Product Environmental Footprint Category Rules for Fresh Produce

Version June 2025

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UNIVERSITY & RESEARCH

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REPORT
2025-038

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The primary objective of this FreshProducePEFCR is to develop a consistent and specific set of rules to calculate the environmental impact of fresh fruits and vegetables. Equally important is the objective to enable comparisons and comparative assertions in all cases where this is feasible, relevant, and appropriate. This FreshProducePEFCR should facilitate to make environmental footprint studies easier, faster, and less costly. This FreshProducePEFCR – Product Environmental Footprint Category Rules for Fresh Produce – is developed as much as possible in alignment with the most recent guidance for developing Product Environmental Footprint Category Rules (European Commission, 2021). It is, however, not fully compliant with the PEF method, as it was developed outside of the official PEF framework, and connecting to the official EF datasets (for background data) was therefore not possible.

Key words: life cycle assessment, LCA, PEFCR, fruits, vegetables, environmental impact, horticulture

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Preface

The Technical Secretariat is honoured to present the FreshProducePEFCR – Product Environmental Footprint Category Rules for Fresh Produce – report, which has been developed for two product categories: Fruits and Vegetables.

There is an increasing need for a standardised approach to measure the environmental impact of fresh produce to respond to the growing demand for sustainability data from both supply chain partners and consumers, as well as the EU ongoing work around Corporate Sustainability Reporting Directive and the Green Claims Directive.

Life Cycle Assessment (LCA) is a quantitative and science-based method to evaluate the environmental impacts of products and/or services. The European Commission launched the Product Environmental Footprint (PEF) method over 10 years ago, with the aim to harmonise the LCA methodology, make outcomes more comparable and provide less space for false claims. In addition to the PEF method, which contains the basic methodology for PEF studies, Category Rules (CRs) are developed for individual product categories. The PEFCRs provide detailed guidance for conducting PEF studies for products within that product category.

The development of this FreshProducePEFCR builds on the HortiFootprint Category Rules published in 2020 (Helmes et al., 2020), which have been widely used in the sector. The HortiFootprint Category Rules contain rules for calculating an environmental footprint of horticultural products for both ornamentals and fruits and vegetables. Following this, FreshProducePEFCR adopts the rules for calculating an environmental footprint of the most recently approved PEFCR for cut flowers and potted plants (hereinafter referred to as 'FloriPEFCR'), approved by the European Commission in 2024 (Broekema et al., 2024). The FloriPEFCR was developed during the official PEF transition phase. This FreshProducePEFCR has being developed outside of the official PEF framework, as there was no opening by the EC to develop new PEFCRs. The fresh produce sector in Europe took the initiative and endorsed the development of this harmonised methodology. This FreshProducePEFCR document is structured following the PEFCR template as provided in Annex II of the guidelines of the European Commission (European Commission, 2021) and to a large extent follows the process of developing a new PEFCR as stipulated in the guidelines. Two open public consultations have been organised to gather feedback on interim versions of this document.

The HortiFootprint Category Rules that have been used widely can now be fully replaced by the released FreshProducePEFCR and by the earlier approved FloriPEFCR. The environmental footprint of fruits and vegetables can now be performed according to the most up-to-date category rules at a European level that are as much as possible aligned with the PEF guidelines of the European Commission.

The following objectives were met when developing the FreshProducePEFCR:

- to develop a consistent and specific set of rules to calculate the relevant environmental impact
- to enable comparisons between environmental footprinting studies within the same sub-category that adhere to this PEFCR

A word of thanks goes to several professionals that helped the team in reviewing and discussing the interim versions of this document during the 1st and 2nd Open Public Consultations. This resulted in very intensive and fruitful collaborations with individual practitioners and organisations from various countries whose efforts are highly appreciated.

Stay tuned to the developments via the Freshfel Europe's project website.

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Wageningen University & Research

Abbreviations

Abbreviation	Explanation
a.i.	Active ingredient
B2B	Business to business
B2C	Business to consumer
BoM	Bill of materials
BSI	British Standards Institution
CF	Characterisation factor
CFCs	Chlorofluorocarbons
CFF	Circular Footprint Formula
CHP	Combined Heat and Power
CPA	Classification of Products by Activity
DC	Distribution centre
DHN	District Heating Network
DNM	Data Needs Matrix
DQR	Data Quality Rating
EC	European Commission
EF	Environmental Footprint
EoL	End of life
EPD	Environmental Product Declaration
FU	Functional unit
GHG	Greenhouse gas
GLO	Global
GeR	Geographical representativeness
GRI	Global Reporting Initiative
GWP	Global warming potential
ILCD	International Reference Life Cycle Data System
ILCD-EL	International Reference Life Cycle Data System – Entry Level
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCDN	Life Cycle Data Network
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
NGO	Non-governmental organisation
NMVOC	Non-methane volatile compounds
P	Precision
PCR	Product Category Rules
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules

Abbreviation	Explanation
PEF-RP	PEF study of the representative product
RER	Europe
RoW	Rest of World
RP	Representative product
SS	Supporting study
TeR	Technological representativeness
TiR	Time representativeness
TS	Technical Secretariat
UNEP	United Nations Environment Programme

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 – Environmental Footprint (EF)impact category that addresses impacts due to acidifying substances in the environment. Emissions of NO_x, NH_3 and SO_x 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.

Active ingredient (a.i.) – the biologically or chemically active component in a product, typically responsible for its intended effect

Additional environmental information – environmental information outside the EF impact categories that is calculated and communicated alongside Product Environmental Footprint (PEF) results.

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

Aggregated dataset - complete or partial life cycle of a product system that – in addition to the elementary flows (and possibly not relevant amounts of waste flows and radioactive wastes) – itemises only the product(s) of the process as reference flow(s) in the input/output list, but no other goods or services.

Aggregated datasets are also called ‘LCI results’ datasets. The aggregated dataset may have been aggregated horizontally and/or vertically.

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

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

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

Average Data – production-weighted average of specific data.

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

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

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

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 PEF study. In some sectors it is equivalent to the bill of components.

Business to business (B2B) – describes transactions between businesses, such as between a manufacturer and a wholesaler, or between a wholesaler and a retailer.

Business to consumers (B2C) – describes transactions between business and consumers, such as between retailers and consumers.

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 CO_2 and the reference unit is kg CO_2 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.

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 EF study - organisation (or group of organisations), such as a commercial company or nonprofit organisation, that finances the EF study in accordance with the PEF method and the relevant PEFCR, if available.

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 with '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.

Comparative assertion – an environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function (including the benchmark of the product category).

Comparison – a comparison, not including a comparative assertion (graphic or otherwise) of two or more products based on the results of a PEF study and supporting PEFCRs.

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.

Critical review – process intended to ensure consistency between a PEFCR and the principles and requirements of the PEF method.

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.

Delayed emissions – emissions that are released over time, e.g., through long use or final disposal stages, versus a single emission at time t.

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

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

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.

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

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

Electricity tracking[3] – the process of assigning electricity generation attributes to electricity consumption.

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[2] https://eplca.jrc.ec.europa.eu/permalink/Guide_EF_DATA.pdf
[3] https://ec.europa.eu/energy/intelligent/projects/en/projects/e-track-ii

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 (EF) impact assessment – phase of the PEF 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 (EF) impact assessment method – protocol for converting life cycle inventory data into quantitative contributions to an environmental impact of concern.

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

Environmental footprint (EF) 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.

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

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.

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.).

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

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

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

Global warming potential (GWP) – An index measuring the radiative forcing of a unit mass of a given substance accumulated over a chosen time horizon. It is expressed in terms of a reference substance (e.g., CO_2 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 EF study or the user of the EF method, and not involved in defining the scope or conducting the EF 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.

Organisation Environmental Footprint Sectorial Rules (OEFSRs) – sector-specific, life-cycle based rules that complement general methodological guidance for OEF studies by providing further specification at the level of a specific sector.

OEFSRs help to shift the focus of the OEF study towards those aspects and parameters that matter the most, and hence contribute to increased relevance, reproducibility and consistency of the results by reducing costs versus a study based on the comprehensive requirements of the OEF method. Only the OEFSRs developed by or in cooperation with the European Commission, or adopted by the European Commission or as EU acts, are recognised as in line with this method.

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).

