consumption mix':

Datasets for residual grid mix, consumption mix, per energy type, per country and per voltage are made available by data providers.

If no suitable dataset is available, the following approach should be used:

Determine the country consumption mix (e.g. X% of MWh produced with hydro energy, Y% of MWh produced with coal power plant) and combine them with LCI datasets per energy type and country/region (e.g. LCI dataset for the production of 1MWh hydro energy in Switzerland):

Activity data related to non-EU country consumption mix per detailed energy type shall be determined based on:

1) Domestic production mix per production technologies;
2) Import quantity and from which neighbouring countries;
3) Transmission losses;

4) Distribution losses;
5) Type of fuel supply (share of resources used, by import and / or domestic supply).

These data may be found in the publications of the International Energy Agency (IEA (www.iea.org).

Available LCI datasets per fuel technologies. The LCI datasets available are generally specific to a country or a region in terms of:

1) fuel supply (share of resources used, by import and/ or domestic supply);
2) energy carrier properties (e.g. element and energy contents);
3) technology standards of power plants regarding efficiency, firing technology, flue-gas desulphurisation, NOx removal and de-dusting.

4.8. Climate change modelling

4.8.1. Guidelines for climate change modelling

[Based on Chapter B.5.9. in Annex II and Chapter 4.4.10. in Annex I of EC (2021)]

The impact category 'climate change' shall be modelled considering three sub-categories:

1. **Climate change – fossil:** This category covers GHG emissions to any media originating from the oxidation and/or reduction of fossil fuels by means of their transformation or degradation (e.g. combustion, digestion, landfilling, etc.). This impact category includes emissions from peat (used as a fuel) and calcination, and uptakes due to carbonation. emission flows ending with '(fossil)' (e.g., 'carbon dioxide (fossil)' and 'methane (fossil)') shall be used, if available. Soil N_2O emission from land use and land use change on mineral and organic soils shall be included in this sub-category (calculated in Chapter 5.2.1)[34].

2. **Climate change – biogenic:** This sub-category covers carbon emissions to air (CO_2, CO and CH_4) originating from the oxidation and/or reduction of biomass by means of its transformation or degradation (e.g. combustion, digestion, composting, landfilling) and CO_2 uptake from the atmosphere through photosynthesis during biomass growth – i.e. corresponding to the carbon content of products and biofuels. Carbon exchanges from native forests[35] shall be modelled under the sub-category "Climate change – land use and land use change" (incl. connected soil emissions, derived products, and residues). The emission flows ending with '(biogenic)' shall be used.
A simplified modelling approach shall be used when modelling foreground emissions. Only the emission 'methane (biogenic)' is modelled (e.g., from enteric metabolism and manure management), while no further biogenic emissions and uptakes from the atmosphere are included. Methane emissions from organic soils are included in

[34] N_2O is not a biogenic emission (i.e. not containing carbon), and therefore, it is considered in the category "climate change – fossil"
[35] Native forests – represents native or long-term, non-degraded forests. Definition adapted from Table 8 in the Annex of Commission Decision C(2010)3751 on guidelines for the calculation of land carbon stocks for the purpose of Annex V of Directive 2009/28/EC.

"Climate change – land use and lands use change". If methane emissions can be both fossil or biogenic, the release of biogenic methane shall be modelled first and then the remaining fossil methane.

3. **Climate change – land use and land use change (LULUC):** This sub-category accounts for carbon uptakes and emissions (CO_2, CO and CH_4) originating from carbon stock changes caused by land use change and land use (LULUC).

   This sub-category includes biogenic carbon exchanges from deforestation, road construction or other soil activities (including soil carbon emissions). For native forests, all related net CO_2 emissions are included and modelled under this sub-category (including connected soil emissions, products derived from native forests and residues), while their net CO_2 uptake is excluded. The emission flows ending with '(land use change)' shall be used. All LULUC emissions from the land with land use change (LUC) in the past 20 years and land without LUC in the past 20 years shall be included.

   Here, we focus on land use and land use changes on cropland[36]. The category 'land converted to cropland´ refers to land converted from other land use categories[37] to cropland within the past 20 years (IPCC 2006a). For land converted to cropland, the carbon stocks included are soil organic carbon (SOC), living biomass, and dead organic matter, related to which, all carbon emissions and removals shall be modelled following PAS 2050:2011 (BSI 2011): 'Large emissions of GHGs can result as a consequence of land use change. Removals as a direct result of land use change (and not as a result of long-term management practices) do not usually occur, although it is recognized that this could happen in specific circumstances. Examples of direct land use change are the conversion of land used for growing crops to industrial use or the conversion from forestland to cropland. All forms of land use change that result in emissions or removals are to be included. Indirect land use change refers to such conversions of land use as a consequence of changes in land use elsewhere. While GHG emissions also arise from indirect land use change, the methods and data requirements for calculating these emissions are not fully developed. Therefore, the assessment of emissions arising from indirect land use change is not included. Indirect land use change may be included under additional environmental information.
   The GHG emissions and removals arising from direct land use change shall be assessed for any input to the life cycle of a product originating from that land and shall be included in the assessment of GHG emissions. [...] The assessment of the impact of land use change shall include all direct land use change occurring not more than 20 years, or a single harvest period, prior to undertaking the assessment (whichever is the longer).'

   The method for the calculation of emissions from land converted to cropland is described in Chapter 4.8.2.

[36] In Finland: Only data regarding activities on land use category cropland are included, activities on grassland are excluded following the definition in the National GHG inventory report ("Grassland includes areas of extensive grass, ditches associated with agricultural land, areas of bioenergy plants and abandoned arable land. In this context, abandoned arable land refers to fields that are no longer used for agricultural production and where natural reforestation is possible or is already taking place").
[37] Forest land, wetland, grassland, settlement, or other land (following IPCC categorisation).

The category ‘cropland remaining cropland´ refers to cropland that has *not* gone through direct land use changes within the past 20 years (IPCC 2006a). For cropland remaining cropland, the carbon stocks included are SOC and living biomass. The included emissions are CH_4 emissions from rice fields (the method to be used is IPCC 2006a), CO_2 from mineral and organic soils, and CH_4 from organic soils (method to be used presented in Chapter 4.8.2.).

Net soil carbon uptake (i.e., soil carbon sequestration) shall be excluded from the results, and it may only be included in the LCA study as additional environmental information and if a proof is provided (see Chapter 3.8).
The sum of the three sub-categories shall be reported. In addition, all three sub-categories shall be reported separately.

4.8.2. Method for “Climate change – land use and land use change (LULUC)”

In this chapter, a method is described to estimate LULUC emission (CO_2 and CH_4) from cropland, in Finland and other countries. The method is described in more detail in Annex 1 of this guidance and in a scientific article (Lehtilä et al. 2024b).

The activity data that shall be used in the calculation:

- Country of origin
- Land use history – share of land gone through LUC in the past 20 years
- Soil types – share of organic[38] and mineral soils

The country of origin shall be based on primary data. If primary data is not available, the country of origin shall be estimated as a weighted sum of countries where the crop is grown. The land use history and soil types shall be based on primary data. If such data is not available, secondary data representing the production area (e.g., country or province averages) shall be used (See Chapter 4.4 for more details).

The LULUC emission factors (kg CO_2 eq./ha) are based on the National GHG Inventories for the countries that are involved in the Kyoto Protocol. The involvement may be checked from https://unfccc.int/ghg-inventories-annex-i-parties/2023 (or a more recent year). For the countries that do not have a National GHG Inventory, the instructions are given separately.

The method for the calculation of the LULUC emissions:

A) When the origin is in Finland

The calculation of LULUC emissions shall be based on the primary data of land use history and soil types representing the production chain. When this data is available, the calculation is done with the equations presented in Annex 1 (LULUC modelling formulas and factors).

[38] Organic soils are determined to be soils containing > 20% organic carbon (corresponds to >35% organic matter) in the topsoil layer of 20 cm (IPCC 2014). See Chapter 5.2.1 for more details.

If the primary data about land use history and soil types is not available, but the province or provinces of the origin are known, the default land use history and soil types of the province(s) shall be used as secondary data. The default cropland LULUC emissions for the provinces of Finland are given in Annex 1 (LULUC modelling formulas and factors; Table 1.1). In case of having multiple provinces of origin, a weighted average of the province default LULUC emissions shall be used.

The default LULUC emission values presented in Annex 1 (LULUC modelling formulas and factors; Table 1.1) are based on The National GHG Inventory document (NID) (Statistics Finland 2024). More recent default LULUC emissions may be derived as instructed in Annex 1 (LULUC modelling formulas and factors).

B) When the origin is other country than Finland and has a National GHG Inventory

The calculation of LULUC emissions shall be based on the primary data of land use history and soil types representing the production chain. When this data is available, the calculation is done with the formulas presented in Annex 1 (LULUC modelling formulas and factors).

If the primary data about land use history and soil types is not available, the default land use history and soil types of the origin country or countries shall be used as secondary data. If the country of origin is not known, but the origin is known to be within the European Union area, the default land use history and soil types of the European Union shall be used. The method for deriving the default land use history and soil types as well as the formulas for the LULUC emission calculation are presented in Annex 1 (LULUC modelling formulas and factors).

In case of having multiple countries of origin, a weighted average of the calculated LULUC emissions for each of the origin countries shall be used.

C) When the origin country does not have a National GHG Inventory

The calculation of LULUC emissions shall be based on the primary data of land use history and soil types representing the production chain. If such data is not available, secondary data representing the production area (e.g., country or province averages) shall be used[39] (See Chapter 4.4 for more details regarding data quality).

The emission factors for cropland LULUC emissions are derived as follows:

- The LULUC emissions from land converted to cropland (with LUC in the past 20 years) shall be calculated according to PAS 2050–1 2012 (BSI 2011; Chapter 4.8.1. in BSI (2011)) including carbon stock changes in SOC (mineral soils) and living biomass.
- LULUC emissions from cropland remaining cropland (no LUC in the past 20 years) shall be calculated with the IPCC (2006a) Tier 1 method including carbon stock changes in SOC (mineral soils) and living biomass. Organic soil emissions (CO_2 and CH_4) from both land converted to cropland and land remaining cropland shall be calculated with the IPCC (2014) emission factors.

[39] Note: the share of organic soils for countries without a National GHG Inventory may be estimated from FAO statistics (FAO 2024a, 2024b)

4.9. Offsets

[Based on Chapter 4.4.11. in Annex I of EC (2021)]

The term 'offset' is frequently used to refer to third-party GHG mitigation activities, e.g. regulated schemes that are part of the Kyoto Protocol (the former clean-development mechanism; joint implementation), new mechanisms discussed in the context of negotiations article 6 of the Paris agreement emissions trading schemes, or voluntary schemes. Offsets are GHG reductions used to compensate for (i.e. offset) GHG emissions elsewhere, for example to meet a voluntary or mandatory GHG target or cap. Offsets are calculated relative to a baseline that represents a hypothetical scenario for what emissions would have been in the absence of the mitigation project that generates the offsets. Examples are carbon offsetting by the clean development mechanism, carbon credits, and other system-external offsets.

Offsets shall not be included in the impact assessment of an LCA study but may be reported separately as additional environmental information.

4.10. Water scarcity footprint modelling

The AWARE method shall be used for the water scarcity impact category. For life cycle inventory, elementary water flows should follow the definition for water consumption by ISO 14046 (ISO 2014). It refers to water removed from, but not returned to the same drainage basin.

A special focus on life cycle inventory for water scarcity footprint impact shall be put on the spatial nature of water consumption data. Data should be spatial. In addition to the volume of water, information on the origin country (or watershed and month in case watershed and month level characterization factors are to be used, see Chapter 3.7) is required for the most important life cycle stages (See Chapter 4.4).

4.11. Freshwater and marine eutrophication modelling

ReCiPe methodology shall be used (Huijbregts et al. 2016; based on the CARMEN model). For freshwater eutrophication impact assessment data on P, PO_4^{-3} and other P compounds emitted to freshwater shall be compiled. Data should be spatial and collected at the country level. For agricultural fields, the phosphorous emissions shall be calculated from phosphorous applications on the field. In addition to fertilizer application, other relevant sources of P and P compounds shall be included. Processes mandatory to be included cover: animal farm and manure management processes and wastewater and wastewater treatment.

ReCiPe2016 methodology provides global characterization factors for P, PO_4^{-3}, phosphoric acid, and phosphorus pentoxide emitted to the freshwater and P, PO_4^{-3}, phosphoric acid, and phosphorus pentoxide emitted to the soil, to be used when phosphorus is applied to the field as a fertilizer. The characterization factor for the ocean is zero. In addition, there are national characterization factors for P and PO_4^{-3}. National characterization factors for P and PO_4^{-3}

emitted to freshwater or soil should be used[40]. In case no data exists on the geographical origin of the emission, the latest version of the global factors may be used.

For marine eutrophication impact assessment data on N and N compounds emitted to freshwater, marine water and soil shall be compiled. For agricultural fields, the nitrogen emissions shall be calculated from nitrogen applications on the field. In addition to fertilizer application, other relevant sources of N and N compounds shall be included. Processes mandatory to be included cover: animal farm and manure management processes and wastewater and wastewater treatment. In terms of marine eutrophication, there is no need to spatially differentiate inventory data.

Note, that marine eutrophication here refers to eutrophication in the ocean, not for example in the Baltic Sea[41].

4.12. Modelling of end of life

[Based on Chapter B.5.10. in Annex II of EC (2021)]

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 products. Overall, this should be modelled and reported at the life cycle stage where the waste occurs. This chapter provides rules on how to model the end of life of products.

The environmental burden of end of life or waste treatment of any output considered as waste, i.e. which has no economic nor utilization value (see Chapter 4.6 and 4.6.1), shall be included in the LCA study. If the producer of the waste is responsible (pays) the transportation to the end of life treatment, also the emissions of transport are included for the product under study.

In the PEF method (EC 2021), the end of life is modelled through the circular footprint formula (CFF). This guidance deviates from the PEF method in this regard, and no CFF shall be used in LCA studies conducted according to this guidance.

[40] https://www.rivm.nl/en/documenten/recipe2016country-factorsv1120171221 or the most recent Recipe document

[41] Luke is working on new models to estimate Baltic Sea eutrophication and instructions will hopefully be added to the future versions of this guidance.

5. Life cycle stages

5.1. Raw material acquisition and pre-processing

[Based on Chapter B.6. in Annex II of EC (2021)]

This life cycle stage shall include at least (but is not limited to) the production of inputs required in agriculture and animal production (e.g. fertilizers, lime, energy inputs), the production of other than agricultural inputs to manufacturing (e.g. energy inputs, packaging materials) and pre-processing of inputs if required.

5.2. Agricultural modelling

[Based on Chapter B.6.2. in Annex II of EC (2021)]

In the following chapters, the modelling of crop production and animal production emissions is described. Part of the GHG emissions directly related to agriculture are covered in Chapter 4.8.2. The summary (Fig. 2) shows the chapters in which the different emission calculation methods are described.

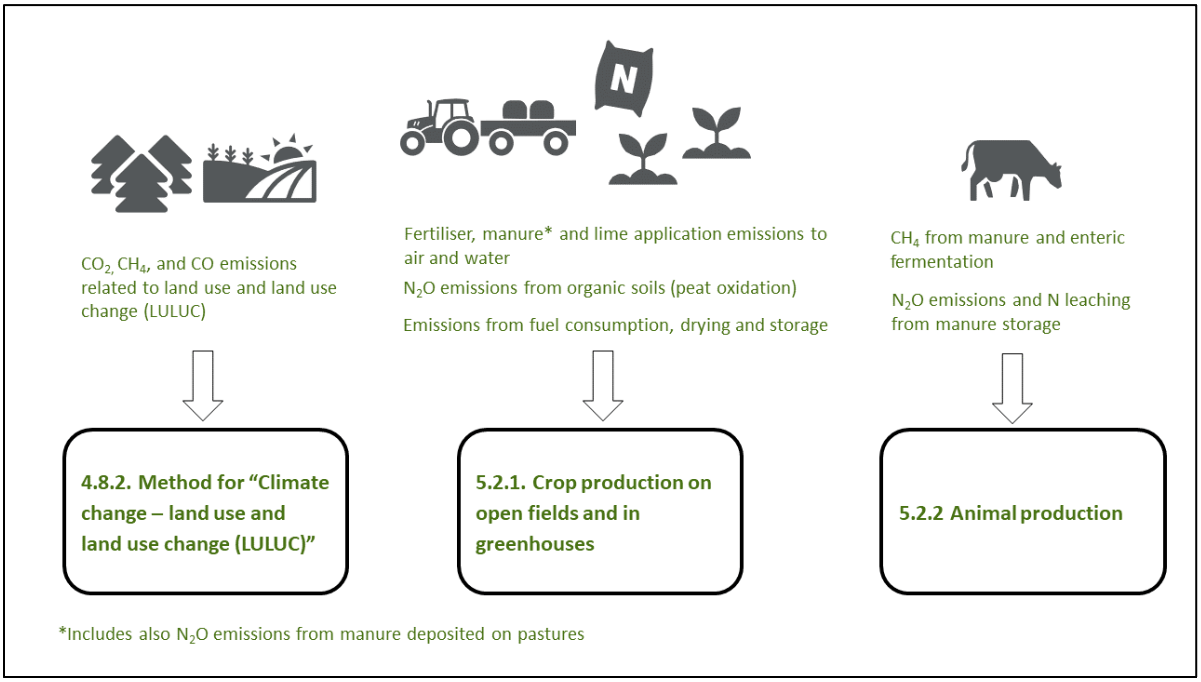

Figure 2. Summary of agricultural emission calculation methods described in different chapters of this guidance.