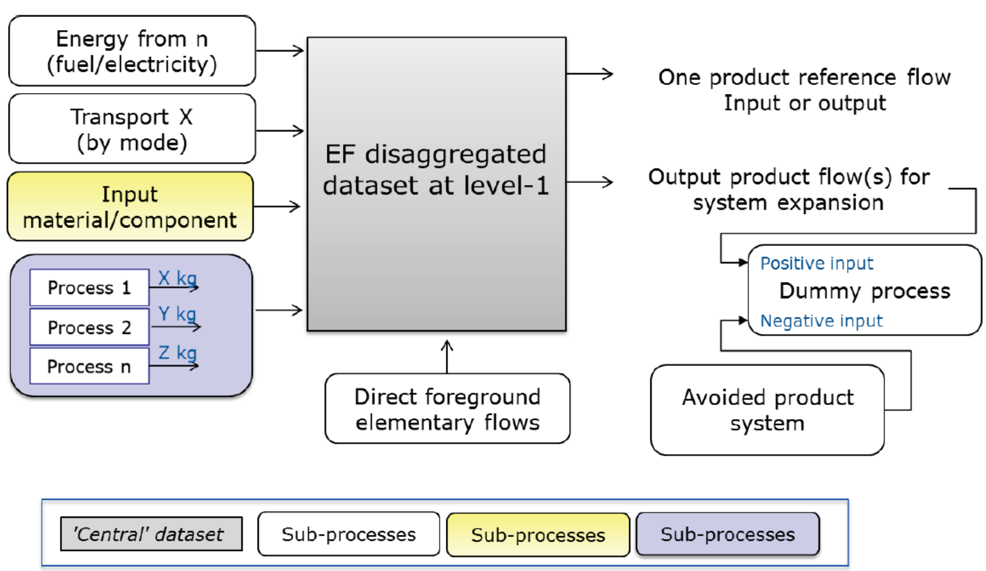

Figure 1 *Example of a dataset partially disaggregated at level 1*

Particulate matter – EF impact category that accounts for the adverse effects on human health caused by emissions of particulate matter (PM) and its precursors (NO_x, SO_x, NH_3).

PEFCR supporting study – PEF study based on a draft PEFCR. It is used to confirm the decisions taken in the draft PEFCR before the final PEFCR is released.

PEF profile – The quantified results of a PEF study. It includes the quantification of the impacts for the various impact categories and the additional environmental information considered necessary to report.

PEF report – Document that summarises the results of the PEF study.

PEF study of the representative product (PEF-RP) – PEF study carried out on the representative product(s) and intended to identify the most relevant life cycle stages, processes, elementary flows, impact categories and any other major requirements needed for to define the benchmark for the product category/ sub-categories in scope of the PEFCR.

PEF study – term used to identify all the actions needed to calculate the PEF results. It includes the modelling, data collection and analysis of the results. PEF study results are the basis for drafting PEF reports.

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 (NO_x) 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 the PEF method or user of the PEFCR.

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 the PEF method or user of the PEFCR.

In this method, 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.

PEFCRs help to shift the focus of the PEF study towards those aspects and parameters that matter most, and hence increase the relevance, reproducibility and consistency of the results by reducing costs, compared to a study based on the comprehensive requirements of the PEF method.

Only PEFCRs developed by or in cooperation with the European Commission, or adopted by the Commission or as EU acts, are recognised as being in line with this method.

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

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

Raw material – primary or secondary material used to produce a product. Reference flow – measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit.

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

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

Representative product (model) – this may be a real or virtual (non-existing) product. The virtual product should be calculated based on average European market sales-weighted characteristics for all existing technologies/materials covered by the product category or sub-category. Other weighting sets may be used, if justified – for example weighted average based on mass (ton of material) or weighted average based on product units (pieces).

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).

Review – procedure intended to ensure that the process of developing or revising a PEFCR has been carried out in accordance with the requirements provided in the PEF method and part A of Annex II.

Review report - a documentation of the review process that includes the review statement, all relevant information about the review process, the detailed comments from the reviewer(s) and the corresponding responses, and the outcome. The document shall carry the electronic or handwritten signature of the reviewer (or the lead reviewer, if a reviewer panel is involved)

Review panel – team of experts (reviewers) who will review the PEFCR.

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

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

Secondary data – data that is not from a specific process within the supply-chain of the company performing a PEF 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 a PEF 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 EF 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). Subprocesses 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 the PEF method, 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 PEF 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.

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

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

Unit process, black box – process chain or plant-level unit process. This covers horizontally averaged unit processes across different sites. Also covers multi-functional unit processes where the different co-products undergo different processing steps within the black box, hence causing allocation problems for this dataset.[4]

Unit process, single operation – unit operation type unit process that cannot be further subdivided. Covers multifunctional processes of the unit operation type.[5]

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

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

User of the PEFCR – stakeholder producing a PEF study based on a PEFCR.

User of the PEF method – stakeholder producing a PEF study based on the PEF method.

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

Utility use – the use of services like water, electricity and heat

Validation – confirmation – by the environmental footprint verifier – that the information and data in the PEF study, PEF 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 PEF 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 EF study, EF report and EF communication vehicles.

Verifier – independent external expert performing a verification of the EF 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 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 met. It assesses the potential for water deprivation, to either humans or ecosystems, based on the assumption that the less water remaining available per area, the more likely it is that another user will be deprived.

Weighting – a step that supports the interpretation and communication of the analysis results. PEF 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

The Product Environmental Footprint (PEF) method provides detailed and comprehensive technical rules on how to conduct PEF studies that are more reproducible, consistent, robust, verifiable, and comparable. Results of PEF studies are the basis for the provision of 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 sustainability programmes.

The goal of the FreshProducePEFCR is to provide a harmonised methodology for conducting environmental footprinting studies using a consistent methodology for fresh fruits and vegetables, resulting in comparable outcomes of studies on products within both sub-categories. This FreshProducePEFCR is developed to the best extent possible in compliance with Annex I and II of the Commission Recommendation (EU) 2021/2279 of 15 December 2021 on the use of the Environmental Footprint Method to measure and communicate the life cycle environmental performance of products and organisations (European Commission, 2021). Please note that certain sections of this document are directly extracted from or primarily based on Annex I and II from the *Recommendation on the use of Environmental Footprint methods* document (European Commission, 2021) and no further referencing is included.

The FreshProducePEFCR is developed outside of the official PEF framework. It is meant to conduct environmental footprinting studies for fruits and vegetables that are reproducible, consistent, robust, verifiable, and comparable, similar to studies conducted with PEFCRs for other product categories. The European Fresh Produce sector would have preferred to develop an official PEFCR, but there is currently (2025) no opening in the official PEF framework to develop new PEFCRs. Since having harmonised category rules in a sector provides great advantages and opportunities, the Fresh Produce sector has chosen to develop this 'shadow' PEFCR. Although developed outside of the official PEF framework, it is aligned to the official PEF framework as much as possible. Hereafter, this document is referred to as the FreshProducePEFCR.

Products falling within the scope of this FreshProducePEFCR may involve multiple inputs (e.g., fertilisers, growing media). If a valid PEFCR is available for the product category of the inputs, the relevant PEFCR shall be used to model the input (e.g., growing media). In cases where no valid PEFCR is available for the relevant product category, the inputs should be modelled in accordance with the FreshProducePEFCR. In the absence of detailed guidance within the FreshProducePEFCR, the PEF method shall be applied.

The compliance with the present FreshProducePEFCR is optional for PEF in-house applications, whilst it is mandatory whenever the results of a PEF study or any of its content is used for any type of external communication (i.e., communication to any interested party other than the commissioners or the practitioner of the study).

Terminology: shall, should and may
The FreshProducePEFCR uses precise terminology to indicate the requirements, the recommendations and options that could be chosen when an environmental footprinting study is conducted.

The term 'shall' is used to indicate what is required in order for an environmental footprinting study to be in conformance with the FreshProducePEFCR.

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

The term 'may' is used to indicate an option that is permissible. Whenever options are available, the environmental footprinting study shall include adequate argumentation to justify the chosen option.

Reading guide

Chapters 1 and 2 provide a general introduction and information about the FreshProducePEFCR, describing the consortium that participated in the development of the methodology, the stakeholder engagement and review process, geographic validity, language, and conformance to other documents.

Chapter 3 is about the scope and provides information specifically on topics like functional unit, system boundaries, impact assessment method, and representative products. This chapter lists product classifications that are covered by the FreshProducePEFCR. Chapter 3 also provides brief descriptions of each of the two product categories and how they were derived. Two PEF Representative Product (PEF-RP) studies have been conducted to inform important methodological decisions. The learnings from the two PEF-RP studies were used for drafting this version of the FreshProducePEFCR. One RP study was conducted for fruits (Weststrate et al., 2025b) and one for vegetables (Weststrate et al., 2025a).