5.2.1. Crop production on open fields and in greenhouses

[Based on Chapters B.6.2. of Annex II and 4.4.1.3. – 4.4.1.6. of Annex I of EC (2021)]

The following activities regarding crop production shall be included[42]:

a) Input of seed material (kg/ha)
b) Input of peat to soil (kg/ha + C/N ratio)
c) Input of organic fertilizer (kg N/ha, kg P/ha, kg K/ha)
d) Input of mineral fertilizer (kg N/ha, kg P/ha, kg K/ha) and fertilizer type
e) Input of lime (kg $CaCO_3$/ha, type)
f) Field operations and machine use (hours, type)
g) Input N from crop residues that stay on the field or are burned (kg residue + N content/ha)
h) Crop yield (kg/ha)
i) Drying and storage of products
j) Soil type (share of field area: mineral soil % and organic soil %)

Organic soils are determined to be soils containing > 20% organic carbon (corresponds to >35% organic matter) in the topsoil layer of 20 cm (IPCC 2014). If the exact organic matter contents (%) of soils are available[43], the soils shall be classified into mineral and organic soils based on that. In Finland, soil data from farms often includes only organic matter content classification without exact percentages. When using this kind of data, soils in the categories mull soil (*multamaa*) and peat soil (*turvemaa*) shall be considered organic soil, and the rest as mineral soil[44].

Cultivation data shall be collected over a period of time sufficient to provide an average assessment of the life cycle inventory associated with the inputs and outputs of cultivation that will offset fluctuations due to seasonal differences:

a) For annual crops, an assessment period of at least three years shall be used (to level out differences in crop yields related to fluctuations in growing conditions over the years such as climate, pests, and diseases, etc.). Where data covering a three-year period is not available i.e. due to starting up a new production system (e.g. new greenhouse, newly cleared land, shift to another crop), the assessment may be conducted over a shorter period, but shall be not less than 1 year. Crops/plants grown in greenhouses shall be considered as annual crops/plants unless the cultivation cycle is significantly shorter than a year and another crop is cultivated consecutively within that year. Tomatoes, peppers, and other crops which

[42] In Finland: Only data regarding activities on land use category *cropland* are included, activities on *grassland* are excluded following the definition in the National GHG inventory report ("Grassland includes areas of extensive grass, ditches associated with agricultural land, areas of bioenergy plants and abandoned arable land. In this context, abandoned arable land refers to fields that are no longer used for agricultural production and where natural reforestation is possible or is already taking place").
[43] For example, when detailed soil analyses are conducted on contract farms.
[44] Soil organic matter content in the category "multamaa" varies from 20 to 40% according to Finnish classification, which is differing from IPCC classification. However, when the precise organic matter content is not known, all "multamaa" soils are considered organic soils due to a lack of data.

are cultivated and harvested over a longer period through the year are considered as annual crops.

b) For perennial plants (including entire plants and edible portions of perennial plants) a steady state situation (i.e. where all development stages are proportionally represented in the studied time period) shall be assumed and a three-year period shall be used to estimate the inputs and outputs[45].

c) Where the different stages in the cultivation cycle are known to be disproportional, a correction shall be made by adjusting the crop areas allocated to different development stages in proportion to the crop areas expected in a theoretical steady state. The application of such correction shall be justified and recorded. The life cycle inventory of perennial plants and crops shall not be undertaken until the production system actually yields output.

d) For crops that are grown and harvested in less than one year (e.g. lettuce produced in 2 to 4 months) data shall be gathered in relation to the specific time period for production of a single crop, from at least three recent consecutive cycles. Averaging over three years may best be done by first gathering annual data and calculating the life cycle inventory per year and then determining the three years average.

Crop production modelling includes emission modelling from N- and P-fertilisers. These emissions are to be used in Climate change, fossil; Freshwater eutrophication; and Marine eutrophication assessment. In addition, crop production modelling includes N_2O emissions from soil and is to be used in Climate change - fossil. Carbon dioxide emissions derived from drained organic soils (i.e., peat soils) shall be included in the category Climate change – Land use and Land use change and modelled as described in Chapters 4.8.1-4.8.2.

Fertiliser (and manure) emissions shall be differentiated per fertilizer type and cover as a minimum:

1) NH_3 and NO_x, to air (from N-fertiliser application[46])
2) N_2O, to air (direct and indirect) (from N-fertiliser application)
3) CO_2, to air (from lime, urea, and urea-compounds application)
4) NO_3, to water unspecified (leaching from N-fertiliser application)
5) PO_4, to water unspecified or freshwater (leaching and run-off of soluble phosphate from P-fertiliser application)
6) P, to water unspecified or freshwater (soil particles containing phosphorous, from P-fertiliser application).

The formulas and factors needed to calculate the greenhouse gas emissions from field crop production are presented in Annex 2 (Crop modelling formulas and factors).

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[45] The underlying assumption in the cradle-to-gate life cycle inventory assessment of horticultural products is that the inputs and outputs of the cultivation are in a 'steady state', which means that all development stages of perennial crops (with different quantities of inputs and outputs) shall be proportionally represented in the period of cultivation that is studied. This approach gives the advantage that inputs and outputs of a relatively short period can be used for the calculation of the cradle-to-gate life cycle inventory from the perennial crop product. Studying all development stages of a horticultural perennial crop can have a lifespan of 30 years or more (e.g. in the case of fruit and nut trees).

[46] Here, N fertiliser refers to both mineral and organic N fertilisers, including manure.

If toxicity impact categories are assessed, then pesticide emissions shall be modelled as specific active ingredients. The USEtox life-cycle impact assessment method has a built-in multimedia fate model which simulates the fate of the pesticides starting from the different emission compartments. Therefore, the ratio of default emission fractions to environmental emission compartments is needed in the LCI modelling. The pesticides applied to the field shall be modelled as 90% emitted to the agricultural soil compartment, 9% emitted to air and 1% emitted to water (based on expert judgement due to current limitations). More specific data may be used if available.

If toxicity impact categories are assessed, then heavy metal emissions from field inputs shall be modelled as emission to soil and/or leaching or erosion to water. The inventory to water shall specify the oxidation state of the metal (e.g., Cr^{+3}, Cr^{+6}). As crops assimilate part of the heavy metal emissions during their cultivation clarification is needed on how to model crops that act as a sink. Two different modelling approaches are allowed:

(a) The final fate of the heavy metal elementary flows is not further considered within the system boundary: the inventory does not account for the final emissions of the heavy metals and therefore shall not account for the uptake of heavy metals by the crop. For example, heavy metals in agricultural crops grown for human consumption end up in the plant. Within the context of this guidance, human consumption is not modelled, the final fate is not further modelled and the plant acts as a heavy metal sink. Therefore, the uptake of heavy metals by the crop shall not be modelled.

(b) The final fate (emission compartment) of the heavy metal elementary flows is considered within the system boundary: the inventory does account for the final emissions (release) of the heavy metals in the environment and therefore shall also account for the uptake of heavy metals by the crop. For example, heavy metals in crops grown for feed will mainly end up in the animal digestion and used as manure back on the field where the metals are released in the environment and their impacts are captured by the impact assessment methods. Therefore, the inventory of the agricultural stage shall account for the uptake of heavy metals by the crop. A limited amount ends up in the animal, which may be neglected for simplification.

5.2.2. Animal production

In this chapter, modelling of emissions from animal metabolism and manure storage[47] (shortened as animal emissions) is instructed. Methods to model emissions from manure application on fields and excretion of manure in pasture are described in the Chapter 5.2.1[48]

Animals included in this chapter are cattle, swine, sheep, poultry, reindeer, and farmed fish.

The animal emissions may be modelled on production unit (=farm or part of the farm) level including all age groups of animals that are included in the production chain. In this approach, animals brought to the farm from another farm shall be considered as input and their

[47] For manure CH_4, also manure deposition on pastures is included. For manure N_2O, the emissions from manure application on fields and deposition on pastures are included in Chapter 5.2.1. See more instructions in Annex 2 and 3.

[48] Except for fish farming. For fish farming, all manure-related emissions are calculated with methods described in Chapter 5.2.2.

emissions during their lifetime shall be included in the calculation. Animal emissions shall be modelled separately for all the production units included in the production chain. The same procedure shall be followed if sampling is used (see Chapter 4.5). Thus, production units shall not be aggregated when modelling animal emissions.

Instead of production unit level, also other approaches may be utilised (e.g., aggregating emissions throughout the lifetime of a single animal).

Primary data used in the modelling shall be averaged over a minimum of three years.

The suggested methods for animal modelling (excluding fish farming) are presented in Table 17. Whenever possible, the methods used in the National GHG inventory of the product origin country should be used. For Finnish animal products, specific modelling methods are given. Detailed modelling guidance for Finnish animal products is in Annex 3.

Table 17. Methods to be used for animal modelling (excluding fish farming), separately for Finland and other countries. The National GHG inventory methods of Finland refer to Statistics Finland (2024).

	Finland	Other countries[49]
Enteric CH_4	Cattle: National GHG inventory method (Tier 2) Country-specific method for gross energy intake (GE). Otherwise, the method is the same as the IPCC (2006b) method. Swine, sheep, and reindeer: National GHG inventory method (Tier 3) Swine: Country-specific method. Sheep and reindeer: Country-specific method to calculate GE. Otherwise, the method is the same as the IPCC (2006b) method. Poultry: not applicable	IPCC (2006b) Tier 2 Based on GE and emission factors (Ym) per animal type. Emission = GE x Ym. or IPCC (2006b) Tier 3 Total dry matter intake (DMI) and digestibility of feed are added to the equation used in Tier 2 or utilize alternative estimation methods based on country-specific methodology.
Manure CH_4	Cattle and sheep: National GHG inventory method (Tier 2) Detailed information about the manure characteristics (calculated based on gross energy intake, and digestibility of the feed) and manure management practices (default values). Swine, poultry, and reindeer: IPCC 2006b (Tier 2) Requires information about VS excretion (default values) and manure management practices (default values).	IPCC (2006b) Tier 2 Detailed information about the manure characteristics (calculated based on gross energy intake, digestibility of the feed) or VS excretion default values, and manure management practices (default values). or IPCC (2006b) Tier 3 Country-specific methodologies and emission factors are used.
N excretion	Cattle, sheep, swine, poultry, and reindeer: IPCC 2006b (Tier 2) N intake is calculated from primary data. N retention is estimated from animal group-specific default values (IPCC 2006b). Annual excretion rate: daily N intake x (1 – a fraction of N retained by the animal) x 365.	IPCC (2006b) Tier 1 Annual excretion rate: default N excretion rate x typical animal mass for livestock category x 365 or IPCC (2006b) Tier 2 Annual excretion rate: daily N intake x (1 – a fraction of N retained by the animal) x 365
Manure storage: direct N_2O	Cattle, sheep, swine, poultry, and reindeer: IPCC 2006b (Tier 2) N excretion multiplied with IPCC (2006b) default emission factors.	IPCC (2006b) Tier 1 The total amount of nitrogen excretion in each type of manure management system is multiplied by an emissions factor for that type of manure management system (default values used). or IPCC (2006b) Tier 2 or 3 Tier 2: As Tier 1 but country-specific data for some or all variables are used. Tier 3: Utilizes alternative estimation methods based on country-specific methodology

[49] Adapted from Dairy PEFCR (EDA 2018)

	Finland	Other countries[49]
Manure storage: indirect N_2O – volatilization	Cattle, sheep, swine, poultry, and reindeer: IPCC 2006b (Tier 1) Nitrogen volatilization (N excretion x $FRAC_{GasMS}$) multiplied by a default emission factor.	IPCC (2006b) Tier 1 Nitrogen volatilization multiplied by a default emission factor. or IPCC (2006b) Tier 2 or 3 Tier 2: As tier 1 but country-specific emission factor used. Tier 3: Utilizes alternative estimation methods based on country-specific methodology
Manure storage: indirect N_2O – leaching/runoff	Cattle, sheep, swine, poultry, and reindeer: National GHG inventory method (Tier 2) Nitrogen leaching (N excretion x $FRAC_{leachMS}$) multiplied by a default emission factor. Only leaching from dry lots is included. The other systems are considered liquid-tight following the Finnish environmental legislation (Statistics Finland 2024).	IPCC (2006b) Tier 1 Nitrogen leaching multiplied by a default emission factor. or IPCC (2006b) Tier 2 or 3 Tier 2: As Tier 1 but country-specific emission factor used. Tier 3: Utilizes alternative estimation methods based on country-specific methodology
Manure storage: N leaching/runoff	Cattle, sheep, swine, poultry, and reindeer: National GHG inventory method (Tier 2) Nitrogen leaching (N excretion x $FRAC_{leach}$). Only leaching from dry lots is included. The other systems are considered liquid-tight following the Finnish environmental legislation (Statistics Finland 2024).	IPCC (2006b) Tier 1 Nitrogen leaching (N excretion x $FRAC_{leach}$).

For fish farming, N_2O emissions to air and N and P emissions to water shall be modelled by using calculation formulas and factors found in Annex 3. The nutrients, which are omitted with the fish material from water systems by fishing can be calculated and announced as negative emissions. The phosphorus and nitrogen contents of different fish species can be found from Appendix 3 of Mäkinen (2008).

5.2.3. Peat for bedding material and horticultural use

Modelling peat used as bedding material in animal production and horticultural peat used in greenhouse production shall include:

- LULUC emissions (CO_2 and CH_4) from the peat extraction site,
- Organic soil N_2O emissions from the peat extraction site,
- GHG emissions from manufacturing of the bedding material/horticulture peat, and
- CO_2 emitted from the peat material after use.

CO_2, CH_4 and N_2O emissions from the peat extraction site should be modelled applying the factors provided in the National GHG Inventory Documents (NID) of the production country, if available. For Finland, emission factors for CO_2, CH_4 and N_2O provided in Tables 6.7-2 and 6.10-3 in the most recent NID should be used.

Carbon will be emitted from the used peat material during the next decades as the peat decomposes but the emission shall be included as emitted immediately after use and shall be considered as fossil CO_2. A default density (90 g/l or more recent) for horticultural peat provided in NID shall be used as a default density for peat bedding material and a default carbon fraction (0.045 t C/m^3 or more recent) for horticultural peat provided in NID shall be used as a default carbon fraction (Statistics Finland 2024). Both values are given in the NID report in "Off-site emissions from horticultural peat" section. In NID, horticultural peat refers to all non-energy peat products.

5.3. Manufacturing

This life cycle stage shall include at least (but is not limited to) the manufacturing of the studied product, transport of inputs of manufacturing, and packaging operations. The user of this guidance shall indicate the amount and type of materials used.

5.4. Distribution stage

[Based on Zampori & Pant (2018) and Chapter B.6.4. in Annex II of EC (2021)]

Products are distributed to users and may be stored at various points along the supply chain. The distribution stage shall include transport from the factory gate to the warehouse/retail, storage at the warehouse/retail and transport from the warehouse/retail to the consumer's home. Examples of processes to be included: 1) energy inputs for warehouse lighting and heating; 2) use of refrigerants in warehouses and transport vehicles; 3) fuel use by vehicles; 4) roads and trucks. Waste from products used during distribution and storage shall be included in the modelling according to Chapter 4.12, and the results taken into consideration during the distribution stage. Default loss rates per type of product during distribution and at the consumer are provided in Annex 6 of this guidance, and shall be used if no specific information is available. Allocation rules on energy consumption at storage are presented in Chapter 4.6.6. For transport, see Chapter 5.4.

The following parameters shall be considered when modelling transport activities. (1) Transport type: the type of transport, e.g. by land (truck, rail, pipe), water (boat, ferry, barge), or air (airplane). (2) Vehicle type: the type of vehicle by transport type. (3) Loading rate (=utilization ratio).[50] (4) Number of empty returns: the number of empty returns (i.e. the ratio of the distance travelled to collect the next load after unloading the product to the distance travelled to transport the product), when applicable and relevant, shall be considered. The kilometers travelled by the empty vehicle shall be allocated to the product. In default transport datasets this is often already considered in the default utilization ratio. (5) Transport distance: transport distances shall be documented, applying average transport distances specific to the context being considered.