Chapter 4 relates to the results obtained from the two PEF-RP studies (Weststrate et al., 2025a, 2025b), such as the most relevant impact categories, life cycle stages, processes, and direct elementary flows.

In Chapter 5, the document lists the processes to be modelled with mandatory company-specific data (i.e., activity data and direct elementary flows). This chapter also lists the data quality requirements and specifies additional criteria for the assessment of data quality for company-specific datasets. Important allocation rules applied in the calculations are also presented in this section.

Chapter 6 elaborates on the methodological rules, providing practitioners with instructions on how to define the steady state in cultivation, deal with allocation in specific instances related to the fresh produce life cycle, model electricity use, emissions of fertilisers and manure, and how to deal with the end-of-life of different products. Additionally, instructions are provided on how to develop the inventory for each life cycle stage, providing instructions on primary and secondary data to be collected.

Chapter 7 provides the results of the benchmark for each representative product. The benchmark results represent the average environmental performance of the representative product sold in the EU market and can be used for comparison. The results are characterised, normalised, and weighted (as absolute values) for fresh fruits and vegetables.

Chapter 8 is about the requirements for verification. An environmental footprint study carried out in compliance with the FreshProducePEFCR shall be done according to all the general requirements stated in the PEF method and this chapter. Verifier(s) shall verify that the environmental footprinting study is conducted in compliance.

2 General information about the FreshProducePEFCR

2.1 Technical Secretariat

The Technical Secretariat (TS) responsible for the development of the FreshProducePEFCR is composed of the following organisations (see Table 1).

Table 1 *Technical Secretariat*

Name of the organisation	Type of organisation	Name of the members
Freshfel Europe (Chair)	European Fresh Produce Association	Phillipe Binard Gil Kaufman Joanna Nathanson
Fresh Produce Centre (GroentenFruit Huis)	Trade association	Richard Schouten Nikki Hulzebos
Greenyard	Fresh produce company	Frederic Rosseneu
Dole PLC	Fresh produce company	Christoffer Carlsmose
Wageningen Social & Economic Research (TS support - Lead)	Research organisation	Jeroen Weststrate Roline Broekema Quinta Bonekamp
PRé Sustainability (TS support)	LCA Consultancy	Marisa Vieira Ellie Williams Laura Schumacher
Mérieux NutriSciences | Blonk (TS support)	LCA Consultancy	Meike Hopman Davide Lucherini

2.2 Consultations and stakeholders

The procedure for the development of a PEFCR considers a number of steps that have been followed by the TS, namely:
- Definition of the product category and scope of the FreshProducePEFCR
- PEF-RP studies
- 1st draft FreshProducePEFCR
- 1st public consultation (including review by external review panel)
- Supporting studies
- 2nd draft FreshProducePEFCR
- 2nd public consultation (including review by external review panel) and
- Final FreshProducePEFCR.

After the PEF-RP studies, the 1st public consultation with stakeholders took place in April 2024. After completion of the supporting studies, the 2nd draft FreshProducePEFCR, was submitted for public consultation in January 2025. Details of the public consultations can be found in Table 2.

After each public consultation, comments were analysed. When relevant, the FreshProducePEFCR was adapted accordingly.

Table 2 *Details of the public consultation*

	1st public consultation	2nd public consultation
Start date	2 April 2024	13 January 2025
End date	30 April 2024	10 February 2025
Duration (weeks)	4	4
Number of participating stakeholders	12	18
Number of comments	129, of which 90 unique	228, of which 190 unique
Organisations that provided comments	BelOrta cv, COLEAD, CTIFL, Growing Media Europe AISBL, Greenhouse Sustainability, Growers United, Harvest House, Hortivation, Oxin Growers, Royal ZON, VBT, Zespri International	Agromondis, Assomela, BelOrta cv COLEAD, CTIFL, Den Berk Delice, FVO, Glimpact, Greenhouse Sustainability, Growing Media Europe AISBL, INRAE, Interfel, Merieux Nutrisciences | Blonk, MPS, Port International GmbH, Technical Univeristy of Darmstad, Trinityagtech, VBT

2.3 Review panel and review requirements

During the 1st Public Consultation in the development of the FreshProducePEFCR, the FreshProducePEFCR was reviewed by a third-party review panel. The review panel was asked to conduct a review again in parallel to the 2nd Public Consultation and prior to final publication. The composition of the review panel is shown in Table 3.

Table 3 *Review panel of the FreshProducePEFCR*

Name of the member	Affiliation	Role
Johannes Lijzen Anne Hollander	RIVM National Institute for Public Health and the Environment	Chair Member
Alan Forrester	Doff Consulting	Member
Judith Brouwer	MilieuCentraal	Member

The reviewers were asked to verify that the following requirements were fulfilled:

- The FreshProducePEFCR has been developed to the best extent in accordance with the requirements provided in Annex I and Annex II of the recommendation on the use of the Environmental Footprint methods from the European Commission (2021).
- The FreshProducePEFCR supports the creation of credible, relevant and consistent environmental footprint profiles.
- The FreshProducePEFCR scope and the representative products are adequately defined.
- The functional unit, allocation and calculation rules are adequate for the product category under consideration.
- The selected additional environmental and technical information are appropriate for the product category under consideration and the selection is done in accordance with the requirements stated in the PEF method.
- The Data Needs Matrix is correctly implemented.
- The classes of performance, if identified, are appropriate for the product category.

2.4 Review statement

The review statement is included in Appendix 3.

2.5 Geographic validity

The FreshProducePEFCR is valid for products in scope sold or consumed in the European Union + European Free Trade Association (EFTA) + United Kingdom (UK). Hereinafter referred to as 'European Market'.

Each PEF study shall identify its geographical validity listing all the countries where the product object of the PEF study is consumed/sold with the relative market share. In case the information on the market for the specific product object of the study is not available, the European market shall be considered as the default market, with an equal market share for each country.

2.6 Language

The FreshProducePEFCR is written in English. The original in English supersedes translated versions in case of conflicts.

2.7 Conformance to other documents

The FreshProducePEFCR has been prepared in conformance with the following documents (in prevailing order):

- Annex I and II of the Commission Recommendation (EU) 2021/2279 of 15 December 2021 on the use of the Environmental Footprint Method to measure and communicate the life cycle environmental performance of products and organisations (European Commission, 2021). The recommendations are followed to the best extent possible, but it should be noted that this FreshProducePEFCR is developed outside of the official PEF framework.
- PEFCR for cut flowers and potted plants (FloriPEFCR) (Broekema et al., 2024) and the Hortifootprint Category Rules (Helmes et al., 2020) were used as a reference for aspects specific to horticultural systems (e.g., greenhouse construction, fertiliser modelling, CHP-unit) and to support harmonisation in the broader horticultural sector.
- Growing Media Environmental Footprint Guideline V2.0 was used as a reference for modelling the production and emissions of growing media constituents and mixes (Growing Media Europe, 2024).

The Fruits and Nuts (EPD International AB & Life Cycle Engineering Srl, 2019) and Arable and Vegetable crops (EPD International AB et al., 2020) Product Category Rules (PCR's) were consulted and evaluated in the process of developing the FreshProducePEFCR. Nevertheless, large methodological differences could not be avoided between these two PCR's and the FreshProducePEFCR. The documents are therefore not in conformance with each other. Differences include, but are not limited to, the products covered, emission calculations, functional unit, allocation strategy, and selection of impact categories.

The development of the FreshProducePEFCR involved reviewing and evaluating the methodologies and reference data from the French Agribalyse®. While this PEFCR incorporates insights from Agribalyse, such as product densities, inedible food parts, and background datasets, the two methodologies are not entirely aligned.

3 PEFCR scope

This chapter includes a description of the scope of the FreshProducePEFCR. The product classifications covered are provided, as well as the description of the representative products, which have been used to guide the development of the FreshProducePEFCR and can be used as a benchmark. The functional unit is described for both product categories: Fruits and Vegetables. A flow chart is used to describe the system boundaries. This chapter also lists the Environmental Footprint (EF) impact categories and the underlying characterisation methods to be used. Furthermore, the additional technical and environmental information which shall be provided when conducting a PEF study according to the FreshProducePEFCR are given. Limitations are provided as well as guidance in terms of comparative assertions and data gaps/proxies.