Transport from factory to final client (including consumer transport) shall be modelled within this life cycle stage. The final client is defined as the purchaser of a food product. The system boundaries shall include the following transport activities: transportation of the raw material, packaging materials and other raw materials from primary production to the processing plant; transportation from final production or storage site to distribution centre, retailer, and consumer; as well as collection and transport of product and packaging materials to recycling or end of life treatment facilities. Also, the production of fuel, transport infrastructure and additional resources and tools needed for logistic operations such as cranes and transporters shall be included, unless they may be excluded based on the cut-off criteria.

In case supply-chain-specific information is available for one or several transport parameters, they may be applied following the Data Needs Matrix (Chapter 4.4.4).

[50] Environmental impacts are directly linked to the actual loading rate, which therefore shall be considered. The loading rate affects the vehicle's fuel consumption.

The waste of products during distribution and retail shall be included in the modelling.

Transport distances for waste collection and treatment should be collected.

Transport emissions shall be reported as tkm (tonne*km) expressing the environmental impact for 1 tonne of product that drives 1km in a transport vehicle with a certain load. If the load is mass-limited, the default utilisation ratio of 64% (including empty return trips) shall be used. However, if the load is volume-limited and the full volume is used, the company-specific utilisation ratio calculated as the kg real load/kg payload of the dataset shall be used. For reusable packaging, the return transport shall be modelled separately.

In the case of van transport (often related to home delivery products), the volume is the limiting factor, and the van is often half empty. In these cases, a default utilisation ratio of 50% shall be used.

In the case that no dataset of lorry is available a lorry of <7.5t shall be used as an approximation, with a utilisation ratio of 20% as a lorry of <7.5t with a payload of 3.3t and a utilisation ratio of 20% comes to the same load as a van with a payload of 1.2t and utilisation ratio of 50%. A lorry of <7.5 t with a payload of 3.3 t and a utilization ratio of 20% has the same load as a van with a payload of 1.2 t and a utilization ratio of 50%.

Consumer transport (typically by passenger car) is modelled in the transport LCA datasets per km. The allocation shall be based on volume. The default total volume to be considered for consumer transport is 0.2 m^3, corresponding to around 1/3 of a passenger car trunk of 0.6 m^3. The product volume shall be used to allocate the transport burdens over the product transported. In case of deliveries to consumers by retail, manufacturer or others, frozen or cooled products shall be transported by default in freezers or coolers.

The default transport distances to be used for the transport of raw materials from suppliers to the processing plant are presented in Table 18. If the producer's country is known, the adequate distance for ship and airplane should be determined using http://www.searates.com/services/routes-explorer or https://co2.myclimate.org/en/flight_calculators/new. If the location of the supplier is unknown, the transport shall be modelled as the supplier was located outside Europe. Default transport distances to be used for the transport from the processing plant to the final client are presented in Table 19. In addition, the following default values for the transport to end of life treatment may be used if no better data is available:

- Consumer transport from home to sorting place: 1 km by passenger car;
- Transport from collection place to methanisation: 100 km by truck (>32 t, EURO 4)
- Transport from collection place to composting: 30 km by truck (lorry <7.5t, EURO 3)

If the producer's country (origin) is known, the adequate distance for ship and airplane transportations should be determined using specific calculators.

In case it is not known whether the supplier is located within or outside Europe, transport shall be modelled as if the supplier was located outside of Europe.

Table 18. Default transport distances to be used for the transport of raw materials from suppliers to the processing plant provided by European Commission (2018) and Zampori & Pant (2019)

Transport vehicle	Transport within Europe			Transports to Europe from other areas
	Packaging materials transported from manufacturing plants to filler plants	Transport of empty bottles	Other products from supplier to factory	
Truck (>32 t, EURO 4)	230 km	350 km	130 km	1000 km
Freight train (average)	280 km	39 km	240 km	-
Barge ship	360 km	87 km	270 km	18 000 km
Cargo plane	-	-	-	10 000 km

Table 19. Default transport distances to be used for the transport from processing plant to the final client provided by European Commission (2018) and Zampori & Pant (2019)

Supply chain type	Transport vehicle	Transport to retail or distribution center, or directly to the final client	Transport from distribution center to final client	Transport from retail to final client
Local supply chain	Truck >32 t, EURO 4	1200 km		
	Van, lorry <7.5t		250 km	5%, 5 km, round trip
	Average passenger car			62%, 5 km
	No impact modelled			33%
Intracontinental supply chain	Truck >32 t, EURO 4	3500 km		
International supply chain	Truck >32 t, EURO 4	1000 km		
	Transoceanic container ship	18 000 km		

5.5. Use stage

[Based on Chapter 4.2.4 in Annex I and Chapter B.6.5. in Annex II of EC (2021)]

The use stage describes how the product is expected to be used by the end user (e.g. the consumer). This stage starts the moment the end user uses the product until it leaves its place of use and enters the end of life stage (e.g., recycling or final treatment).

The use stage includes all activities and products that are needed for proper use of the product (i.e. to ensure it performs its original function throughout its lifetime). Waste generated by using the product, such as food waste and its primary packaging or the product itself once no longer functional, is excluded from the use stage and shall be part of the end of life stage of the product.

The manufacturer's recommended method to be applied in the use stage (e.g. cooking in an oven at a specified temperature for a specified time) should be used to provide a basis for determining the use stage of a product. The actual usage pattern may, however, differ from those recommended and should be used if this information is available and documented. Default loss rates per type of product during distribution and at consumer are provided in Annex 6 of this guidance and shall be used if no specific information is available. Default data for modelling the use stage can be found in Annex 4 of this guidance.

For the use stage, the consumption grid mix shall be used. The electricity mix shall reflect the ratios of sales between EU countries/ regions. To determine the ratio a physical unit shall be used (e.g. number of pieces or kg of product). Where such data are not available, the average EU consumption mix (EU+EFTA), or region-representative consumption mix, shall be used.

5.6. End of life

[Based on Chapter B.6.6. in Annex II of EC (2021)]

The end of life stage begins when the product in scope and its packaging is discarded by the user and ends when the product is returned to nature as a waste product or enters another product's life cycle (i.e. as a recycled input). In general, it includes the waste of the product in scope, such as the food waste, and primary packaging.

Other waste (different from the product in scope) generated during the manufacturing, distribution, retail, use stage or after use shall be included in the life cycle of the product and modelled at the life cycle stage where it occurs.

The end of life shall be modelled using the rules provided in Chapter 4.12.

5.7. Capital goods – infrastructure and equipment

[Based on Chapter A.4.2.4. in Annex II of EC (2021)]

Capital goods (including infrastructure) and their end of life should be excluded, unless there is evidence from previous studies that they are relevant. If capital goods are included, the LCA report shall include a clear and extensive explanation on why they are relevant, reporting all assumptions made.

6. Interpretation of results

6.1. Identification of hotspots

[Based on Chapter A.6.1. in Annex II of EC (2021)]

Once the user of this guidance ensures that the LCA model is robust and conforms to all aspects defined in the goal and scope definition phases, the main contributing elements to the LCA results shall be identified. This step may also be referred to as 'hotspot' analysis. The user of this guidance shall identify and list in the LCA report (together with the %) the most relevant:

1. impact categories (if all 16 impact categories are assessed)
2. life-cycle stages
3. processes
4. elementary flows.

There is an important operational difference between most-relevant impact categories and life-cycle stages on one hand and most-relevant processes, and elementary flows on the other. In particular, most-relevant impact categories and life-cycle stages may be mainly relevant in the context of communicating the results of an LCA study. They might serve to highlight environmental areas where the organisation should focus their attention.

Identifying the most-relevant processes and elementary flows is more important for the engineers and designers to identify actions for improving the overall footprint, e.g. by-passing or changing a process, further optimising a process, or applying anti-pollution technology. This is particularly relevant for internal studies, to look deeper into how to improve the product's environmental performance. The procedure that shall be followed to identify the most-relevant impact categories, life-cycle stages, processes and elementary flows is described in the following chapters.

6.2. Procedure to identify the most relevant impact categories

[Based on Chapter A.6.1.1. in Annex II of EC (2021)]

If all 16 impact categories have been assessed for the product, the user of this guidance may evaluate the importance of different impact categories following the PEF method (EC 2021) for identifying the most relevant impact categories.

The identification of the most-relevant impact categories shall be based on the normalised and weighted results. The most-relevant impact categories shall be identified as all of those impact categories that together contribute to at least 80% of the single overall score. This shall start from the largest to the smallest contributions.

At least three relevant impact categories shall be identified as most-relevant ones.

6.3. Procedure to identify the most relevant life cycle stages

[Based on Chapter A.6.1.2. in Annex II of EC (2021)]

The most-relevant life-cycle stages are those that together contribute more than 80% to any of the most-relevant impact categories identified. This shall start from the largest to the smallest contributions.

If the use stage accounts for more than 50% of the total impact of an impact category, the procedure shall be re-run, excluding the use stage. In this case, the list of most-relevant life-cycle stages shall be those selected through the latter procedure plus the use stage.

6.4. Procedure to identify the most relevant processes

[Based on Chapter A.6.1.3. in Annex II of EC (2021)]

Each most-relevant impact category shall be further investigated by identifying the most-relevant processes used to model the product in scope. The most-relevant processes are those that together contribute more than 80% to any of the impact categories identified. Identical processes 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 shall be reported in the report together with the respective life-cycle stage (or multiple life-cycle stages if relevant) and the contribution in %. The identification of the most-relevant processes shall be carried out according to Table 20.

Table 20. Criteria to select at which life-cycle stage level to identify the most-relevant processes.

Contribution of the use stage to the total impact of an impact category	Most-relevant processes identified at the level of
≥ 50%	whole life-cycle excluding use stage, and use stage
< 50%	whole life cycle

This analysis shall be reported separately for each impact category.

6.5. Procedure to identify the most relevant direct elementary flows

[Based on Chapter A.6.1.4. in Annex II of EC (2021)]

The most-relevant elementary flows are defined as those elementary flows that together contribute at least 80% to the total impact of each most-relevant specific impact category for each most-relevant process, starting from those that contribute the most to those that contribute the least. This analysis shall be reported separately for each most- relevant impact category.

Elementary flows belonging to the background system of a most-relevant process may dominate the impact. Therefore, if disaggregated datasets are available, the user of this guidance should also identify the most-relevant direct elementary flows for each most-relevant process.

Most-relevant direct elementary flows are defined as those direct elementary flows that together contribute at least 80% to the total impact of the direct elementary flows of the process, for each most-relevant impact category. The analysis shall be limited to the direct emissions of the level-1 disaggregated datasets[51]. This means that the 80% cumulative contribution shall be calculated against the impact caused by the direct emissions only, and not against the total impact of the process.

The list of most-relevant elementary flows (or, if applicable, direct elementary flows) per most- relevant process shall be reported in the LCA report.

6.6. Summary of requirements

[Based on Chapter 6.3.6. in Annex I of EC (2021)]

Table 21. Summary of requirements to define most relevant contributions.

Item	At what level does relevance need to be identified?	Threshold
Most-relevant life-cycle stages	For each most-relevant impact category	All life-cycle stages that together contribute more than 80% to that impact category. If the use stage accounts for more than 50% of the total impact of a most-relevant impact category, the procedure shall be re-run, excluding the use stage.
Most-relevant processes	For each most-relevant impact category	All processes that together contribute (along the entire life cycle) more than 80% to that impact category, considering absolute values.
Most-relevant elementary flows	For each most-relevant process considering the most-relevant impact categories	All elementary flows that together contribute to at least 80% of the total impact of a most-relevant impact category for each most-relevant process. If disaggregated data are available: for each most- relevant process, all direct elementary flows that together contribute at least 80% to that impact category (caused by the direct elementary flows only).

[51] See http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml for description of level-1 disaggregated datasets.

7. Reporting results

[Based on Chapter B.7. in Annex II of EC (2021)]

The results shall be provided according to the template provided below (Table 22). If all 16 impact categories of the EF method are calculated, the results may be provided also normalised and weighted (as absolute values). See Chapter 3.3 for more details on normalisation and weighting.

Table 22. Results of the LCA study

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Climate change, total	kg CO_2 eq		
Climate change - fossil			
Climate change - biogenic			
Climate change – land use and land use change			
Ozone depletion	kg CFC-11 eq		
Particulate matter	disease incidence		
Ionising radiation, human health	kBq U^{235} eq		
Photochemical ozone formation, human health	kg NMVOC eq		
Acidification	mol H+ eq		
Eutrophication, terrestrial	mol N eq		
Eutrophication, freshwater	kg P eq		
Eutrophication, marine	kg N eq		
Human toxicity, cancer	CTU_h		
Human toxicity, non-cancer	CTU_h		
Ecotoxicity	CTUe		
Land use	Dimensionless (pt)		
Water scarcity footprint	m^3 water eq of deprived water		
Resource use, minerals and metals	kg Sb eq		
Resource use, fossils	MJ		

The user of the guidance shall calculate the LCA profile of its product in compliance with all requirements included in this guidance. The following information shall be included in the LCA report:

a) full life cycle inventory;
b) characterised results in absolute values, for all assessed impact categories (as a table);

If normalisation, weighting or single overall score are included in the LCA study, the following information shall be included in the LCA report:
c) normalised results in absolute values, for all impact categories (as a table);
d) weighted result in absolute values, for all impact categories (as a table);
e) the aggregated single overall score in absolute values.

8. Verification and validation of LCA studies, reports

[Based on Chapter 8. in Annex I of EC (2021)]

8.1. Defining the scope of the verification

[Based on Chapter 8.1. in Annex I of EC (2021)]

The verification and validation of the LCA study is mandatory whenever the study, or part of the information therein, is used for any type of external communication (i.e. communication to any interested party other than the commissioner or the user of this guidance of LCA study).

Verification means the conformity assessment process carried out by an environmental footprint verifier(s) to check whether the LCA study has been carried out in compliance with this guidance.

Validation means the confirmation by the environmental footprint verifier(s) who carried out the verification, that the information and data included in the LCA study, the LCA report and the communication vehicles available at the time of validation are reliable, credible and correct.

The verification and validation shall cover the following three areas:

1. the LCA study (including, but not limited to the data collected, calculated, and estimated and the underlying model);
2. the LCA report;
3. the technical content of the communication vehicles, if applicable.

The verification of the LCA study shall ensure that the LCA study is conducted in compliance with this guidance.

The validation of information in the LCA study shall ensure that:

(a) the data and information used for the LCA study are consistent, reliable and traceable;
(b) the calculations performed do not include significant[52] mistakes.

The verification and validation of the LCA report shall ensure that:

(a) the LCA report is complete, consistent, and compliant with the LCA report template provided in Annex 5 of this guidance;
(b) the information and data included are consistent, reliable and traceable;
(c) the mandatory information and sections are included and appropriately filled in;
(d) all the technical information that could be used for communication purposes, independently from the communication vehicle to be used, are included in the report.

[52] Mistakes are significant if they change the final result by more than 5% for any of the impact categories, or the identified most relevant impact categories, life cycle stages and processes.

Note: confidential information shall be validated, while it may be excluded from the LCA report.

The validation of the technical content of the communication vehicle content shall ensure that:

(a) the technical information and data included are reliable and consistent with the information included in the LCA study and the LCA report;
(b) that the information is compliant with the requirements of the Unfair Commercial Practices Directive[53];
(c) that the communication vehicle complies with the principles of transparency, availability and accessibility, reliability, completeness, comparability and clarity, as described in the Commission Communication on Building the Single Market for Green Products[54].

8.2. Verification procedure

[Based on Chapter 8.2. in Annex I of EC (2021)]

The verification procedure covers the following steps.

1. The commissioner shall select the verifier(s) or verification team following the rules outlined in Chapter 8.3.1.
2. The verification shall take place following the verification process described in Chapter 8.4.
3. The verifier(s) shall communicate to the commissioner any misstatement, non-conformities and need for clarifications (Chapter 8.3.2), and draft the validation statement (Chapter 8.5.2)
4. The commissioner shall respond to the verifier's comments and introduce necessary corrections and changes (if needed) to ensure the final compliance of the LCA study, LCA report and technical content of LCA communication vehicles. If, in the verifier's judgement, the commissioner does not respond appropriately within a reasonable time period, the verifier shall issue a modified validation statement.
5. The final validation statement is provided, considering (if needed) the corrections and changes introduced by the commissioner.
6. Surveillance that the LCA report is available during the validity of the validation statement (as defined in Chapter 8.5.3)

If a matter comes to the verifier's attention that causes the verifier to believe in the existence of fraud or noncompliance with laws or regulations, the verifier shall communicate this immediately to the commissioner of the study.

[53] Directive 2005/29/EC of the European Parliament and of the Council of 11 May 2005 concerning unfair business-to-consumer commercial practices in the internal market and amending Council Directive 84/450/EEC, Directives 97/7/EC, 98/27/EC and 2002/65/EC of the European Parliament and of the Council and Regulation (EC) No 2006/2004 of the European Parliament and of the Council ('Unfair Commercial Practices Directive')
[54] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0196

8.3. Verifier(s)

[Based on Chapter 8.3. in Annex I of EC (2021)]

This chapter is without prejudice to specific provisions of EU legislation.

The verification/validation may be conducted by a single verifier or by a verification team. The independent verifier(s) shall be external to the organisation that conducted the LCA study.

In all cases the independence of the verifiers shall be guaranteed, i.e. they shall fulfil the intentions in the requirements of EN ISO/IEC 17020:2012 regarding a third party verifier, they shall not have conflicts of interests on concerned products.

The minimum requirements and score for the verifier(s) as specified below shall be fulfilled. If the verification/ validation is conducted by a single verifier, they shall satisfy all the minimum requirements and the minimum score (see Chapter 8.3.1); if the verification/validation is conducted by a team, the team as a whole shall satisfy all the minimum requirements and the minimum score. The documents proving the qualifications of the verifier(s) shall be provided as an annex to the verification report or they shall be made available electronically.

In case a verification team is established, one of the members of the verification team shall be appointed as lead verifier.

8.3.1. Minimum requirements for verifier(s)

[Based on Chapter 8.3.1. in Annex I of EC (2021)]

This chapter is without prejudice to specific provisions of EU legislation.

The assessment of the competences of verifier or verification team is based on a scoring system that takes into account: (i) verification and validation experience; (ii) EF/LCA methodology and practice; and (iii) knowledge of relevant technologies, processes or other activities included in the product(s)/organisation(s) in scope of the study.

Table 23 presents the scoring system for each relevant competence and experience topic.

Unless otherwise specified in the context of the intended application, the verifier's self-declaration on the scoring system constitutes the minimum requirement. Verifier(s) shall provide a self-declaration of their qualifications (e.g. university diploma, working experience, certifications), stating how many points they achieved for each criterion and the total points achieved. This self-declaration shall form part of the verification report.

A verification of an LCA study shall be conducted as per the requirements of the intended application. Unless otherwise specified, the minimum score necessary to qualify as a verifier or a verification team is six points, including at least one point for each of the three mandatory criteria (i.e. verification and validation practice, PEF/LCA methodology and practice, and knowledge of technologies or other activities relevant to the LCA study).

Table 23. Scoring system for each relevant competence and experience topic for the assessment of the competences of verifier(s).

	Topic	Criteria	Score (points)				
			0	1	2	3	4
Mandatory criteria	Verification and validation practice	Years of experience (1)	<2	2 ≤ x < 4	4 ≤ x < 8	8≤ x < 14	≥14
		Number of verifications (2)	≤5	5 < x ≤ 10	11 ≤ x ≤ 20	21 ≤ x ≤ 30	>30
	LCA methodology and practice	Years of experience (3)	<2	2 ≤ x < 4	4 ≤ x < 8	8≤ x < 14	≥14
		Number of LCA studies or reviews (4)	≤5	5 < x ≤ 10	11 ≤ x ≤ 20	21 ≤ x ≤ 30	>30
	Knowledge of the specific sector	Years of experience (5)	<1	1 ≤ x < 3	3 ≤ x < 6	6≤ x < 10	≥10
Additional criteria	Review, verification/ validation practice	Optional scores relating to verification/ validation	— 2 points: Accreditation as third party verifier for EMAS — 1 point: Accreditation as third party reviewer for at least one EPD scheme, EN ISO 14001:2015, or other EMS				

(1) Years of experience in the field of environmental verifications and/or review of LCA/PEF/EPD studies.
(2) Number of verifications for EMAS, EN ISO 14001:2015, international EPD scheme or other EMS.
(3) Years of experience in the field of LCA modelling. Work done during master and bachelor degrees shall be excluded. Work done during a relevant Ph.D./Doctorate course shall be accounted for. Experience in LCA modelling include among others:

- LCA modelling in commercial and non-commercial software;
- Datasets and database development.

(4) Studies compliant with one of the following standards/methods: PEF, OEF, ISO 14040-44, EN ISO 14067:2018, EN ISO 14025:2010.
(5) Years of experience in a sector related to the studied product(s). The experience in the sector may be gained through LCA studies or through other types of activities. The LCA studies shall be done on behalf of and with access to primary data of the producing/operating industry. The qualification of knowledge about technologies or other activities is assigned according to the classification of NACE codes (Regulation (EC) No 1893/2006 of the European Parliament and of the Council of 20 December 2006 establishing the statistical classification of economic activities - NACE Revision 2). Equivalent classifications of other international organisations may also be used. Experience gained with technologies or processes in a whole sector are considered valid for any of its subsectors.

8.3.2. Role of the lead verifier in the verification team

[Based on Chapter 8.3.2. in Annex I of EC (2021)]

The lead verifier is a team member with additional tasks. The lead verifier shall:

- distribute the tasks to be fulfilled between the team members according to the specific competencies (skills /abilities) of the team members, to get the full coverage of the tasks to be done and to use in the best manner the specific competencies of the team members;
- coordinate the whole verification/validation process and ensure that all team members have a common understanding of the tasks they need to fulfil;
- assemble all comments and ensure they are communicated to the commissioner of the LCA study in a clear and understandable way;
- resolve any conflicting statements between team members;
- ensure that the verification report and validation statement are generated and are signed by each member of the verification team.

8.4. Verification and validation requirements

[Based on Chapter 8.4. in Annex I of EC (2021)]

The verifier(s) shall present all the outcomes related to the verification of the LCA study and the validation of the LCA study, LCA report and LCA communication vehicles and give the commissioner of the LCA study the opportunity to improve the work, if necessary. Depending on the nature of the outcomes, additional iterations of comments and responses may be necessary. Any changes made in response to the verification or validation outcomes shall be documented and explained in the verification or validation report. Such a summary may take the form of a table in the respective documents. The summary shall include the comment(s) from the verifier(s), the commissioner's answer and the motivation for the changes.

Verification may take place after the LCA study has been concluded or in parallel (concurrent) to the study, while validation shall always take place after the study has been concluded.

The verification/validation shall combine document review and model validation.

- The document review includes the LCA report, the technical content of related communication vehicles available at the time of validation, and the data used in the calculations through requested underlying documents. Verifier(s) may organise the document review either as an 'at desk' or 'on-site' exercise, or as a mix of the two. If the reliability of the validation requires, the validation of the company-specific data should be organised through a visit to the production site(s) the data refer to.[55]
- The validation of the model may take place at the production site of the commissioner of the study or be organised remotely. The verifier(s) shall access the model to verify its structure, the data used, and its consistency with the LCA report and LCA study. The commissioner of the LCA study and the verifier(s) shall agree on how the verifier(s) accesses the model.
- The validation of the LCA report shall be carried out by checking enough information to provide reasonable assurance that the content is in line with the modelling and re

The verifier(s) shall ensure that data validation includes:

a) coverage, precision, completeness, representativeness, consistency, reproducibility, sources and uncertainty;
b) plausibility, quality and accuracy of the LCA-based data;
c) quality and accuracy of additional environmental and technical information;
d) quality and accuracy of the supporting information.

The verification and validation of the LCA study shall be carried out by following the minimum requirements listed in Chapter 8.4.1.

[55] In the PEF method (EC 2021), the validation of the company-specific data shall always be organised through a visit to the production site(s) the data refer to.

8.4.1. Minimum requirements for the verification and validation of the LCA study

[Based on Chapter 8.4.1. in Annex I of EC (2021)]

The verifier(s) shall validate the accuracy and reliability of the quantitative information used in the calculation of the study. As this may be highly resource intensive, the following requirements shall be fulfilled.

- The verifier(s) shall check if the correct version of all impact assessment methods was used. If all 16 EF impact categories are assessed, for each of the most-relevant EF impact categories (ICs), at least 50% of the characterisation factors shall be verified, while all normalisation and weighting factors of all ICs shall be verified. If only limited number of impact categories are assessed, then at least 50% of the characterisation factors of all assessed impact categories shall be verified. In particular, the verifier(s) shall check that the characterisation factors correspond to those included in this guidance. This may also be done indirectly, for example:

  1) Export the used datasets from the LCA software used to do the LCA study and run them in Look@LCI88 to obtain LCIA results. If Look@LCI[56] results are within a deviation of 1% from the results in the LCA software, the verifier(s) may assume that the implementation of the characterisation factors in the software used to do the LCA study was correct.
  2) Compare the LCIA results of the most-relevant processes calculated with the software used to do the LCA study with the ones available in the metadata of the original dataset. If the compared results are within a deviation of 1%, the verifier(s) may assume that the implementation of the characterisation factors in the software used to do the LCA study was correct.

- The verifier(s) shall check that the cut-off applied (if any) fulfils the requirements at Chapter 4.2.
- The verifier(s) shall check that all datasets used fulfil the data requirements (Chapter 4.4.).
- For at least 50%[57] (in number) of the most-relevant processes (as defined in Chapter 6.4), the verifier(s) shall validate all related activity data and the datasets used to model these processes. The verifier(s) shall check that the most-relevant processes are identified as specified in Chapter 6.4.
- For at least 30% (in number) of all other processes (corresponding to 20% of the processes as defined in Chapter 6.4) the verifier(s) shall validate all related activity data and the datasets used to model these processes.
- The verifier(s) shall check that the datasets are correctly implemented in the software (i.e. LCIA results of the dataset in the software are within a deviation of 1% to the ones in the metadata). At least 50% (in number) of the datasets used to model most-relevant processes and 10% of those used to model other processes shall be checked.

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[56] https://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml
[57] In the PEF method (EC 2021), at least 80%.

8.4.2. Verification and validation techniques

[Based on Chapter 8.4.2. in Annex I of EC (2021)]

The verifier(s) shall assess and confirm whether the calculation methodologies applied are of acceptable accuracy, reliable, are appropriate and performed in line with this guidance. The verifier(s) shall confirm the correct application of conversion of measurement units.

The verifier(s) shall check if applied sampling procedures are in line with the sampling procedure defined in the LCA method as set out in Chapter 4.5. The data reported shall be checked against the source documentation in order to check their consistency.

The verifier(s) shall evaluate whether the methods for making estimates are appropriate and have been applied consistently.

The verifier(s) may assess alternatives to estimations or choices made, to determine whether a conservative choice has been selected.

The verifier(s) may identify uncertainties that are greater than expected and assess the effect of the identified uncertainty on the final LCA results.

8.4.3. Data confidentiality

[Based on Chapter 8.4.3. in Annex I of EC (2021)]

Data for validation shall be presented in a systematic and comprehensive way. All the project documentation supporting the validation of an LCA study shall be provided to the verifier(s), including the LCA model, confidential information, data, and the LCA report. The verifier(s) shall treat all information and data undergoing verification/validation as confidential and shall use them only during the verification/validation process.

The commissioner of the LCA study may exclude confidential data and information from the LCA report, provided that:

- only input information is excluded and all output information is included;
- the commissioner provides the verifier(s) with sufficient information of the nature of the data and information excluded as well as the reasoning for excluding them;
- the verifier(s) accept(s) the non-disclosure and includes in the verification and validation report the reasons for doing so; if the verifier(s) do(es) not accept the non-disclosure and the commissioner does not take corrective action, the verifier(s) shall include in the verification and validation report that the non-disclosure is not justified;
- the commissioner keeps a file of the non-disclosed information for possible future re-evaluation of the decision for non-disclosure.

Business data could be of confidential nature because of competition aspects, intellectual property rights or similar legal restrictions. Therefore, business data identified as confidential and provided during the validation process shall be kept confidential. Hence, verifier(s) shall not disseminate or otherwise retain for use, without the organisation's permission, any information disclosed to them during the course of the verification/validation process. The commissioner of the LCA study may ask the verifier(s) to sign a non-disclosure agreement (NDA).

8.5. Outputs of the verification/validation process

8.5.1. Content of the verification and validation report

[Based on Chapter 8.5.1. in Annex I of EC (2021)]

The verification and validation report[58] shall include all findings of the verification/ validation process, the actions taken by the commissioner to answer the comments of the verifier(s), and the final conclusion. The report is mandatory, but it may be confidential.

The final conclusion may be of a different nature:

- 'compliant' if the document or on-site checks prove that the requirements of this chapter are fulfilled;
- 'not compliant' if the document or on-site checks prove that the requirements of this chapter are not fulfilled;
- 'complementary information needed' if the document or on-site checks do not allow the verifier(s) to conclude on compliance. This may happen if the information is not transparently or sufficiently documented or made available.

The verification and validation report shall clearly identify the specific LCA study under verification.

To this purpose, it shall include the following information:

- title of the LCA study under verification/validation, together with the exact version of the LCA report to which the validation statement belongs;
- the commissioner of the LCA study;
- the user of the LCA method;
- the verifier(s) or, in the case of a verification team, the team members with the identification of the lead verifier;
- absence of conflicts of interest of the verifier(s) with respect to concerned products and the commissioner and any involvement in previous work (where relevant, consultancy work carried out for the user of the LCA method over the last three years);
- a description of the objective of the verification/validation;
- the actions taken by the commissioner to answer the comments of the verifier(s);
- a statement of the result (findings) of the verification/validation containing the final conclusion of the verification and validation reports;
- any limitations of the verification/validation outcomes;
- date on which the validation statement has been issued;
- version details of this guidance;
- signature of the verifier(s).

[58] The two aspects, validation and verification, are included in one report.

8.5.2. Content of the validation statement

[Based on Chapter 8.5.2. in Annex I of EC (2021)]

The validation statement is mandatory and shall always be provided as an annex to the LCA report.

The verifier(s) shall include at least the following elements and aspects in the validation statement:

- title of the LCA study under verification/validation, together with the exact version of the LCA report to which the validation statement belongs;
- the commissioner of the LCA study;
- the user of this guidance;
- the verifier(s) or, in the case of a verification team, the team members with the identification of the lead verifier;
- absence of conflicts of interest of the verifier(s) with respect to concerned products and the commissioner and any involvement in previous work (where relevant, consultancy work carried out for the user of this guidance over the last three years);
- a description of the objective of the verification/validation;
- a statement of the result of the verification/validation containing the final conclusion of the verification and validation reports;
- any limitations of the verification/validation outcomes;
- date on which the validation statement has been issued;
- version details of this guidance;
- signature of the verifier(s).

8.5.3. Validity of the verification and validation report and the validation statement

[Based on Chapter 8.5.3. in Annex I of EC (2021)]

A verification and validation report, and a validation statement shall refer to one specific LCA report only. The verification and validation report and the validation statement shall clearly identify the specific LCA study under verification (e.g. by including the title, the commissioner of the LCA study, the user of the this guidance – see Chapters 8.5.1 and 8.5.2), together with the explicit version of the final LCA report to which the verification and validation report and a validation statement apply (e.g. by including the report date, the version number).

Both the verification and validation report and the validation statement shall be completed based on the final LCA report, after the implementation of all the corrective actions requested by the verifier(s). They shall carry the handwritten or electronic signature of the verifier(s) in line with Regulation (EU) n° 910/2014[59].

[59] Regulation N° 910/2014 of the European Parliament and of the Council of 23 July 2014 on electronic identification and trust services for electronic transactions in the internal market and repealing Directive 1999/93/EC, OJEU L 257, 28.8.2014, p. 73.

The maximum validity of the verification and validation report and of the validation statement shall not exceed three years starting from their issue date.

During the validity period of the verification, surveillance (follow-up) shall be agreed between the commissioner of the LCA study and the verifier(s) to evaluate if the content is still consistent with the current situation (the suggested periodicity for this follow-up is once per year, to be agreed between the LCA study commissioner and the verifier(s)).

The periodic checks shall focus on the parameters that according to the verifier(s) might lead to relevant changes in the results of the LCA study. This means, that the results shall be recalculated considering the changes of the identified parameters. The list of such parameters includes:

- bill of material/bill of components;
- energy mix used for processes in Situation 1 of the Data Needs Matrix;
- change of packaging;
- changes in the suppliers (materials/geography);
- changes in the logistics;
- relevant technological changes in the processes in Situation 1 of the Data Needs Matrix.

At the time of the periodic check the reasons for non-disclosure of information should also be reconsidered. The surveillance verification may be organised as a document check and/or through on-site inspections.

Regardless of the validity, the LCA study (and consequently the LCA report) shall be updated during the surveillance period if the results of one of the impact categories communicated has worsened by more than 10.0% compared to the verified data, or if the total aggregated score has worsened by more than 5.0% compared to the verified data.

If these changes also affect the content of the communication vehicle, it shall be updated accordingly.

The verification of the report shall be carried out by randomly checking enough information to provide reasonable assurance that the report fulfils all the conditions listed in Chapter 7 of this guidance.