3.1 Product classification

This section lists categories and codes from the Classification of Products by Activity (CPA) that are covered by the FreshProducePEFCR. Terminology used here is from the CPA, which is not necessarily consistent with the terminology used in other parts of this document. In selecting coverage of the CPA codes by the FreshProducePEFCR, the representative products have been considered. The CPA codes for the products included in the FreshProducePEFCR are presented in Table 4.

Table 4 *CPA codes for the products included in the FreshProducePEFCR*

CPA code	Coverage by the FreshProducePEFCR
01.2 Perennial crops	
01.21 Grapes	
0806 10 10 Fresh table grapes	
0806 10 90 Fresh grapes (excl table grapes)	
01.22 Tropical and subtropical fruits	
0804 40 00 Fresh or dried avocados	Dried product not covered[6]
0803 10 10 Plantains, fresh	
0803 90 10 Bananas, fresh (excl plantains)	
0804 10 00 Fresh or dried dates	Dried product not covered[6]
0804 20 10 Fresh figs	
0804 30 00 Fresh or dried pineapples	Dried product not covered[6]
0804 50 00 Fresh or dried guavas, mangoes and mangosteens	Dried product not covered[6]
0807 20 00 Fresh pawpaws 'papayas'	
0810 60 00 Fresh durians	
01.23 Citrus fruits	
0805 40 00 Fresh or dried grapefruit	Dried product not covered[6]
0805 50 10 Fresh or dried lemons 'citrus limon, Citrus limonum'	Dried product not covered[6]
0805 10 90 Fresh or dried limes 'Citrus aurantifolia, Citrus Latifolia'	Dried product not covered[6]
0805 10 20 Fresh sweet oranges	
0805 10 80 Fresh or dried oranges (excl. fresh sweet oranges)	Dried product not covered[6]
0805 20 10 Fresh or dried clementines	Dried product not covered[6]
0805 20 30 Fresh or dried monreales and satsumas	Dried product not covered[6]
0805 20 50 Fresh or dried mandarins and wilkins	Dried product not covered[6]
0805 20 70 Fresh or dried tangerines	Dried product not covered[6]

[6] Dried products are not within the scope of this PEFCR, but they have been included in the market data used to construct the representative products due to the unavailability of data. The impact of this is judged small.

CPA code	Coverage by the FreshProducePEFCR
0805 20 90 Fresh or dried tangelos, ortaniques, malaquinas and similar citrus hybrids (excl. clementines, monreales, satsumas, mandarins, wilkings and tangerines)	Dried products not covered[6]
0805 90 00 Fresh or dried citrus fruit (excl. oranges, lemons, limes, grapefruit, mandarins, incl. tangerines and satsumas, clementines, wilkings and similar citrus hybrids)	Dried products not covered[6]
01.24 Pome fruits and stone fruits	
0808 10 10 Fresh cider apples, in bulk, from 16 September to 15 December	Not covered
0808 10 80 Fresh apples (excl cider apples, in bulk, from 16 September to 15 December)	
0808 30 10 Fresh perry pears, in bulk, from 1 August to 31 December	Not covered
0808 30 90 Fresh pears (excl. perry pears in bulk from 1 August to 31 December)	
0808 40 00 Fresh quinces	
0809 10 00 Fresh apricots	
0809 21 00 Fresh sour cherries ‘Prunus cerasus’	
0809 29 00 Fresh cherries (excl sour cherries)	
0809 30 90 Fresh peaches (excl nectarines)	
0809 30 10 Fresh nectarines	
0809 40 05 Fresh plums	
0809 40 90 Fresh sloes	
0810 90 20 Fresh tamarinds, cashew apples, lychees, jackfruit, sapodilla plums, passion fruit, carambola and pitahaya	
01.25 Other tree and bush fruits and nuts	
0810 50 00 Fresh kiwifruit	
0810 20 10 Fresh raspberries	
0810 20 90 Fresh blackberries, mulberries and loganberries	
0810 10 00 Fresh strawberries	
0810 30 10 Fresh blackcurrants	
0810 30 30 Fresh redcurrants	
0810 30 90 Fresh white currants and gooseberries	
0810 40 10 Fresh cowberries, foxberries or mountain cranberries ‘fruits of the species Vaccinium vitis-idaea’	
0810 40 30 Fresh fruit of the species Vaccinium myrtillus	
0810 40 50 Fresh fruit of species Vaccinium macrocarpum and Vaccinium carybosum	
0810 40 90 Fresh fruits of genus Vaccinium (excl of species Vaccinium vitis-idaea, myrtillus, macrocarpum and carybosum	
01.1 Non-perennial crops	
01.11.6 Green leguminous vegetables	
0708 20 00 Fresh or chilled beans ‘Vigna spp., Phaseolus ssp.’, shelled or unshelled	
0708 10 00 Fresh or chilled peas ‘Pisum sativum’, shelled or unshelled	
0708 90 00 Fresh or chilled leguminous vegetables, shelled or unshelled (excl. peas ‘Pisum sativum’ and beans ‘Vigna spp., Phaseolus spp.’)	
01.11.7 Dried leguminous vegetables	Not covered
01.13 Vegetables and melons, roots and tubers	
01.13.1 Leafy or stem vegetables	
0709 20 00 Fresh or chilled asparagus	
0704 20 00 Brussels sprouts, fresh or chilled	
0704 90 10 White and red cabbages, fresh of chilled	
0704 90 90 Kohlrabi, kale and similar edible brassicas, fresh or chilled (excl. cauliflowers, headed broccoli, Brussels sprouts, white and red cabbages)	
0704 10 00 Fresh or chilled cauliflowers and headed broccoli	
0705 11 00 Fresh or chilled lettuce	
0705 19 00 Fresh or chilled lettuce (excl. cabbage lettuce)	
0705 21 00 Fresh of chilled witloof chicory	
0705 29 00 Fresh or chilled chicory (excl witloof chicory)	
0709 70 00 Fresh or chilled spinach, New Zealand spinach and orache spinach	
0709 91 00 Fresh or chilled globe artichokes	
0709 99 10 Fresh or chilled salad vegetables (excl. lettuce and chicory)	
0709 99 20 Fresh or chilled chard ‘white beet’ and cardoons	

CPA code	Coverage by the FreshProducePEFCR
0709 99 50 Fresh or chilled fennel	
01.13.2 Melons	
0807 11 00 Fresh watermelons	
0807 19 00 Fresh melons (excl watermelons)	
01.13.3 Other fruit-bearing vegetables	
0709 60 10 Fresh or chilled sweet peppers	
0709 60 91 Fresh or chilled fruits of genus Capsicum for industrial manufacture of capsicum or capsicum oleoresin dyes	Not covered
0709 60 95 Fresh or chilled fruits of genus Capsicum or Pimenta for industrial manufacture of essential oils or resinoids	Not covered
0709 60 99 Fresh or chilled fruits of genus Capsicum or Pimenta (excl. for industrial manufacture of capsicin or capsicum oleoresin dyes, for industrial manufacture of essential oils or resinoids, and sweet peppers)	
0707 00 05 Cucumbers, fresh or chilled	
0707 00 90 Fresh or chilled gherkins	
0709 30 00 Fresh or chilled aubergines 'eggplants'	
0702 00 00 Tomatoes, fresh of chilled	
0709 93 10 Fresh or chilled courgettes	
0709 93 90 Fresh of chilled pumpkins, squash and gourds 'Cucurbita spp.' (excl. courgettes)	
0709 99 60 Fresh or chilled sweetcorn	
0709 99 90 Fresh or chilled vegetables n.e.c[7].	
01.13.4 Root, bulb or tuberous vegetables	
0706 10 00 Fresh or chilled carrots and turnips	
0703 20 00 Garlic, fresh or chilled	
0703 10 11 Onion sets, fresh or chilled	Not covered
0703 10 19 Onions, fresh or chilled (excl. sets)	
0703 10 90 Shallots, fresh or chilled	
0703 90 00 Leeks and other alliaceous vegetables, fresh or chilled (excl. onions, shallots and garlic)	
0706 90 10 Fresh or chilled celeriac 'rooted celery or German celery'	
0706 90 30 Fresh of chilled horse-radish 'Cochlearia armoracis'	
0709 90 90 Fresh or chilled salad beetroot, salsify, radishes and similar edible roots (excl. carrots, turnips, celeriac and horse-radish)	
01.13.8 Mushrooms and truffles	
0709 51 00 Fresh or chilled mushrooms of the genus 'Agaricus'	
0709 59 10 Fresh or chilled chanterelles	Not covered
0709 59 30 Fresh or chilled flap mushrooms	Not covered
0709 59 50 Fresh or chilled truffles	Not covered
0709 59 90 Fresh or chilled edible mushrooms (excl. chanterelles, flat mushrooms, mushrooms of the genus 'Agaricus' and truffles	Not covered
01.13.9 Vegetables, fresh n.e.c.	
0709 40 00 Fresh or chilled celery (excl. celeriac)	

All production systems, indoor and outdoor, in soil and soilless, are included.