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ANNEX 1 - LULUC modelling formulas and factors

Note: The calculation method presented in Annex 1 applies only to countries that have a National Greenhouse Gas (GHG) Inventory and are involved in the Kyoto Protocol. The involvement may be checked from https://unfccc.int/ghg-inventories-annex-i-parties/2023. The default parameters presented in Annex 1 are for Finland.

Note: the references to specific tables and chapters in this Annex refer to this Annex (Annex 1 – LULUC modelling formulas and factors). References to the main document (*Guidance for environmental footprint assessment of food products (Food-LCA) – Specification for external communicational purposes on the Finnish market)* or other Annexes are mentioned with the references.

1. Abbreviations and definitions

DOM = dead organic matter

LB = living biomass

LULUC = land use and land use change

SOC = soil organic carbon

Land converted to cropland = land converted from other land use categories[60] to cropland within the past 20 years (IPCC 2006a,b).

Cropland remaining cropland = cropland that has *not* gone through direct land use changes within the past 20 years (IPCC 2006a,b).

2. Formulas

2.1. LULUC emission from cropland

$$LULUC_{cropland} = (A_{conv} \times \Delta C_{conv} + A_{rem} \times \Delta C_{rem}) \times 44/12 \times (-1) + LULUC_{CH4} \times 29.8$$

where,

$LULUC_{cropland}$	total carbon dioxide and methane LULUC emission (kg CO_2 eq./ha/year)
A_{conv}	share of land converted to cropland (dimensionless)
ΔC_{conv}	net C stock change, land converted to cropland (kg C/ha/year) (see chapter 2.2)
A_{rem}	share of cropland remaining cropland (dimensionless)
ΔC_{rem}	net C stock change, cropland remaining cropland (kg C/ha/year) (see chapter 2.3)

[60] Forest land, wetland, grassland, settlement, or other land (following IPCC categorisation, IPCC (2006a)).

44/12	factor to convert C into CO_2
$LULUC_{CH4}$	methane LULUC emissions (kg CH_4/ha/year) (see chapter 2.4)
29.8	factor to convert CH_4 to CO_2 equivalents

2.2. Net C stock change on land converted to cropland (ΔC_{conv})

$$\Delta C_{conv} = \Delta LB_{conv} + \Delta DOM_{conv} + \Delta SOC_{conv}$$
$$\Delta SOC_{conv} = (A_{min} \times \Delta SOC_{conv,min}) + (A_{org} \times \Delta SOC_{conv,org})$$

where,

ΔC_{conv}	net C stock change, land converted to cropland (kg C/ha/year)
ΔLB_{conv}	net C stock change in LB, land converted to cropland (kg C/ha/year)
ΔDOM_{conv}	net C stock change in DOM, land converted to cropland (kg C/ha/year)
ΔSOC_{conv}	net C stock change in SOC, land converted to cropland (kg C/ha/year)
A_{min}	Share of mineral cropland[61] (dimensionless)
A_{org}	Share of organic cropland (dimensionless)
$\Delta SOC_{conv,min}$	net C stock change in SOC on mineral soil, land converted to cropland (kg C/ha/year)
$\Delta SOC_{conv,org}$	net C stock change in SOC on organic soil, land converted to cropland (kg C/ha/year)

2.3. Net C stock change on cropland remaining cropland (ΔC_{rem})

$$\Delta C_{rem} = \Delta LB_{rem} + (A_{min} \times \Delta SOC_{rem,min}) + (A_{org} \times \Delta SOC_{rem,org})$$

where,

ΔC_{rem}	net C stock change, cropland remaining cropland (kg C/ha/year)
ΔLB_{rem}	net C stock change in LB, cropland remaining cropland (kg C/ha/year)[62]
$\Delta SOC_{rem,min}$	net C stock change in SOC on mineral soil, cropland remaining cropland (kg C/ha/year)
$\Delta SOC_{rem,org}$	net C stock change in SOC on organic soil, cropland remaining cropland (kg C/ha/year)

[61] Same A_{min} and A_{org} can be used for cropland remaining cropland and land converted to cropland. If data is available, separate A_{min} and A_{org} may be used for cropland remaining cropland and land converted to cropland.
[62] Refers to woody biomass of perennial crops.

2.4. CH_4 emission from cropland ($LULUC_{CH4}$)

$$LULUC_{CH4} = A_{org} \times Methane_{org}$$

where,

$LULUC_{CH4}$	methane LULUC emissions (kg CH_4/ha/year)
$Methane_{org}$	methane emission from drained organic soil cropland (kg CH_4/ha/year)

3. How to derive parameters for the equations

Primary data shall be used for soil types (areas of mineral and organic soils, A_{min} and A_{org}) and land use history (areas of land converted to cropland (A_{conv}) and cropland remaining cropland (A_{rem})). If the data is not available, secondary data shall be based on the CRF tables that are attachments to the National GHG Inventory reports. CRF tables are available at https://unfccc.int/ghg-inventories-annex-i-parties/2023 (or more recent year). The default LULUC emissions of Finland and the provinces of Finland based on the National GHG Inventory 2024 (Statistics Finland 2024) are presented in Table 1.1. The instructions to derive A_{min}, A_{org}, A_{conv} and A_{rem} from the more recent CRF tables than Statistics Finland (2024) are given in Table 1.2.

Note: There is no need to derive A_{min}, A_{org}, A_{conv} and A_{rem}, if the default LULUC emissions of Finland or provinces of Finland based on Statistics Finland (2024) are used (Table 1.1).

For Finland, the carbon stock change (ΔC) values for LB, SOC, and DOM (Statistics Finland 2024) are given in Table 1.3. The instructions to derive ΔC values from the latest available CRF table are given in Table 1.4.

Note: There is no need to derive ΔC values if the default LULUC emissions of Finland or provinces of Finland based on Statistics Finland (2024) are used (Table 1.1).

Table 1.1. The default LULUC emission values for cropland in Finland and the provinces of Finland. Based on Statistics Finland (2024) and Luke Economy doctor[63].

Category	Area	Emission (kg CO_2/ha/year)
National default	Finland	3531
Provinces of Finland	Etelä-Karjala	3610
	Etelä-Pohjanmaa	4486
	Etelä-Savo	1798
	Kainuu	6442
	Kanta-Häme	1642
	Keski-Pohjanmaa	6847
	Keski-Suomi	3143
	Kymenlaakso	1761
	Lappi	6477
	Pirkanmaa	2389
	Pohjanmaa	2223
	Pohjois-Karjala	3297
	Pohjois-Pohjanmaa	6921
	Pohjois-Savo	3252
	Päijät-Häme	1125
	Satakunta	3254
	Uusimaa	1585
	Varsinais-Suomi	1702

Table 1.2. Instructions on how to derive the secondary data for A_{min}, A_{org}, A_{conv} and A_{rem} from the CRF tables.

Parameter	Unit	Table number	How to derive the parameter
A_{conv}	dimensionless	Table 4.B	Land converted to cropland area / Total cropland area
A_{rem}*	dimensionless	Table 4.B	Cropland remaining cropland area / Total cropland area
A_{min}*	dimensionless	Table 4.B	Area of mineral soils for total cropland / Total cropland area
A_{org}	dimensionless	Table 4.B	Area of organic soils for total cropland / Total cropland area

*A_{min} and A_{org} may be given as an average for all cropland or separately for cropland remaining cropland and land converted to cropland. For the provinces of Finland, the A_{min} and A_{org} values may be derived from Luke Economy doctor websites (https://taloustohtori.luke.fi/en/soil-class-information/timeline/parent-material-types-wrb/region/).

[63] https://taloustohtori.luke.fi/en/greenhouse-gas-emission/timeline/ton-co2-ekv-per-farm-by-production-types/

Table 1.3. The carbon stock change values ($\Delta C_{rem}/\Delta C_{conv}$) and methane emissions in Finland. The values are based on Statistics Finland 2024.

Parameter	Unit	Value
ΔLB_{conv}	kg C/ha/year	-970
ΔDOM_{conv}	kg C/ha/year	-4
$\Delta SOC_{conv,min}$	kg C/ha/year	-527
$\Delta SOC_{conv,org}$	kg C/ha/year	-6800
ΔLB_{rem}	kg C/ha/year	0.00032
$\Delta SOC_{rem,min}$	kg C/ha/year	-176*
$\Delta SOC_{rem,org}$	kg C/ha/year	-6550*
$Methane_{org}$	kg CH_4/ha/year	0 **

*Value is a Finland average weighted by areas of annual and perennial crops[64]. It shall be used; in case the crop rotation is unknown, or the crop rotation includes both annual and perennial crops. Alternatives: i) if the cropland has been cultivated for the past 20 years only with annual crops, $\Delta SOIL_{rem,org}$ = -7900 kg C/ha/year, ii) if the cropland has been cultivated for the past 20 years only with perennial crops, $\Delta SOIL_{rem,org}$ = -5700 kg C/ha/year.

** The estimate used in the National GHG Inventory of Finland: 0 kg CH_4-C/ha/a (IPCC 2014).

Table 1.4. Instructions on how to derive the carbon stock change values (ΔC) and methane emissions from the CRF tables.

Parameter	Unit	CRF table number	How to derive the parameter
ΔLB_{conv}	kg C/ha/year	Table 4.B	Carbon stock change in living biomass per area> Net change > Land converted to cropland*
ΔDOM_{conv}	kg C/ha/year	Table 4.B	Net carbon stock change in dead organic matter per area > Land converted to cropland*
$\Delta SOC_{conv,min}$	kg C/ha/year	Table 4.B	Net carbon stock change in soils per area > Mineral soils > Land converted to cropland*
$\Delta SOC_{conv,org}$	kg C/ha/year	Table 4.B	Net carbon stock change in soils per area > Organic soils > Land converted to cropland*
ΔLB_{rem}	kg C/ha/year	Table 4.B	Carbon stock change in living biomass per area > Cropland remaining cropland*
$\Delta SOC_{rem,min}$	kg C/ha/year	Table 4.B	Net carbon stock change in soils per area > Mineral soils > Cropland remaining cropland*
$\Delta SOC_{rem,org}$	kg C/ha/year	Table 4.B	Net carbon stock change in soils per area > Organic soils > Cropland remaining cropland*
$Methane_{org}$	kg CH_4/ha/year	Table 4(II)	Cropland > Drained organic soils

*Convert values presented as t C/ha/year into kg C/ha/year

For the provinces of Finland, the $\Delta SOC_{rem,min}$ and $\Delta SOC_{rem,org}$ values may be derived from Luke Economydoctor websites (https://portal.mtt.fi/portal/page/portal/economydoctor/greenhouse_gas_emission/timeline/ton_co2_ekv_per_arable_land/).

[64] A weighted average is used to account for year-to-year variation in organic soil SOC stock losses depending on cultivated crop species.

4. References

IPCC 2006a. Chapter 2: Generic methodologies applicable to multiple land-use categories. Volume 4: Agriculture, Forestry and Other Land Use. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf

IPCC 2006b. Chapter 5: Cropland. Volume 4: Agriculture, Forestry and Other Land Use. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf

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ANNEX 2 – Crop modelling formulas and factors

1. General

Annex 2 describes the modelling of emissions from field cultivation. Formulas are global, but some of the parameters apply only in boreal regions. The rest of the parameters are available in the original sources.

The most common parameters in crop modelling are given in Table 2.1.

Note: the references to specific tables and chapters in this Annex refer to this Annex (Annex 2 – crop modelling formulas and factors). References to the main document (*Guidance for environmental footprint assessment of food products – Specification for external communicational purposes on the Finnish market)* or other Annexes are mentioned with the references.

Table 2.1. The most common parameters in crop modelling.

Parameter	Unit	Explanation	Default value, in case no data exists
Yield	kg	fresh yield	n.a.
DRY	%	dry matter content of the harvested product	Table 2.5
Crop	kg	yield dry matter	Crop = DRY × Yield
Area	ha	area of the field plot	n.a.
$Area_{burnt}$	ha	area of the field plot where crop residues are burnt	0
F_{SN}	kg N	synthetic N fertilizer, as total N	n.a.
F_{ON}	kg N	manure and other organic fertilizer, as total N	n.a.
F_{PRP}	kg N	amount of N in urine and dung inputs to grazed pastureland, as total N	n.a.
F_{CR}	kg N	amount of N in crop residues, as total N	n.a.
F_{SOM}	kg N	amount of N mineralized from mineral soils (in association with loss of soil C from soil organic matter), as total N	n.a.

n.a. = not applicable

2. CO_2 emissions from liming and urea

2.1 CO_2 emissions from liming

$$CO_2\_liming = ((M_{limestone} \times EF_{limestone}) + (M_{dolomite} \times EF_{dolomite})) \times 44/12$$

source: IPCC (2006b), Eq. 11.12

$$CO_2\_liming\_annual = CO_2\_liming / Liming\_period$$

where,

CO_2_liming	direct CO_2 emissions from liming (kg CO_2/ha)
$M_{limestone}$	amount of calcic limestone (kg/ha)
$M_{dolomite}$	amount of dolomite (kg/ha)
$EF_{limestone}$	emission factor for limestone (kg CO_2-C/kg limestone), see Table 2.2
$EF_{dolomite}$	emission factor for dolomite (kg CO_2-C/ kg dolomite $CaMg(CO_3)_2$), see Table 2.2
CO_2_liming_annual	annual CO_2 emissions from liming (kg CO_2/ha)
Liming_period	period in years between lime applications (number of years)

Table 2.2. Emission factors $EF_{limestone}$ and $EF_{dolomite}$.

Emission factor	Compartment	Value	Unit	Source
$EF_{limestone}$	Air	0.12	kg CO_2-C/kg limestone or dolomite	IPCC (2006b), section 11.3.1
$EF_{dolomite}$	Air	0.13	kg CO_2-C/kg limestone or dolomite	IPCC (2006b), section 11.3.1

2.2 CO_2 emissions from urea application

$$CO_2\_urea = (M_{urea} \times EF_{urea}) \times 44/12$$

source: IPCC (2006b), Eq. 11.13

where,

CO_2_urea	direct CO_2 emissions from urea applications (kg CO_2/ha)
M_{urea}	amount of urea fertilization (kg/ha)
EF_{urea}	emission factor (kg CO_2-C/kg urea), see Table 2.3

Table 2.3. Emission factor EF_{urea}.

Emission factor	Compartment	Value	Unit	Source
EF_{urea}	Air	0.20	kg CO_2-C/kg urea	IPCC (2006b), section 11.4.1

3. Direct N_2O emissions from managed soils (N_2O_direct)

In this chapter, both land types, cropland remaining cropland and land converted to cropland are covered.

N_2O_direct = N_2O_fertilizers + N_2O_pasture + N_2O_crop_residues + N_2O_mineral_soil + N_2O _organic_soil

source: IPCC (2006b), Eq. 11.1 (parameter names adapted)

where,

N_2O_direct	direct N_2O emissions from crop production (kg N_2O/ha)
N_2O_fertilizers	direct N_2O emissions from fertilizer (both mineral and organic fertilizers) applications, crop residues and soil nitrogen (kg N_2O/ha)
N_2O_ pasture	direct N_2O emission from urine and dung inputs to pastures (kg N_2O/ha)
N_2O_crop_residues	direct N_2O emissions from crop residues (kg N_2O/ha)
N_2O _mineral_soil	N_2O emissions associated with loss of soil organic matter (mineral soils) (kg N_2O/ha)
N_2O _organic_soil	N_2O emissions from managed organic soils[65] (kg N_2O/ha)

and

N_2O_fertilizers = $(F_{SN} + F_{ON}) \times EF_1 \times 44/28$

where,

F_{SN}	amount of synthetic fertilizer as total N (kg/ha)
F_{ON}	amount of organic fertilizer as total N (kg/ha) (manure and other organic fertilizers)
EF_1	emission factor, see Table 2.4

and

N_2O_ pasture = $F_{PRP} \times EF_3 \times 44/28$

where,

F_{PRP}	amount of N as total N (kg/ha) in urine and dung inputs to grazed pastureland, see Chapter 3.1.
EF_3	emission factor, see Table 2.4

[65] Definition for organic soils is given in Chapter 5.2.1. of the main document of this guidance.

and

$N_2O\_crop\_residues = F_{CR} \times EF_1 \times 44/28$

where,

F_{CR} amount of N in crop residues, as total N (kg/ha), see Chapter 3.2.

EF_1 emission factor, see Table 2.4

and

$N_2O\_mineral\_soil = F_{SOM} \times EF_1 \times 44/28$

where,

F_{SOM} amount of N (kg/ha) mineralized from mineral soils (in association with loss of soil C from soil organic matter), see Chapter 3.3.

EF_1 emission factor, see Table 2.4

and

$N_2O\_organic\_soil = N_2O\text{-}N_{OS} \times 44/28$

where,

$N_2O\text{-}N_{OS}$ amount of N (kg/ha) mineralized from cultivated organic soils, see Chapter 3.4.

Table 2.4. Emission factors EF_1 and EF_3.

Emission factor	Compartment	Value	Unit	Source
EF_1	Air	0.01	kg N_2O-N/kg N	IPCC (2006b), table 11.1
EF_3 for cattle, poultry, and swine	Air	0.02	kg N_2O-N/kg N	IPCC (2006b), table 11.1
EF_3 for sheep and other animals	Air	0.01	kg N_2O-N/kg N	IPCC (2006b), table 11.1

3.1 Nitrogen in urine and dung deposits on the pasture (F_{PRP})

$F_{PRP} = N_{ex} \times Pasture\_days$

source: IPCC (2006b), Eq. 11.5 (parameter names adapted)

where,

N_{ex} N excretion in urine and faeces (kg N/animal/day), see Annex 3 (Animal modelling formulas and factors) Chapter 4.

Pasture_days Length of the pasture season per year (number of days)

3.2 Nitrogen in crop residues (F_{CR})

$$F_{CR} = Frac_{renew} \times [(Area - Area_{burnt} \times C_F) \times AG_{DM} \times 1000 \times N_{AG} \times (1 - Frac_{remove}) + Area \times (AG_{DM} \times 1000 + Crop) / Crop \times R_{BG\_BIO} \times N_{BG}]$$

Source: IPCC (2006b), Eq. 11.7A

where,

F_{CR}	Amount of N, as total N (kg/ha) in crop residues
Area	Area (hectares)
$Area_{burnt}$	Total area burnt after harvest (hectares)
C_F	Combustion factor, default value 0.9 for crops in Finland (all factors available in IPCC (2006a), Table 2.6)
AG_{DM}	Above-ground residue dry matter (tonnes/ha)
N_{AG}	N content of above-ground residues (kg N/kg dry matter)
$Frac_{remove}$	Fraction of above-ground residues removed annually (for purposes such as bedding or feed) (kg N / kg N in crop) values from 0 to 1. Crop residues left on field: $Frac_{remove}$ = 0, crop residues removed: $Frac_{remove}$ = 1.
$Frac_{renew}$	Fraction of total area that is renewed annually (examples: $Frac_{renew}$ =1 for annual crops and $Frac_{renew}$ =1/5 for perennial grass renewed every 5 years)
Crop	Harvested dry matter yield for a crop (kg dry matter/ha)
R_{BG_BIO}	Ratio of below-ground residues to aboveground biomass (kg dry matter/kg dry matter)
N_{BG}	N content of below-ground residues for a crop (kg N/kg dry matter)

and

$$Crop = Yield \times Dry\_matter$$

Source: IPCC (2006b), Eq. 11.7

where

Crop	Harvested dry matter yield for a crop (kg dry matter/ha)
Yield	Harvested fresh yield[66] (kg fresh weight/ha)
Dry_matter	Dry matter content of the yield (kg dry matter/kg fresh weight). Primary data should be used, but in case it is not available, default values in Table 2.5 (DRY) shall be used as dry matter content of a crop.

and

[66] For grains, harvested fresh yield is measured in most cases after drying.

$$AG_{DM} = (Crop / 1000) \times Slope + Intercept$$

Source: IPCC (2006b), Table 11.2

where,

AG_{DM}	Above-ground residue dry matter (tonnes/ha)
Slope	Factor, crop-specific, see Table 2.5
Intercept	Factor, crop-specific, see Table 2.5

Table 2.5. Examples of default factors for calculating nitrogen in crop residues. The original table with more crops included and further information is given in IPCC (2006b), Table 11.2.

Crop	DRY	Slope	Intercept	N_{AG}	R_{BG_BIO}	N_{BG}
Major crop types						
Grains	0.88	1.09	0.88	0.006	0.22	0.009
Beans & pulses	0.91	1.13	0.85	0.008	0.19	0.008
Tubers	0.22	0.1	1.06	0.019	0.20	0.014
Root crops, other	0.94	1.07	1.54	0.016	0.20	0.014
N-fixing forages	0.90	0.3	0	0.027	0.40	0.022
Non-N-fixing forages	0.90	0.3	0	0.015	0.54	0.012
Perennial grasses	0.90	0.3	0	0.015	0.80	0.012
Grass-clover mixtures	0.90	0.3	0	0.025	0.80	0.016
Individual crops						
Wheat	0.89	1.51	0.52	0.006	0.24	0.009
Winter wheat	0.89	1.61	0.40	0.006	0.23	0.009
Spring wheat	0.89	1.29	0.75	0.006	0.28	0.009
Barley	0.89	0.98	0.59	0.007	0.22	0.014
Oats	0.89	0.91	0.89	0.007	0.25	0.008
Rye	0.88	1.09	0.88	0.005	n.a.	0.011
Potato	0.22	0.10	1.06	0.019	0.20	0.014
Non-legume hay	0.90	0.18	0	0.015	0.54	0.012

3.3 Nitrogen mineralized in mineral soils (F_{SOM})

$$F_{SOM} = (A_{rem} \times (\Delta SOC_{rem,min} \times (-1)) \times (1/R)) + (A_{conv} \times (\Delta SOC_{conv,min} \times (-1)) \times (1/R))$$

Source: IPCC (2006b), Eq. 11.8. (formula, parameter names and units adapted)

where,

A_{rem}	share of cropland remaining cropland (dimensionless). See definition in Annex 1.
$\Delta SOC_{rem,min}$	net C stock change in SOC on mineral soil, cropland remaining cropland (kg C/ha/year) (see general method in Chapter 4.8.2 of the main document of this guidance and Chapter 2.3. in Annex 1 for detailed calculation method).
R	C:N ratio of the soil. A measured value may be used, or if not available, a default value should be used. C:N ratio value used in the newest Finnish National Greenhouse Gas inventory shall be used for cultivation in Finland. The IPCC default value shall be used for the rest of the world if primary data is not available. See Table 2.6.
A_{conv}	share of land converted to cropland (within the past 20 years; dimensionless). See definition in Annex 1.
$\Delta SOC_{conv,min}$	net C stock change in SOC on mineral soil, land converted to cropland (kg C/ha/year) (see general method in Chapter 4.8.2 of the main document of this guidance and Chapter 2.2. in Annex 1 for detailed calculation method).

Table 2.6. Default values for C:N ratio (=R).

Parameter	Value	Unit	Source
R, Cropland remaining cropland, Finland	13	dimensionless	Statistics Finland (2024), section 5.4.2.1
R, Land converted to cropland, Finland	21.4	dimensionless	Statistics Finland (2024), section 6.10.3.2
R, Cropland remaining cropland, Rest of the world[67]	10	dimensionless	IPCC (2006b), Eq. 11.8
R, Land converted to cropland, Rest of the world[68]	15	dimensionless	IPCC (2006b), Eq. 11.8

[67] Alternatively, R values from the national greenhouse gas inventory of the origin country may be used, if available.
[68] Alternatively, R values from the national greenhouse gas inventory of the origin country may be used, if available.

3.4 Nitrogen mineralized in organic soils ($N_2O\text{-}N_{OS}$)

$$N_2O\text{-}N_{OS} = EF_2 \times Area$$

where,

EF_2 — emission factor for managed organic soil (remaining and converted) (kg N_2O-N/ha/year), see Table 2.7.

Area — Area of organic soil (hectares)

Table 2.7. Emission factor EF_2 for annual and perennials.

Emission factor	Compartment	Value	Unit	Source
EF_2 for annuals on organic soils	Air	13	kg N_2O-N / ha / year	IPCC (2014), Table 2.5, boreal and temperate[69]
EF_2 for perennials on organic soils	Air	9.5	kg N_2O-N / ha / year	IPCC (2014), Table 2.5, boreal[70]

4. N_2O indirect emission from volatilization and leaching

Indirect N_2O emissions in crop production include N_2O from N volatilization from synthetic fertilizers, N_2O from N volatilization from manure and other organic fertilizers and N_2O from N leaching.

$$N2O\_indirect = N2O\_indirect\_vol + N2O\_indirect\_leach$$

$$N2O\_indirect\_vol = [(F_{SN} \times Frac_{GASF}) + ((F_{ON} + F_{PRP}) \times Frac_{GASM})] \times EF_4 \times 44/28$$

$$N2O\_indirect\_leach = [(F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM} + N_2O\text{-}N_{OS}) \times Frac_{LEACH}] \times EF_5 \times 44/28$$

Source: IPCC (2006b), Eq. 11.9 and Eq. 11.10 (parameter names and formula adapted)

where,

F_{SN} — amount of synthetic fertilizer N, as total N (kg/ha)

F_{ON} — amount of organic fertilizer N, as total N (kg/ha) (manure and other organic fertilizers)

F_{PRP} — amount of N, as total N (kg/ha), in urine and dung inputs to grazed pastureland, see Chapter 3.1.

F_{CR} — amount of N, as total N (kg/ha), in crop residues, see Chapter 3.2.

F_{SOM} — amount of N, as total N (kg/ha), mineralized from mineral soils (in association with loss of soil C from soil organic matter), see Chapter 3.3.

$N_2O\text{-}N_{OS}$ — amount of N, as total N (kg/ha), mineralized from cultivated organic soils, see Chapter 3.4.

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[69] EF_2 for other regions are available in IPCC (2014) Table 2.5.

[70] In the national greenhouse gas inventory of Finland (Statistics Finland 2024), EF_2 for grassland is used for perennial grasses on cropland. EF_2 for other regions are available in IPCC (2014) Table 2.5.

EF_4	emission factor for N_2O emissions (kg N_2O-N/kg NH_3–N + NO_x–N volatilised) from atmospheric deposition of N on soils and water surfaces, see Table 2.8.
$Frac_{GASF}$	fraction of synthetic fertilizer N that volatilizes as NH_3 and NO_X (kg NH3–N + NOx–N volatilised / kg of N applied), see Table 2.9
$Frac_{GASM}$	fraction of organic N fertilizers (F_{ON}) and urine and dung N deposited by grazing animals (F_{PRP}) that volatilizes as NH_3 and NO_X (kg NH_3–N + NOx–N volatilised / kg of N applied or deposited), see Table 2.9.
EF_5	emission factor for N_2O emissions (kg N_2O-N/kg N leached and runoff) from N leaching and runoff, see Table 2.8.
$Frac_{LEACH}$	fraction of all N added to/mineralized in managed soils that is lost through leaching and runoff kg (kg N/kg of N additions), see Table 2.9.

Table 2.8. Emission factors EF_4 and EF_5.

Emission factor	Compartment	Value	Unit	Source
EF_4	Air	0.01	kg N_2O-N/kg NH_3-N + NO_X-N volatilised	IPCC (2006b), Table 11.3
EF_5	Air	0.0075	kg N_2O-N/kg N leached and runoff	IPCC (2006b), Table 11.3

Table 2.9. Fraction-parameters $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH}$.

Parameter	Compartment	Value	Unit	Source
$Frac_{GASF}$	Air	0.1	kg NH_3-N + NO_X-N/kg N applied	IPCC (2006b), Table 11.3
$Frac_{GASM}$	Air	0.2	kg NH_3-N + NO_X-N/kg N applied or deposited	IPCC (2006b), Table 11.3
$Frac_{LEACH}$	Water	0.3	kg N/kg of N additions	IPCC (2006b), Table 11.3

5. References

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ANNEX 3 - Animal modelling factors and formulas

1. General

Annex 3 describes modelling of the animal-based metabolism and manure storage emissions in Finland with the use of partly country-specific methods and parameters.

The recommended procedure for animal modelling:

1) Identification of animal groups included in the production chain.
2) Identification of the number of animals in each of the animal groups on a production unit (e.g., farm).
3) Emission calculation for animal groups (per animal/year).
4) Calculation of emissions of the production unit (per year) as a sum of animal group emissions.

The default animal group categorisation to be used is presented in Table 3.1. Also, more detailed animal group categorisation may be used if data is available. However, emission factors and default values presented in Annex 3 are only available for the default animal groups (Table 3.1).

Note: the references to specific tables and chapters in this Annex refer to this Annex (Annex 3 – Animal modelling formulas and factors). References to the main document (*Guidance for environmental footprint assessment of food products (Food-LCA) – Specification for external communicational purposes on the Finnish market)* or other Annexes are mentioned with the references.

Table 3.1. The default animal categorisation.

Main category	Sub-category	Description
Cattle	Dairy cows	
	Suckler cows	
	Heifers	
	Bulls	> 1 year
	Calves	<1 year, both female and male
Sheep	*no subcategories*	
Swine	Market swine – growing	< 8 months
	Market swine – adult	> 8 months
	Breeding swine – growing	< 8 months
	Breeding swine – adult	> 8 months
Poultry	Layers	
	Broilers	
Reindeer	*no subcategories*	

Note: The country-specific calculation formulas and factors presented in Annex 3 are based on the national greenhouse gas inventory document of Finland, the year 2024 (Statistics Finland 2024). The latest version of the National GHG Inventory Document (NID) shall always be used, i.e., the latest national default values shall be derived if available.

2. Enteric CH_4

2.1. Cattle

$CH_4\_cattle = (GE_{diet} \times Y_m \times 365) / 55.65$

source: IPCC (2006b), Eq. 10.21 (parameter names adapted), a method used in Statistics Finland (2024)

$GE_{diet} = (0.02336 \times CP_{diet} + 0.0398 \times EE_{diet} + 0.0189 \times NDF_{diet} + 0.0173 \times NFC_{diet}) \times DMI_{diet}$

source: Statistics Finland (2024) chapter 5.2.2.3. (adapted to include DMI, parameter names adapted), originally Jentsch et al. (2003)

$NFC_{diet} = 1000 - ASH_{diet} - CP_{diet} - EE_{diet} - NDF_{diet}$

source: Ramin & Huhtanen (2013) (parameter names adapted)

where,

CH_4_cattle	Methane from cattle enteric fermentation (kg CH_4/animal/year)
GE_{diet}	Gross energy intake in feed, whole diet (MJ/animal/day)
Y_m	Methane conversion rate, a fraction of gross energy in feed converted to methane (dimensionless). See Table 3.2.
55.65	Factor to convert MJ to kg CH_4.
CP_{diet}	Crude protein content of the diet (g/kg DM). Derived as described in Chapter 7 in Annex 3.
EE_{diet}	Ester extracts (i.e., crude fat[71]) content of the diet (g/kg DM). Derived as described in Chapter 7.
NDF_{diet}	Neutral detergent fibre content of the diet (g/kg DM). Derived as described in Chapter 7.
NFC_{diet}	Non-fibrous carbohydrates (i.e., non-structural carbohydrates, NSC) content of the diet (g/kg DM).
DMI_{diet}	Dry matter intake of feed, whole diet (kg DM/animal/day). Derived as described in Chapter 7.
ASH_{diet}	Ash content of the diet (g/kg DM). Derived as described in Chapter 7.

[71] "Crude fat" term used in Statistics Finland (2024).

Table 3.2. Default methane conversion rate, a fraction of gross energy in feed converted to methane.

Parameter	Value	Unit	Source
Y_m	0.065	dimensionless	IPCC (2006b) Table 10.12

2.2. Sheep and reindeer

$$CH_4\_sheep/reindeer = (GE_{diet} \times Y_m \times 365) / 55.65$$

source: IPCC (2006b), Eq. 10.21 (parameter names adapted), used in Statistics Finland (2024)

$$GE_{diet} = (0.0226 \times CP_{diet} + 0.0407 \times EE_{diet} + 0.0192 \times CF_{diet} + 0.0177 \times NFE_{diet}) \times DMI_{diet}$$

source: Statistics Finland (2024) chapter 5.2.2.3 (adapted to include DMI, parameter names adapted), based on McDonald et al. (2011)

where,

$CH_4\_sheep/reindeer$	Methane from enteric fermentation (kg CH_4/animal/year) Note: lambs younger than 2 months are not assumed to emit CH_4.
GE_{diet}	Gross energy intake in feed, whole diet (MJ/animal/day)
Y_m	Methane conversion rate, a fraction of gross energy in feed converted to methane. See Table 3.3.
55.65	factor to convert MJ to kg CH_4.
CP_{diet}	Crude protein content of the diet (g/kg DM). Derived as described in Chapter 7.
EE_{diet}	Ester extracts (i.e., crude fat) content of the diet (g/kg DM). Derived as described in Chapter 7.
CF_{diet}	Crude fibre content of the diet (g/kg DM). Derived as described in Chapter 7.
NFE_{diet}	Nitrogen free extracts content of the diet (g/kg DM). Derived as described in Chapter 7.
DMI_{diet}	Dry matter intake of feed, whole diet (kg DM/animal/day). Derived as described in Chapter 7.

Table 3.3. Default methane conversion rate, a fraction of gross energy in feed converted to methane.