The FreshProducePEFCR is about fresh produce. The scope focuses on products from these categories that are marketed as fresh produce directly to the consumer, without processing (i.e., transformation of the product itself). Cutting, slicing, and compiling of products is not seen as processing and therefore within the scope of the FreshProducePEFCR. For modelling of those 'fresh cut' products, we refer to the memo on fresh produce handling (Willems et al., 2025).

The FreshProducePEFCR covers products sold and consumed within the European market. This means it also covers products that are produced outside Europe, but are consumed in Europe (see section 2.5).

[7] Not elsewhere classified.

3.2 Representative product(s)

Two representative products are considered in the FreshProducePEFCR; one for fresh fruits and one for fresh vegetables. Both representative products are virtual (i.e., non-existing) products and reflect the average consumption of fresh fruits or vegetables (in kg/year/capita) in the European market. The representative products are considered to represent the diversity of the products on the consumer market for the two product categories.

These representative products represent what is made available at the European market for consumption (in weight units), not what is produced within the European market. Therefore, the representative products are composed from a consumption perspective, rather than a production perspective. For products that are mostly exported from, or imported to the European market, this nuance may have significant effects on the overall environmental impact of fruits and vegetables.

The consumer market assessment underlying the representative products is based on:
- The average consumption of fresh fruits at the European market (in kg/capita/year)
- The average consumption of fresh vegetables at the European market (in kg/capita/year).

This approach deviates from the preferred approach in the PEF method (selection based on average European market sales-weighted characteristics). However, average consumption tends to be the most appropriate selection criterion for fruits and vegetables. Sales-weighted characteristics are deemed to not represent the environmental footprint correctly, as they are substantially influenced by the inherent variability and fluctuations in product prices. Other agri-food related PEFCRs (e.g., feed (FEFAC, 2018) and marine fish (FHF, 2024) also adopted a mass/volume-based approach.

To determine the average consumption of fruits and vegetables per capita at product level (in kg/capita) at the European market, data were retrieved from FAOSTAT (production, population) and EUROSTAT (trade). The consumption data include inedible product parts (e.g., peels). Average consumption at the European market (in kg/year/capita) at product level for both sub-categories was calculated using the following formula:

Average EU consumption per capita (kg/year/capita) =
(European production (kg/year) - Export (Extra EU) (kg/year) + Import (intra EU) (kg/year)) / European population (capita) Equation 1

It should be noted that actual human consumption of fruits and vegetables might differ. The formula above accounts for what is coming available at the market, but some fruits and vegetables might go to other sources than human consumption (e.g., animal feed) or parts may be wasted. The impact of this limitation is judged small.

Data was collected for a time period of 5 years (2017-2021), being the latest data available at the time of conduction of the market assessment. This time period is considered to limit the impact of variations over the years (e.g., climate circumstances, price fluctuations), whilst still reflecting current consumption patterns of fruit and vegetables. Negative values were ignored. Taking into account that FAOSTAT data does not distinguish between what is destined for fresh or transformed consumption (e.g., pureed tomatoes, fruit for juice), a correction factor was applied to the production data to only account for fresh vegetables and fruits. These correction factors were delivered by TS lead Freshfel Europe and retrieved from several EC working groups.

Table 5 and Table 6 represent data on the average consumption of fruits and vegetables at the European market per sub-category. The sub-category '01.13.9 Vegetables, fresh n.e.c.'[7] was excluded from the study, as the market share was small, namely 0.2%. The other sub-categories have been corrected for the exclusion.

Table 5 *Average consumption of fruits at the European market (2017-2021), per sub-category*

Sub-categories ***(categorisation according to CPA)***	**Average consumption (in kg/capita/year)**	**Share of total consumption (in %)**
01.24 Pome fruits and stone fruits	28.09	35.5
01.23 Citrus fruits	16.78	21.2
01.22 Tropical and subtropical fruits	14.90	18.8
01.13.2 Melons	8.58	10.8
01.21 Grapes	5.69	7.2
01.25 Other tree and bush fruits	5.13	6.5
Total:	**79.16**	**100.00**

Table 6 *Average consumption of vegetables at the European market (2017-2021), per sub-category*

Sub-categories ***(categorisation according to CPA)***	**Average consumption (in kg/capita/year)**	**Share of total consumption (in %)**
01.13.3 Other fruit-bearing vegetables	22.70	42.5
01.13.1 Leafy or stem vegetables	15.85	29.7
01.13.4 Root, bulb or tuberous vegetables	10.79	20.2
01.11.6 Green leguminous vegetables	2.92	5.5
01.13.8 Mushrooms	1.18	2.2
Total:	**53.44**	**100.0**

Within each of the sub-categories, there is still a large variation of products, production systems, management practices, producing countries, transport modalities etc. To construct the representative product, the product dominating the consumption per capita at the European market (in kg/year for period: 2017-2021) in each sub-category was selected. The selected products were then traced back to country of origin. After ranking in decreasing order of production volume (kg), the production countries were selected that together reflect ≥50% of the total EU consumption (kg), starting from the top of this list.

The resulting preliminary construction of the RP was consulted with the TS. The following questions guided the selection of products within the product groups:

1. Is there any other product in the product group dominating the consumption?
2. Is there more than one dominant production country?
   i.e., if there is more than one dominant production country, more than one country of origin was included.
3. Do we expect to miss any relevant calculation rules or other requirements for any other product within the product group?
   i.e., due to a difference in production systems (e.g., open field, greenhouse)

A more detailed analysis on the construction of the representative products is available upon request to the TS coordinator that has the responsibility of distributing it with an adequate disclaimer about its limitations.

3.2.1 Fruits

For fruits, a virtual product was constituted based on six real products from various countries of cultivation. These products were selected to represent six sub-categories of fruits, namely:

- Apple, from Poland and Italy, was chosen to represent 01.24 Pome and stone fruits.
- Orange, from Spain and South-Africa, was chosen to represent 01.23 Citrus fruits. Oranges from South Africa represent only 5.8% of the market for oranges; however, following consultation with the TS, it was decided to include South Africa as a country of origin. This decision was based on the importance of South Africa as a sourcing region for the European market, particularly considering seasonality (Northern/Southern Hemisphere production window).
- Banana, from Ecuador, was chosen to represent 01.22 Tropical and subtropical fruits.
- Watermelon, from Spain, was chosen to represent 01.13.2 Melons.
- Fresh grape, from Italy, was chosen to represent 01.21 Grapes.

- Strawberry, from Spain, was chosen to represent 01.25 Other tree and bush fruits.

In Figure 2 the composition of the representative product for fruits is illustrated, including market shares that are used to calculate the environmental impact (percentages may not add up to 100% due to rounding). Market shares are based on the average consumption in kilograms, per capita-year at the European market.