Parameter	Value	Unit	Source
Y_m	0.06	dimensionless	Statistics Finland (2024)

2.3. Swine

CH_4_swine = ((Age factor + 0.02997 × CF% + Interaction × CF%) × Feed units × 365) / 55.65

source: Statistics Finland (2024) Chapter 5.2.2.3. (formula structure and parameter names adapted)

Feed units = (NE_{diet} × DMI_{diet}) / 9.3

where,

CH_4_swine	Methane emission from enteric fermentation (kg CH_4/animal/year)
Age factor	Coefficient. See Table 3.4.
CF%	Crude fibre content of the diet (%). Derived as described in Chapter 7. Note: g/kg DM shall be converted to % (e.g., 20 g/kg DM = 2%).
Interaction	Coefficient. See Table 3.4.
Feed units	Amount of feed units fed (kg/animal/day). 1 feed unit = 9.3 megajoules (MJ) (MTT 2006). MJ content of the feed is derived as described in Chapter 7.
55.65	Factor to convert MJ to kg CH_4
NE_{diet}	Net energy content of the diet (MJ/kg DM). Derived as described in Chapter 7.
DMI_{diet}	Dry matter intake of feed, whole diet (kg DM/animal/day). Derived as described in Chapter 7.
9.3	Factor to convert MJ into feed units. Based on MTT (2006) used in Statistics Finland (2024).

Table 3.4. Dimensionless default values to be used in the calculation of methane from enteric fermentation (swine).

Parameter	Value	Unit	Source
Age factor – growing pigs	0.004479	dimensionless	Statistics Finland (2024), Chapter 5.2.2.3.
Age factor – adult pigs	0.01075		Statistics Finland (2024), Chapter 5.2.2.3.
Interaction – growing pigs	-0.01748		Statistics Finland (2024), Chapter 5.2.2.3.
Interaction – adult pigs	0.00		Statistics Finland (2024), Chapter 5.2.2.3.

3. Manure CH_4

3.1. Methane emissions – all animals

CH_4_manure = CH4_indoor + CH4_pasture

CH_4_indoor = VS × B_0 × 0.67 × ∑ ((MCF_S / 100) × MS_S) × (365 – pasture_days)

CH_4_pasture = VS × B_0 × 0.67 × $MCF_{pasture}$ / 100 × pasture_days

source: IPCC (2006b) Eq. 10.23 (parameter names and formula adapted), used in Statistics Finland (2024) for cattle and sheep.

where,

CH_4_manure	Methane from manure management (kg CH_4/animal/year)
CH_4_indoor	Methane from manure management indoors (kg CH_4/animal/year)
CH_4_pasture	Methane from manure deposited on pasture (kg CH_4/animal/year)
VS	Volatile solid excretion on a dry organic matter basis (kg VS/animal/day). See Chapter 3.2 for cattle and sheep and 3.3 for swine, poultry and reindeer.
B_0	Maximum methane-producing capacity of the manure (m^3 methane/kg VS). See Table 3.5.
0.67	Factor to convert m^3 into kg
MCF_S	Methane conversion factors for each manure management system (MS) S (%). See Table 3.6.
MS_S	Fraction of manure handled using manure management system S (dimensionless). Derived from primary data.
$MCF_{pasture}$	Methane conversion factors for manure deposited on pasture (%). See Table 3.6.
Pasture_days	Length of the pasture season per year (number of days).

Table 3.5. Default values for B_0.

Parameter	Value							Unit	Source
	Dairy cow	Other cattle	Sheep	Swine	Poultry (layers)	Poultry (broilers)	Reindeer		
B_0	0.24	0.18	0.19	0.45	0.39	0.36	0.19	m^3 methane/kg VS	IPCC (2006b), Table 10A4–10A9; Western Europe or developed countries

Table 3.6. Default values for MCF_S.[72]

Manure management system (MS)	MCF_S	Unit	Source
Slurry without natural crust or floating cover	17	%	IPCC (2006b), Table 10.17 (Cool temperature, <=10 °C)- Also in Statistics Finland (2024), Table 5.3-7.
Slurry with natural crust or floating cover	10		
Solid storage (incl. urine)	2		
Deep litter (cattle, swine)	17		
Deep litter (poultry)	1.5		
Deep litter (sheep, goats, horses)	1		
Dry lot	1		
Pasture (=$MCF_{pasture}$)	1		
Reindeer	2		IPCC (2006b), Table 10A–9. Also in Statistics Finland (2024), Table 5.3-7.

3.2. VS for cattle and sheep

$$VS = (GE_{diet} \times (1 - (DE\% / 100)) + (UE \times GE)) \times ((1 - (ASH_{diet} / 1000)) / 18.45)$$

source: IPCC (2006b) Eq. 10.24. (parameter names and units adapted), used in Statistics Finland (2024)

where,

VS	Volatile solid excretion on a dry organic matter basis (kg VS/animal/day).
GE_{diet}	Gross energy intake in feed, whole diet (MJ/animal/day) (see chapter 2.1 for cattle and 2.2 for sheep)
DE%	Digestible energy, i.e., the proportion of gross energy in the feed not excreted with faeces (%). See Table 3.7 for sheep and calculation later in the chapter 3.2 for cattle. Note: the value is presented as % (e.g., 20%), not as g/kg DM or kg/kg DM.
(UE × GE)	Urinary energy expressed as a fraction of GE (dimensionless). See Table 3.8.
ASH_{diet}	Ash content of the diet (g/kg DM). Derived as described in Chapter 7.
1000	Value to convert ASH from g/kg DM to kg/kg DM.
18.45	Conversion factor for dietary GE per kg dry matter (MJ/kg).

[72] Detailed description of the manure management systems in IPCC (2006b), Table 10.17.

Table 3.7. Default values for DE% for sheep.

Parameter	Value	Unit	Source
DE% – pasture-fed (and fed with high-quality forage)[73]*	65	%	IPCC (2006b), Table 10.2. Values are medians of DE% ranges presented in the table.
DE% – fed with low-quality forage**	50	%	

* Typically includes lamb, young sheep less than 7–9 months and lactating ewes.

** Typically includes breeding animals outside breeding and lactation season.

Table 3.8. Default values for UE × GE.

Parameter	Value	Unit	Source
UE × GE – ruminants	0.04	dimensionless	IPCC (2006b), Chapter 10.4.2
UE × GE – ruminants fed with ≥85% grain	0.02		

DE% calculation for cattle:

$$DE\% = (-11.3 + 0.977 \times OMd_{diet}) \times 0.1$$

source: Ramin & Huhtanen (2013) (parameter names adapted), used in Statistics Finland (2024)

where,

DE% Digestible energy, i.e., the proportion of gross energy in the feed not excreted with faeces (%). Note: the value is presented as % (e.g., 20%), not as g/kg DM or kg/kg DM.

OMd_{diet} Digestibility of organic matter, whole diet (g/kg). Derived as described in Chapter 7.

3.3. VS for swine, poultry, and reindeer

See Table 3.9 for VS defaults to be used.

Table 3.9. Dimensionless default values to be used in the calculation of methane from enteric fermentation.

Parameter	Unit	Value	Source
VS – market swine	kg VS/animal/day	0.30	IPCC (2006b) Table 10A-7 and Table10A-8, Western Europe
VS – breeding swine	kg VS/animal/day	0.46	IPCC (2006b) Table 10A-7 and Table10A-8, Western Europe
VS – layers	kg VS/animal/day	0.02	IPCC (2006b) Table 10A-9, Developed countries
VS – broilers	kg VS/animal/day	0.01	IPCC (2006b) Table 10A-9, Developed countries
VS – reindeer	kg VS/animal/day	0.39	IPCC (2006b) Table 10A-9.

[73] In IPCC (2006b) Table 10.2, only DE% - pasture-fed is mentioned. Here, the category is specified to include also animals fed with high-quality forage. Also, the typical animal categories fed with different forage types are specified here unlike in IPCC (2006b).

4. N excretion

In this Chapter, the calculation of N excretion in manure is instructed for all animal groups. N excretion is further used in the calculation of N_2O emissions from manure storage (Chapter 5), as well as from manure spreading and manure excreted on pasture (Annex 2, Crop modelling formulas and factors).

$$N_{ex} = N_{intake} \times (1 - N_{retention})$$

source: IPCC (2006b) Eq. 10.31 (units and parameter names adapted)

$$N_{intake} = DMI_{diet} \times ((CP_{diet} / 6.25) / 1000)$$

where,

N_{ex}	N excretion in urine and faeces (kg N/animal/day)
N_{intake}	Daily N intake in feed (kg N/animal/day). Derived from primary data.
$N_{retention}$	Fraction of N intake in the feed that is retained by an animal (dimensionless). See Table 3.10.
DMI_{diet}	Dry matter intake of feed, whole diet (kg DM/animal/day). Derived as described in Chapter 7.
CP_{diet}	Crude protein content of the diet (g/kg DM). Derived as described in Chapter 7.
6.25	Factor to convert from CP to N
1000	Factor to convert g into kg.

Table 3.10. Default values for $N_{retention}$.

Parameter	Value						Unit	Source
	Dairy cow	Other cattle	Sheep	Swine	Poultry	Reindeer*		
$N_{retention}$	0.20	0.07	0.10	0.30	0.30	0.10	dimensionless	IPCC (2006b) Table 10.20.

* No default N retention available for reindeer. The default value for goats (0.10) shall be used for reindeer to align with the methodology in Statistics Finland (2024). Alternatively, a default N_{ex} of 0.03 kg N/animal/day may be used for reindeer (Statistics Finland 2024, Table 3_App_5a).

5. Manure N_2O

In this Chapter, the calculation related to the N_2O emissions from manure storage is instructed. The N_2O emission from manure spreading on fields and manure excreted on pasture are instructed in Annex 2 (Crop modelling formulas and factors).

5.1. Direct N_2O

$$Direct\_N2O = \sum ((N_{ex} \times (365 - Pasture\_days) \times MS_S \times EF3_S) \times 44/28)$$

source: IPCC (2006b) Eq. 10.25. (units and parameter names adapted)

where

Direct_N2O	Direct N_2O emission from manure storage (kg N_2O/animal/year)
N_{ex}	N excretion in urine and faeces (kg N/animal/day). See Chapter 4.
Pasture_days	Length of the pasture season per year (number of days).
MS_S	Fraction of manure handled using manure management system S (dimensionless). Derived from primary data.
$EF3_S$	Emission factor (kg N_2O-N/kg N) for direct N_2O emissions from manure management system *S*. See Table 3.11.
44/28	Factor to convert from N_2O-N to N_2O

Table 3.11. Manure management system (MS) categories and default values to be used for $EF3_S$.[74]

Manure management system (MS)	$EF3_S$	Unit	Source
Daily spread	0	N_2O-N/kg N	IPCC (2006b), Table 10.21
Solid storage	0.005		
Dry lot	0.02		
Liquid/slurry – with natural crust cover	0.005		
Liquid/slurry – without natural crust cover	0		
Uncovered anaerobic lagoon	0		
Pit storage below animal confinements	0.002		
Anaerobic digester	0		
Cattle and swine deep bedding – no mixing	0.01		
Cattle and swine deep bedding – active mixing	0.07		
Composting - in-vessel	0.006		
Composting – static pile	0.006		
Composting – intensive windrow	0.1		
Composting – passive windrow	0.01		
Poultry manure with litter	0.001		
Poultry manure without litter	0.001		
Aerobic treatment – natural aeration systems	0.01		
Aerobic treatment – forced aeration systems	0.005		

[74] More detailed information about the manure management systems available in IPCC (2006b), Table 10.21.

5.2. Manure storage: indirect N_2O – volatilisation (NH_3 and NO_x)

$$Indirect\_vol\_N_2O = (N_{volatilisation} \times EF_4) \times 44/28$$

source: IPCC (2006b) Eq. 10.27 (parameter names adapted)

$$N_{volatilisation} = \sum ((N_{ex} \times (365 - Pasture\_days) \times MS_S) \times (Frac_{GasMS} / 100))$$

source: IPCC (2006b) Eq. 10.26. (parameter names and units adapted)

where,

Indirect_vol_N_2O	Indirect N_2O emissions due to volatilisation of N from manure storage (kg N_2O/animal/year)
$N_{volatilisation}$	Amount of manure nitrogen that is lost due to volatilisation of NH_3 and NO_x (kg N/animal/year)
EF_4	Emission factor for N_2O emissions from N volatilisation and re-deposition. See Table 3.12.
44/28	Factor to convert from N_2O-N to N_2O
N_{ex}	N excretion in urine and faeces (kg N/animal/day). See Chapter 4.
Pasture_days	Length of the pasture season per year (number of days).
MS_S	Fraction of manure handled using manure management system *S* (dimensionless). Derived from primary data.
$Frac_{GasMS}$	Percent of managed manure nitrogen that volatilises as NH_3 and NO_x in the manure management system *S* (%). See Table 3.13.

Table 3.12. Emission factor for Indirect_vol_N_2O.

Emission factor	Value	Unit	Source
EF_4	0.01	kg N_2O-N/kg NH_3-N +NO_x-N	IPCC (2006c) Table 11.3

Table 3.13. Default values for $Frac_{GasMS}$.

Manure management system (MS)	$Frac_{GasMS}$					Unit	Source
	Dairy cow	Other cattle	Sheep	Swine	Poultry		
Anaerobic lagoon	35	-	-	40	40	%	IPCC (2006b) Table 10.22.
Pit storage	28	-	-	25	-		
Deep bedding		30	25	40	-		
Liquid/slurry	40		-	48	-		
Solid storage	30	45	12	45	-		
Daily spread	7	-	-	-	-		
Poultry without litter	-	-	-	-	55		
Poultry with litter	-	-	-	-	40		
Dry lot	20	30	-	-	-		

5.3. Manure storage: indirect N_2O – leaching/runoff

$$Indirect\_leach\_N_2O = (N_{leach} \times EF_5) \times 44/28$$

source: IPCC (2006b) Eq. 10.29 (parameter names adapted)

$$N_{leach} = N_{ex} \times (365 - Pasture\_days) \times MS_{dry\_lot} \times Frac_{leachMS}$$

source: IPCC (2006b) Eq. 10.28. (parameter names and units adapted)

where,

$Indirect\_leach\_N_2O$	indirect N_2O emissions due to leaching of N from manure storage (kg N_2O/animal/year)
N_{leach}	Amount of manure nitrogen that is lost due to leaching/runoff (kg N_2O/animal/year).
EF_5	Emission factor for N_2O emissions from N volatilisation and re-deposition. See Table 3.14.
44/28	Factor to convert from N_2O-N to N_2O
N_{ex}	N excretion in urine and faeces (kg N/animal/day). See Chapter 4.
Pasture_days	Length of the pasture season per year (number of days).
MS_{dry_lot}	Fraction of N_{ex} in dry lot (dimensionless). In Finland, only leaching from dry lots is included in the calculations. Other manure management systems are considered not to cause N leaching/runoff in compliance with Finnish environmental legislation (Statistics Finland 2024).
$Frac_{leachMS}$	Fraction of managed manure nitrogen losses due to runoff and leaching during storage of manure (dimensionless). The default value = 0.144 (Statistics Finland 2024).

Table 3.14. Emission factor for $Indirect\_leach\_N_2O$.

Emission factor	Value	Unit	Source
EF_5	0.011	kg N_2O-N / kg N leaching/runoff	Statistics Finland (2024) Chapter 5.3.2.3., originally from IPCC (2019)

5.4. Manure storage: N leaching/runoff

$N_{leach} = N_{ex} \times (365 - Pasture\_days) \times MS_{dry\_lot} \times Frac_{leachMS}$

source: IPCC (2006b) Eq. 10.28. (parameter names and units adapted)

where,

N_{leach}	Amount of manure nitrogen that is lost due to leaching/runoff (kg N_2O/animal/year).
N_{ex}	N excretion in urine and faeces (kg N/animal/day). See Chapter 4.
Pasture_days	Length of the pasture season per year (number of days).
MS_{dry_lot}	Fraction of N_{ex} in dry lot (dimensionless). In Finland, only leaching from dry lots is included in the calculations. Other manure management systems are considered not to cause N leaching/runoff in compliance with Finnish environmental legislation (Statistics Finland 2024).
$Frac_{leachMS}$	Fraction of managed manure nitrogen losses due to runoff and leaching during storage of manure (dimensionless). The default value = 0.144 (Statistics Finland 2024).