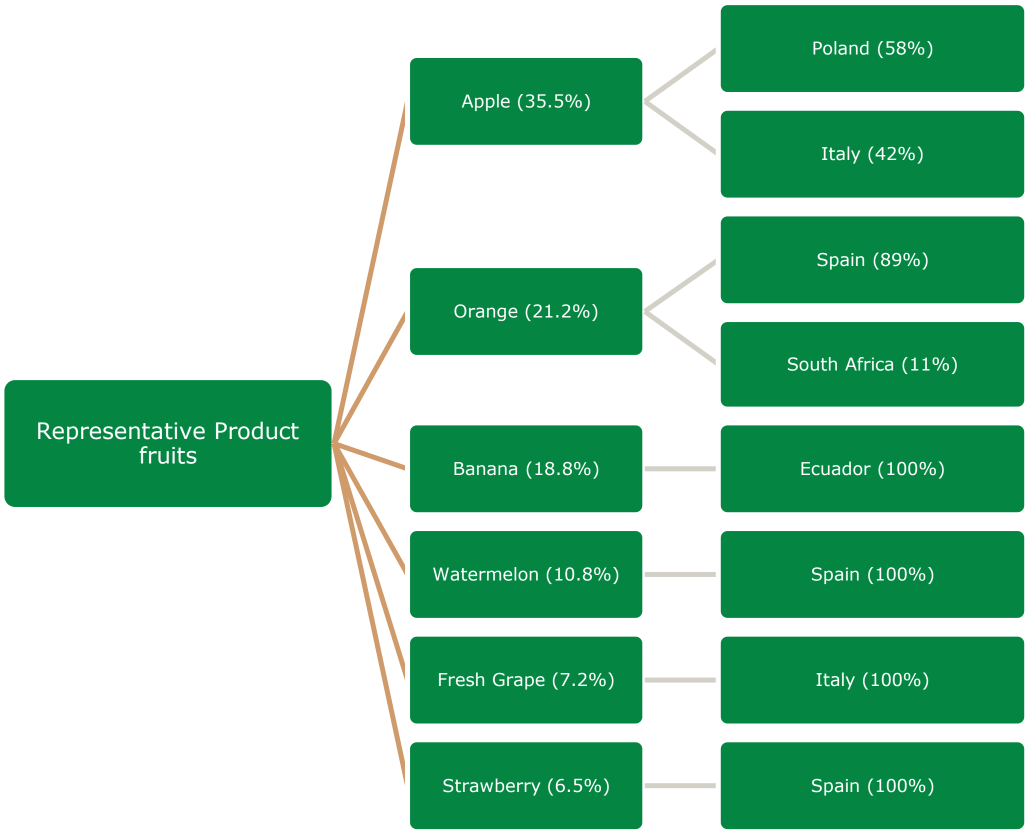

Figure 2 *Composition of the representative product fruits, including market shares that are used to calculate the environmental impact (percentages may not add up to 100% due to rounding). Market shares are based on the average consumption in kilograms, per capita-year at the European market*

3.2.2 Vegetables

The virtual representative product for vegetables is composed of five real products, from various countries of cultivation. These products were selected to represent five sub-categories of vegetables, namely:

- Tomato, from Italy, Spain and the Netherlands, was chosen to represent 01.13.3 Other fruit-bearing vegetables. This selection also includes various production techniques: open field, shade nets, glass greenhouses.
- Cabbage, from Poland, was chosen to represent 01.13.1 Leafy or stem vegetables.
- Carrot, from the Netherlands, was chosen to represent 01.13.4 Root, bulb or tuberous vegetables.
- Green bean, from France, was chosen to represent 01.11.6 Green leguminous vegetables.
- White mushroom, from the Netherlands, was chosen to represent 01.13.8 Mushrooms.

In Figure 3 the composition of the representative product for vegetables is illustrated, including market shares that are used to calculate the environmental impact (percentages may not add up to 100% due to rounding). Market shares are based on the average consumption in kilograms, per capita-year at the European market.

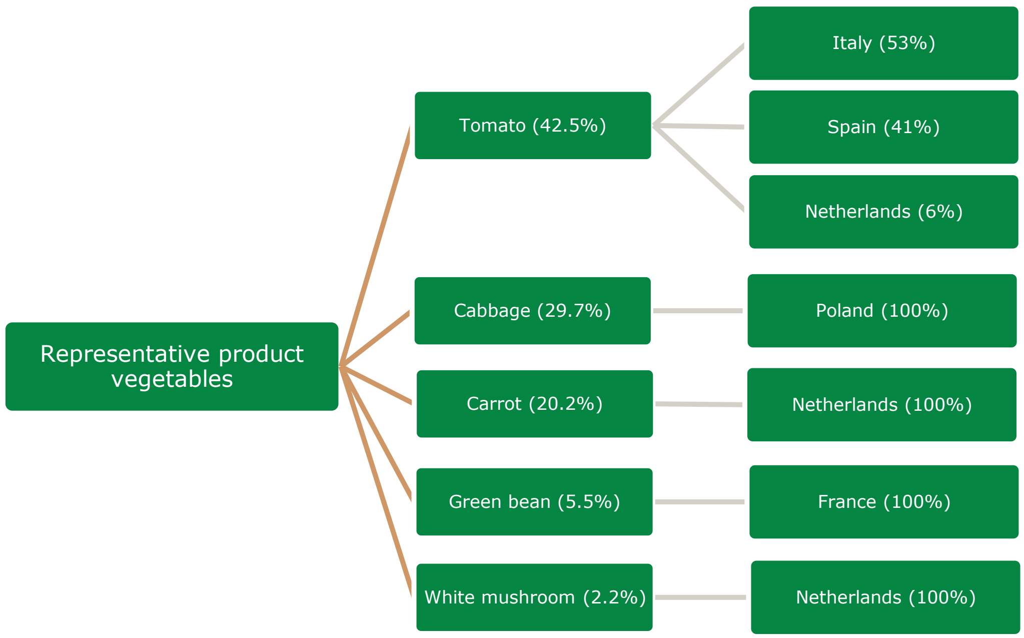

Figure 3 *Composition of the representative product vegetables, including market shares that are used to calculate the environmental impact (percentages may not add up to 100% due to rounding). Market shares are based on the average consumption in kilograms, per capita-year at the European market*

3.3 Functional unit and reference flow

The functional unit (FU) is the quantified performance of a product system, to be used as reference unit. The functional unit qualitatively and quantitatively describes the function(s) and duration of the product in scope. The reference flow is the amount of product needed to provide the defined function. All quantitative input and output data collected in the study shall be calculated in relation to this reference flow.

The reference unit for fruits:
one kilogram of consumable fresh fruit (i.e., excluding inedible parts), excluding preparation.

The reference unit for vegetables:
one kilogram of consumable fresh vegetable (i.e., excluding inedible parts), excluding preparation.

Although both sub-categories share the same reference unit, they are documented separately because results should not be compared between them. Comparisons are only valid within a sub-category (see also Section 3.8.1).

Exclusion of inedible food parts (e.g., stem) from the reference unit means additional consumable food parts are needed to fulfil the reference unit. This approach allows comparability between products with different levels of edibility within the product category.

Exclusion of the preparation (e.g., cooking) from the reference unit means that raw-to-cook ratios and product dependent and independent processes related to cooking shall not be considered (Section 6.7). The weight of the functional unit refers to the weight of edible parts before preparation and does not include moisture losses during preparation.

Food losses shall be quantified and taken into account in the life cycle stage where the loss occurs. It should be noted that the type of packaging might affect the shelf-life of fruits and vegetables. The Technical Secretariat did not find sufficient data or methods to integrate this aspect into the functional unit satisfactorily. This constitutes a deviation from the PEF method.

Table 7 provides a description of the FU, encompassing its four defining aspects: What? How much? How well? How long? The main function of fresh fruits and vegetables is to provide nutrition to humans. The magnitude of the function is 1 kilogram. Mass is used, because single nutritional aspects like fibre content or vitamin content only partly cover the function, and there is no scientifically sound and accepted way to consider all nutritional aspects in the functional unit (McLaren et al., 2021). The expected level of quality is related to the amount of inputs and outputs needed in all life cycle stages to achieve the specifications of the producer or retailer. The duration of the product provided is along the supply chain.

Table 7 *Key aspects of the functional unit*

Sub-category	Aspect detail	Fresh fruits and vegetables
What?	Function provided	To provide nutrition to humans.
How much?	Magnitude of the function	1 kg of consumable product consistent with system boundary defined (excluding packaging weight and preparation). Practitioners shall be mindful that the study correctly considers moisture losses and/or waste to correctly fulfil the functional unit at the defined system boundary (see Section 3.4).
How well?	Expected level of quality	According to the specifications on consumer packaging or information otherwise known by the consumer related to the characteristics of the specific product. Variability of longevity innate to the product or storage method shall be communicated.
How long?	Duration of the product provided	According to the specifications of the producer or the retailer, and in accordance with the specific system boundary defined.

3.4 System boundary

The life cycle stages and processes to be included in the system boundary are defined in Figure 4 and Table 8. Depending on the product subcategory (fruits or vegetables), different activity data can be applicable per life cycle stage.