6. Fish farming

6.1. Nitrogen emissions

$Fish\_N_2O = EF \times N_{surplus} \times 44/28$

source: IPCC (2006a) (parameter names and units adapted)

$N_{surplus} = 10 \times fcr \times N_{diet} - N_{fish}$

source: Mäkinen & Ruohonen (1992) (parameter names adapted)

$N_{diet} = (CP_{diet} / 6.25) / 10$

$N_{emission\_fish} = N_{ex\_fish} - (Fish\_N_2O / 44/28)$

where,

$Fish\_N_2O$	N_2O emissions from fish farming, including direct and indirect N_2O (kg N_2O/tonne of produced fish)
EF	Emission factor of N_2O (kg N_2O-N/kg N). Default: 0.005 kg N_2O-N/kg N (IPCC 2006a)
$N_{surplus}$	N surplus in fish farming (kg N/tonne of produced fish)
44/28	Factor to convert N_2O-N into N_2O
fcr	Feed conversion ratio
N_{diet}	N content of feed, whole diet (%).
N_{fish}	N content of fish (kg N/tonne of produced fish). Default value: 27.5 kg N/tonne of produced fish (Seppälä et al. 2001)

CP_{diet}	Crude protein content of the diet (g/kg DM). Derived as described in Chapter 7.
6.25	Factor to convert CP into N
10	Factor to convert g/kg into %
$N_{emission\_fish}$	N emissions from fish farming to water (kg N/tonne of produced fish)

6.2. Phosphorus emissions

$$P_{emission\_fish} = 10 \times fcr \times P_{diet} - P_{fish}$$

source: Mäkinen & Ruohonen (1992) (parameter names adapted)

where,

$P_{emission\_fish}$	P emissions from fish farming to water (kg P/tonne of produced fish).
fcr	Feed conversion ratio
P_{diet}	P content of feed, whole diet (%). Derived as described in Chapter 7. Note: g/kg DM shall be converted to % (e.g., 20 g/kg DM = 2%).
P_{fish}	P content in fish (kg/tonne of produced fish). Default value: 4 kg P/tonne of produced fish (Seppälä et al. 2001).

7. DM, DMI and feed quality parameters

The DM content of the feed components ($DM_{component,i}$) shall be derived from the primary data. The DM content of the whole diet (DM_{diet}) shall be calculated as:

$$DM_{diet} = \sum (DM_{component,\,i} \times (feed\_intake_{component,\,i} \,/\, feed\_intake_{diet}))$$

where,

DM_{diet}	Dry matter content of the whole diet (g/kg), weighted average of all feed components.
$DM_{component,i}$	Dry matter content of a feed component *i* (g/kg). From primary data.
$feed\_intake_{component,i}$	Intake of a feed component *i* on wet basis (kg/animal/day). From primary data.
$feed\_intake_{diet}$	Intake of feed, whole diet on wet basis (kg/animal/day). From primary data.

The dry matter intake (kg DM/animal/day) of the different feed components ($DMI_{component,i}$) and the whole diet (DMI_{diet}) shall be derived from primary data. In case $DMI_{component,i}$ and/or DMI_{diet} are not directly available as primary data, they may be derived from primary data as follows:

$$DMI_{component,i} = DM_{component,i} \times feed\ intake_{component,i} / 1000$$

$$DMI_{diet} = \sum(DMI_{component,i})$$

where,

$DMI_{component,I}$	Dry matter intake of a feed component *i* (kg DM/animal/day).
$DM_{component,i}$	Dry matter content of a feed component *i* (g/kg). From primary data.
$feed\_intake_{component,i}$	Intake of a feed component *i* on wet basis (kg/animal/day). From primary data.
1000	Factor to convert g into kg
DMI_{diet}	Dry matter intake of feed, whole diet (kg DM/animal/day).

The feed quality parameters (CP, EE, NDF, ASH, NFE, CF, NE and OMd) shall be derived for all the feed components and the full diet (Table 3.15) preferably from primary data. If primary data is not available, Luke feed tables (https://px.luke.fi/PxWeb/pxweb/en/maatalous/maatalous__rehutaulukot/)[75] shall be used.

The quality parameters shall be first defined for the different feed components, and then, a weighted average of all the feed components shall be calculated. The weighting shall be done by the DM intake, based on the share of DM intake from each of the feed components.

An example of the calculation of CP (to be applied similarly for all feed quality parameters):

$$CP_{diet} = \sum (CP_{component,\ i} \times (DMI_{component,\ i} / DMI_{diet}))$$

where,

CP_{diet}	Crude protein content of the diet (g/kg DM), weighted average of all feed components
$CP_{component}$	Crude protein content of a feed component *i* (g/kg DM)
$DMI_{component}$	Dry matter intake of a feed component *i* (kg DM/animal/day)
DMI_{diet}	Dry matter intake of feed, whole diet (kg DM/animal/day)

[75] Always the latest version of the Luke feed tables shall be used.

Table 3.15. The feed quality parameters to be derived for the calculations from primary data and/or Luke Feed Tables.

Parameter	Description	Unit	Where the parameter is used (chapter)
CP_{diet}	Crude protein content of the diet	g/kg DM	2.1., 2.2., 4.
EE_{diet}	Ether extracts content of the diet	g/kg DM	2.1., 2.2.
NDF_{diet}	Neutral detergent fibre content of the diet	g/kg DM	2.1.
ASH_{diet}	Ash content of the diet	g/kg DM	2.1., 3.2.
NFE_{diet}	Nitrogen free extracts content of the diet	g/kg DM	2.2.
CF_{diet}	Crude fibre content of the diet	g/kg DM	2.2.
NE_{diet}*	Net energy content of the diet	MJ/kg DM	2.3.
OMd_{diet}	Digestibility of organic matter, whole diet	g/kg**	3.2.
P_{diet}	P content of feed, whole diet (%)	%***	6.2.

* In Luke Feed tables, separate values are given for different swine age groups (NE_{grow} and NE_{adult}). The correct NE values for different age groups shall be derived from Luke Feeb tables.
**note the unit: in feed tables g/g, but here, g/kg.
***note the unit: in feed tables g/kg DM, but here, %.

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ANNEX 4 – Default data for modelling the use stage

[Based on Part D in Annex II of EC (2021)]

The following table shall be used in LCA studies unless better data is available. The data provided is based on assumptions, except if specified otherwise.

Product	Use stage assumptions per product category
Meat, fish, eggs	Chilled storage. Cooking: 10 minutes in frying pan (75% on gas and 25% electricity), 5 gram sunflower oil (incl. its life cycle) per kg product. Dishwashing of frying pan.
Milk	Chilled storage, drunk cold in 200 ml glass (i.e., 5 glasses per L milk), incl. glass life cycle and dishwashing.
Pasta	Per kg pasta cooked in pot with 10 kg water, 10 min boiling (75% on gas and 25% electricity). Boiling phase: 0.18 kWh per kg of water, Cooking phase: 0.05 kWh per minute of cooking.
Frozen dishes	Frozen storage. Cooked in oven 15 minutes at 200°C (incl. a fraction of a stove, a fraction of a baking sheet). Baking sheet rinsing: 5 L water.
Roast and ground coffee	7 g roast and ground coffee per cup Filter coffee preparation in a filter coffee machine: machine production and end of life (1.2 kg, 4380 uses, with 2 cups/use), paper filter (2 g/use), electricity consumption (33 Wh/cup) and water consumption (120 ml/cup). Machine rinsing/washing: 1 L cold water per use, 2 L hot water per 7 uses, decanter dishwashing (every 7 uses) Cup (mug) production and end of life and dishwashing Source: based on PEFCR Coffee (draft as of Feb 1, 2015)
Beer	Cooling, drunk in 33 cl glass (i.e., 3 glasses per L beer), glass production, end of life and dishwashing. See also PEFCR of beer.
Bottled water	Chilled storage. Storage duration: 1 day. 2.7 glasses per L water drunk, 260 gram glass production, end of life and dishwashing.

ANNEX 5 – LCA report template

[Based on Part E in Annex II of EC (2021)]

This Annex presents the LCA report template that shall be applied for all types of LCA studies. The template presents the mandatory report structure to be followed and the information to be reported as a non-exhaustive list. All items required to be reported by this guidance shall be included, even if they are not explicitly mentioned in this template.

Life Cycle Assessment Report
[Insert product name here]

Table of contents

Acronyms
List in this section all the acronyms used in the LCA study. The acronyms shall be provided in alphabetical order.

Definitions
List in this section all the definitions that are relevant for the LCA study.
The definitions shall be provided in alphabetical order.

1 SUMMARY
The summary shall include as a minimum the following elements:
a) The goal and scope of the study, including relevant limitations and assumptions;

b) A short description of the system boundary;

c) Relevant statements about data quality,

d) The main results of the LCIA: these shall be presented showing the results of all assessed EF impact categories (characterized). If all 16 EF impact categories are assessed, the results may be presented also normalized and weighted;

e) A description of what has been achieved by the study, any recommendation made and conclusions drawn;

To the extent possible, the summary should be written with a non-technical audience in mind and should not be longer than 3-4 pages.

2. GENERAL
The information below should ideally be placed on the front-page of the study:
a) Name of the product (including a photo),

b) Product identification (e.g. model number),

c) Product classification (CPA) based on the latest CPA list version available,

d) Company presentation (name, geographic location),

e) Date of publication of the LCA study (the date shall be written in extended format, e.g. 25 June 2015, to avoid confusion over the date format),

f) Geographic validity of the LCA study (countries where the product is consumed/sold),

g) Compliance with this guidance,

h) Conformance to other documents, additional to this guidance,

i) Name and affiliation of the verifier(s)

3. GOAL OF THE STUDY
Mandatory reporting elements include, as a minimum:
a) Intended application(s);
b) Methodological limitations;
c) Reasons for carrying out the study;
d) Target audience;
e) Commissioner of the study;
f) Identification of the verifier

4. SCOPE OF THE STUDY
The scope of the study shall identify the analysed system in detail and address the overall approach used to establish: i) reference flow, ii) system boundary, iii) list of EF impact categories, iv) additional information (environmental and technical) iv) assumptions and limitations.

4.1. Declared unit and/or reference flow

Provide at least the declared unit.

4.2. System boundary
This section shall include as a minimum:
a) All life-cycle stages that are part of the product system. In case the naming of the default life cycle stages has changed, the user shall specify to which default life cycle stage it corresponds. Document and justify if life cycle stages were split and/or new ones were added.

b) The main processes covered in each life cycle stage. The co-products, by-products and waste streams of at least the foreground system shall be clearly identified.

c) The reason for and potential significance of any exclusion.

d) A system boundary diagram with the processes that are included and those excluded, highlight those activities which falls respectively under situation 1, 2, and 3 of the Data Needs Matrix, and highlight where company-specific data are used.

4.3. Environmental Footprint impact categories
Provide a table with the list of EF impact categories, units, and EF reference package used (see http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml for further details).

For climate change, specify if the results of the three sub-indicators are reported separately in the results section.

4.4. Additional information

Describe any additional environmental information and additional technical information included in the LCA study. Provide references and exact calculations rules adopted.

Explain if biodiversity is relevant/not relevant for the product in scope.

4.5. Assumptions and limitations

Describe all limitations and assumptions. Provide list of data gaps, if any, and the way in which these gaps were filled. Provide list of proxy datasets used.

5. LIFE CYCLE INVENTORY ANALYSIS

This section shall describe the compilation of the LCI and include:
a) Screening step, if performed,

b) List and description of life cycle stages,

c) Description of modelling choices,

d) Description of allocation approaches applied,

e) Description and documentation of data used and sources,

f) Data quality requirements and rating

5.1. Screening step

Provide a description of the screening step, including relevant information regarding data collection, data used (e.g. list of secondary data sets, activity data, direct elementary flows), cut-off, and results of the life cycle impact assessment phase. Document main findings.

5.2. Modelling choices

Describe all modelling choices for the applicable aspects listed below (more can be added, when relevant):
a) Transport and logistics: all data used shall be provided in the report (e.g. transportation distance, payload, re-use rate for packaging, etc.). If default scenarios were not used in the modelling, provide documentation of all specific data used;

b) Capital goods: if capital goods are included, the report shall include a clear and extensive explanation, reporting all assumptions made;

c) Storage and retail;

d) Use stage: Product dependent processes shall be included in the system boundary of the LCA study. Product independent processes shall be excluded from the system boundary and qualitative information may be provided, see Chapter 5.5. Describe the approach taken to model the use stage (main function approach or delta approach);

e) End of life modelling;

f) Electricity use;

g) Sampling procedure (report if a sampling procedure was applied and indicate the approach taken);

h) Greenhouse gas emissions;

i) Offsets (if reported as additional environmental information).

5.3. Handling multi-functional processes

Describe the allocation rules used in the LCA study and how the modelling/calculations were made. Provide the list of all allocation factors used for each process and the detailed list of processes and datasets used.

5.4. Data collection

This section shall include as a minimum:
a) Description and documentation of all company-specific data collected:
a. list of processes covered by company-specific data indicating to which life cycle stage they belong;

b. list of resource use and emissions (i.e. direct elementary flows);

c. list of activity data used;

d. link to detailed bill of materials and/or ingredients, including substance names, units and quantities, including information on grades/ purities and other technically and/or environmentally relevant characterisation of these;

e. company-specific data collection/estimation/calculation procedures;

b) List of all secondary datasets used;

c) Modelling parameters;

d) Cut-off applied, if any;

e) Sources of published literature;

f) Validation of data, including documentation;

g) If a sensitivity analysis has been conducted, this shall be reported.

5.5. Data quality requirements and rating

Provide a table listing all processes and their situation according to the Data Needs Matrix (DNM).
Provide the DQR of the LCA study.

6. IMPACT ASSESSMENT RESULTS [CONFIDENTIAL, IF RELEVANT]

6.1. LCA results

This section shall include as a minimum:

a) Characterised results of all EF impact categories shall be calculated and reported as absolute values in the report. 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);

b) If all 16 EF impact categories are calculated, normalised and weighted results as absolute values may be reported;

c) For final products the LCIA results shall be reported for (i) the sum of all life cycle stages and (ii) the total life cycle excluding the use stage.

6.2. Additional information

This section shall include:

a) Results of the additional environmental information;

b) Results of the additional technical information.

7. INTERPRETING RESULTS

This section shall include as a minimum:

a) Assessment of the robustness of the LCA study;

b) List of most relevant impact categories, life cycle stages, processes and elementary flows (see table 5.1 below);

c) Limitations and relationship of the EF results relative to the defined goal and scope of the LCA study,

d) Conclusions, recommendations, limitations and improvement potentials.

Table 5.1. The most important impact categories, life cycle stages, processes, and elementary flows.

Item	At what level does relevance need to be identified?	Threshold
Most relevant impact categories, if all 16 impact categories are assessed	Single overall score	Impact categories cumulatively contributing at least 80% of the single overall score
Most relevant life cycle stages	For each most relevant impact category	All life cycle stages contributing cumulatively more than 80% to that impact category. If the use stage accounts for more than 50% of the total impact of a most relevant impact category, the procedure shall be re-run with the exclusion of the use stage
Most relevant processes	For each most relevant impact category	All processes contributing cumulatively (along the entire life cycle) more than 80% to that impact category, considering absolute values.
Most relevant elementary flows	For each most relevant process considering the most relevant impact categories	All elementary flows contributing cumulatively to at least 80% of the total impact of a most relevant impact category for each most relevant process. If disaggregated data are available: for each most relevant process, all direct elementary flows contributing cumulatively at least to 80% to that impact category (caused by the direct elementary flows only)

ANNEX 6 – Default loss rates per type of product

[Based on Part F in Annex II of EC (2021)]

Default loss rates per type of product during distribution and at consumer (including restaurant, etc.) (assumptions if not specified otherwise). For simplification purposes, the values for restaurant are considered the same as for consumer at home.

Retail trade sector	Category	Loss rate (incl. broken products but not products returned to the manufacturer) during distribution (overall consolidated value for transportation, storage and retail place)	Loss rate at consumer (including restaurant, etc.)
Food	Fruits and vegetables	10% (FAO 2011)	19% (FAO 2011)
	Meat and meat alternatives	4% (FAO 2011)	11% (FAO 2011
	Dairy products	0.5% (FAO 2011)	7% (FAO 2011)
	Grain products	2% (FAO 2011)	25% (FAO 2011)
	Oils and fats	1% (FAO 2011)	4% (FAO 2011)
	Prepared/processed meals (ambient)	10%	10%
	Prepared/processed meals (chilled)	5%	5%
	Prepared/processed meals (frozen)	0.6%	0.6%
	Confectionery	5%	2%
Beverages	Coffee and tea	1%	5%
	Alcoholic beverages	1%	5%
	Other beverages	1%	5%
Other	Live animals	0%	0%

Food losses at the distribution center, during transport and at retail place, and at home: assumed to be 50% trashed (i.e., incinerated and landfilled), 25% composted and 25% methanised. Product losses (excluding food losses) and packing/repacking/unpacking at distribution center, during transport and at retail place: assumed to be 100% recycled. Other waste generated at the distribution center, during transport and at the retailer (except food and product losses) such as repacking/unpacking are assumed to follow the same end of life treatment as for home waste. Liquid food wastes (as for instance milk) at consumer (including restaurant, etc.) are assumed to be poured in the sink and therefore treated in the wastewater treatment plant.

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