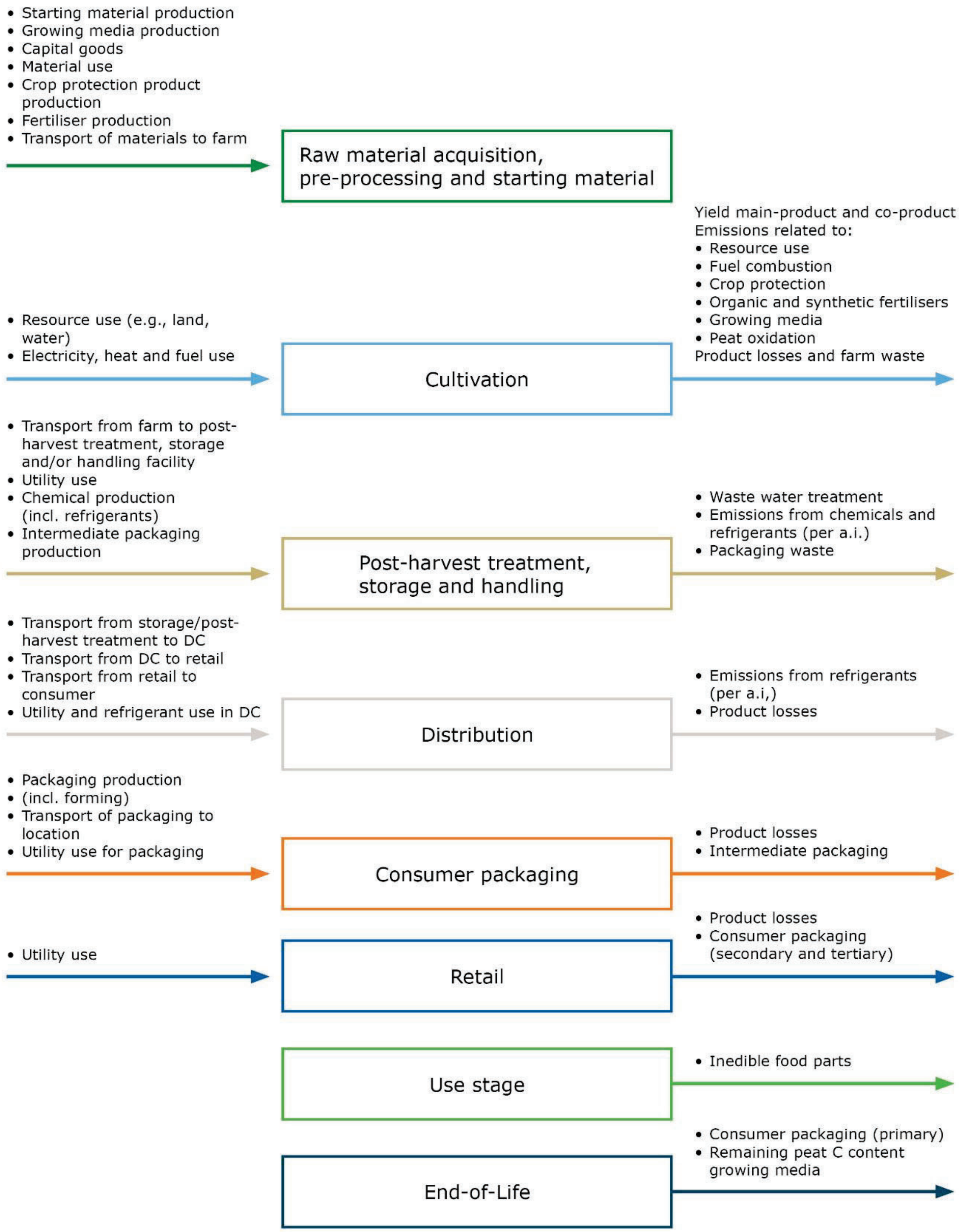

Figure 4 *Life cycle stages and processes included in the system boundaries*

Table 8 *Life cycle stages*

Life cycle stage	Short description of the processes included
Raw material acquisition, pre-processing and starting material	Considers all materials acquired for the cultivation stage (e.g., starting materials, fertilisers, crop protection products), including transport to farm. This life cycle also includes greenhouse constructions (including depreciation and maintenance) and material use (e.g., trellis systems).
Cultivation	Considers all activities related to the cultivation of fruits and vegetables. Emissions from (the use of) crop protection products, fertilisers, growing media, land use and land use change, and peat oxidation are considered in this life cycle stage. Energy used for cultivation activities and CO_2 generation via CHP on site are in this stage.
Post-harvest treatment, storage and handling	Considers all activities related to the post-harvest treatment, storage and handling of the product, including, but not limited to: transport from cultivation to storage or post-harvest treatment location, utility use, waste water treatment, chemical production and use (including refrigerants), intermediate packaging production, and waste (including the additional quantity needed to fulfil the FU). These activities might take place at different locations along the value chain, but shall all be accounted for in this life cycle stage.
Distribution	Considers all activities related to delivering the product to the final consumer, including but not limited to: all transport legs from post-harvest treatment and/or storage facility to the final consumer, utility use at the distribution centre (DC), waste of secondary and tertiary packaging and waste (including the additional quantity needed to fulfil the FU).
Consumer packaging	Considers all activities related to the production of packaging materials for consumer packaging (primary, secondary, tertiary), utility use for packaging operations, transport of packaging materials to location and waste of intermediate packaging.
Retail	This life cycle stage refers to utility use (including refrigerants) for climate control and lighting during storage for retail and the treatment of waste which occurs and the EoL of consumer packaging (secondary and tertiary).
Use stage	The waste of the inedible parts of the fresh fruit or vegetable in this stage is considered by the additional quantity that is necessary to fulfil the functional unit, including the waste treatment of these inedible parts.
End of life	Considers the EoL of the consumer packaging (primary) and Carbon from growing media.

According to this FreshProducePEFCR, the following processes may be excluded based on the cut-off rule:[8]

- The production of capital goods, other than (if applicable):
  - Greenhouses
  - Geothermal heat installations
  - District heating network (DHN)
  - Primary, secondary, and tertiary packaging used, other than during distribution and/or consumer packaging of the product under study, e.g., the packaging of fertilisers
- Chemical agents and/or materials used for cleaning purposes and not in direct contact with the product under study (unless specified otherwise).

No additional cut-off is allowed.

Each environmental footprint study done in accordance with the FreshProducePEFCR shall provide in the report a diagram indicating the activities falling in situation 1, 2, or 3 of the data needs matrix (see Section 5.4 for more information).

3.5 List of EF impact categories

Each environmental footprint study carried out in compliance with the FreshProducePEFCR shall calculate the environmental footprint profile including all EF impact categories and underlying characterisation models as listed in Table 9.

The impact categories vary in terms of robustness. The European Commission classifies the EF impact categories into three groups, ranging from more robust (I) to less robust (III). The robustness of each

[8] Processes and elementary flows may be excluded up to 3.0% (cumulatively) based in material and energy flows and the level of environmental significance (single overall score) (European Commission, 2021).

impact category is indicated in column 5 of Table 9. These differences in robustness have been accounted for in the weighting factors provided by the European Commission.

Table 9 *List of the impact categories to be used to calculate the environmental footprint profile*

EF Impact category	Impact Category Indicator	Unit	Characterisation model	Robustness (I= robust, II = medium robust, III = not robust)
Climate change (total) *Sub-category:* • Biogenic • Fossil • Land use and LU change	Radiative forcing as global warming potential (GWP100)	kg CO_2 eq	Bern model – Global warming potentials (GWP) over a 100-year time horizon (based on IPCC (2021)).	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 ((World Meteorological Organisation (WMO), 2014) + integrations)	I
Human toxicity, cancer	Comparative Toxic unit for humans (CTU_h)	CTU_h	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)	CTU_h	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) and Frischknecht et al. (2000)	II
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC eq	LOTUS-EUROS model (van Zelm et al., 2008) as applied in ReCiPe 2008)	II
Acidification	Accumulated Exceedance (AE)	mol H^+ eq	Accumulated exceedance (Seppälä et al., 2006; Posch et al., 2008)	II
Eutrophication, terrestrial	Accumulated Exceedance (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 2008)	II
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N eq	EUTREND model (Struijs et al., 2009 as applied in ReCiPe 2008)	II
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTU_e)	CTU_e	Based on USEtox2.1 model (Fantke et al., 2017), adapted as in Saouter et al. (2018)	III
Land use[9]	Soil quality index[10]	Dimensionless (pt)	Soil quality index based on LANCA model (De Laurentiis et al., 2019) and LANCA CF version 2.5 (Horn and Maier, 2018)	III
Water use	User deprivation potential (deprivation weighted water consumption)	m^3 world eq	Available WAter REmaining (AWARE) model (Boulay et al., 2018; UNEP, 2016))	III
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq	van Oers et al. (2002) as in CML methods, v.4.8.	III
Resource use, fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)[11]	MJ	van Oers et al. (2002) as in CML methods, v.4.8.	III

[9] Refers to occupation and transformation.

[10] 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 LANCA model as indicators for assessing impacts due to land use as reported in De Laurentiis et al. (2019).

[11] 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.

The EF impact assessment includes four steps: classification, characterisation, normalisation, and weighting. Results of a PEF study shall be calculated and reported in the PEF report as characterised, normalised, and weighted results for each EF impact category, and as single overall score. Results shall be reported for the total life cycle.

The EF impact category 'Climate Change, total' is constituted of three sub-categories: Climate Change, fossil; Climate Change, biogenic; and Climate Change, land use and land use change. The sub-indicators are further described in Section 5.9. The sub-categories Climate Change, fossil; Climate Change, biogenic; and Climate Change, land use and land use change shall be reported separately if one of the individual sub-categories show of more than 5% to the total score of climate change indicator. Due to the intrinsic uncertainty of some of the sub-indicators, the TS recommends to report the sub-indicators separately, independent from the results.

The EF reference package v3.1 shall be used. The full list of characterisation factors is available here: http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml. The user of this FreshProducePEFCR is responsible for ensuring that all substances used in the LCA model are (correctly) implemented in the LCA software employed for the PEF study.

Normalisation and weighting are required steps of the Life Cycle Impact Assessment (LCIA). Those steps enable the aggregation of LCA results into a single score, giving different weight to the different environmental impacts. The full list of normalisation factors and weighting factors are available in Appendix 1.

3.6 Additional technical information

A large variety of fruits and vegetables are available on the market, which might raise questions in terms of comparability of outcomes of analyses using the FreshProducePEFCR.

To allow further interpretation, several characteristics of the product under study shall be reported, namely:
- The expected shelf-life of the product under study (in days), including the amount and type of primary packaging material. In case the type of packaging affects the shelf-life of the product under study, the user of the FreshProducePEFCR may indicate the potential effects of primary packaging on food waste.
- The production and use of biological pest control is not (yet) captured in the FreshProducePEFCR. If biological pest control is used, this shall be reported together with the amount and type of biological pest control. If no biological pest control is used this shall be reported.

3.7 Additional environmental information

Additional environmental information should be provided and properly documented by the user of the FreshProducePEFCR on the topic of biodiversity.

Biodiversity is considered as relevant for the FreshProducePEFCR, as agricultural practices can have significant impacts on biodiversity — both negative and positive. However, impacts of cultivation systems for fruits and vegetables (and their supply chain) on biodiversity are only partly covered by LCA impact categories. The PEF method does not include any impact category named 'biodiversity', as currently there is no consensus on an LCIA method capturing that impact. However, the PEF method includes at least eight impact categories that have an effect on biodiversity (i.e., climate change, eutrophication (aquatic freshwater), eutrophication (aquatic marine), eutrophication (terrestrial), acidification, water use, land use and ecotoxicity (freshwater)). This is a topic of the Agricultural Working Group discussions of the European Commission and the FreshProducePEFCR should be updated once these discussions have led to an improved method.

In the meantime, the user of the FreshProducePEFCR should provide a qualitative description of how the product's cultivation influences biodiversity, including negative impacts (e.g., habitat alteration, pesticide use, soil degradation) and positive contributions (e.g., supporting pollinators, enhancing soil health, conserving ecosystems). The description should highlight specific agricultural practices aimed at minimising harm or enhancing biodiversity.

The user of this FreshProducePEFCR may add additional environmental information wherever deemed relevant (e.g., on offsets, soil carbon storage). The environmental information shall be in line with the requirements given in Section 3.2.4.1. in the PEF method (Annex I) (European Commission, 2021).

3.8 Limitations

There are various limitations related to this FreshProducePEFCR that influences the result of a PEF study carried out in accordance with this PEFCR. Some of these topics are already part of the mandate of several working groups (e.g., AWG, DWG) or Technical Advisory Board (TAB) of the EF transition phase. The FreshProducePEFCR aims to integrate the learnings in further versions of this document.

General
It should be noted that the FreshProducePEFCR was drafted using the learnings of the PEF-RP study of fruits (Weststrate et al., 2025b) and vegetables (Weststrate et al., 2025a). The PEF-RP studies are based on a selection and representative variety of crops, cropping systems and regions, but carries the risk that products or production systems with a relatively small market share are overlooked in the development of calculations rules.

This FreshProducePEFCR is developed outside the official PEF framework. Using the EF3.1 datasets was therefore not possible. Datasets to be used come from databases that are not fully interoperable with the certain aspects of the PEF method (e.g., Circular Footprint Formula, default transport scenarios in market processes and data quality rating (DQR)).

Although the impact for the current situation is judged small, the circular footprint formula that shall be used to model recycled content and end-of-life is not applied on the material input side (recycled content) and faces several shortcomings in modelling the end-of-life, e.g., not including an actual recycling process.

The application of this FreshProducePEFCR poses challenges for smallholder farmers, particularly in terms of the LCA knowledge and expertise required, as well as the costs and substantial data demands involved. The TS is aware of these difficulties and recognises the importance of considering the unique circumstances faced by smallholder farmers. However, given the requirements of the PEF framework, the TS does not see a feasible way to simplify the process for smallholder farmers at this moment while still ensuring compliance with the established guidelines.

Agricultural modelling
Characterisation factors for water extraction are provided at country-level, more granularity in the regionalisation of water flows would enable a more specific assessment of water scarcity.

Biodiversity impacts that go beyond impacts covered in the current list of impact categories (Section 3.5) or additional environmental information (Section 3.7) are not fully covered in this FreshProducePEFCR.

The production and application of biological pest control cannot be captured because of missing background data and characterisation factors.

The fate of crop protection active ingredients (i.e., environmental compartment destination post-application) depends on the farm system, climate conditions, the distance to surface area, and the spraying technology. In this version of the FreshProducePEFCR, no specific emission model is recommended that differentiates fate factors based on these parameters.

The system boundaries of this FreshProducePEFCR are focused on a single crop and its co-product(s). As a result, inter-crop rotation effects, such as carbon and nitrogen cycling, are (partly) neglected.

Full carbon oxidation of peat (as part of the growing media) is assumed to occur during the life cycle of the product in which the growing media is first used. This assumption follows a conservative approach, as it does not consider the partial incorporation of peat into soil organic matter, which could influence the long-term carbon dynamics. Furthermore, this approach allocates all environmental burdens to the first user, whereas subsequent users may utilise the peat as a soil improver, potentially mitigating some of the environmental impacts.

When CO_2 from an external party is used as fertiliser, its emissions resulting from application are omitted in the FreshProducePEFCR. Although this approach aligns with other LCA standards (e.g., BSI (2012) and Broekema et al. (2024)), this approach comes with the following limitations:

- There is no certainty that the supplying industry fully accounts for these emissions, which may lead to discrepancies in emissions reporting across industries.
- CO_2 obtained from an external source may have economic value upon entering the system and therefore cannot be considered entirely burden-free under economic allocation.
- This approach results in an artificial disparity in PEF outcomes between greenhouses with CHP systems and those without, placing CHP systems at a disadvantage.

In accordance with the LCA standards mentioned above, CHP emissions allocation is based on the energy content of outputs. However, this approach may not fully capture the actual dynamics of the energy market and could disadvantage CHP systems in their role of balancing the power grid. The allocation of upstream environmental burdens and credits in CHP systems within the horticultural sector is a highly complex and multifaceted issue, highlighting the need for careful consideration, further discussion, and additional research. During the two public consultations, multiple stakeholders raised this concern and provided valuable insights to refine this topic in future versions of the FreshProducePEFCR.

While the TS regularly assesses whether the chosen methods for CO_2 fertilisation and CHP allocation accurately reflect real-world conditions and provide appropriate incentives for stakeholders both within and beyond the horticultural sector, addressing these challenges at the EU level is crucial to prevent inconsistencies between PEFCRs.

Impact assessment

The EF 3.1 impact assessment method has country-specific characterisation factors (CFs) for ammonia and NO_x emissions to air and water for marine and terrestrial eutrophication for EU member states. This is acknowledged as a limitation in the evaluation of these impact categories for production sites outside the EU, which is frequently the case for fruits and vegetables. When no country-specific CF is available, practitioner shall use the non-regional substance ammonia or NO_x in the appropriate compartment and indicate this limitation in the reporting of results.

Distribution

Aviation emissions are calculated per tkm and the emission factor strongly depends on the length of the flight, due to differences between take-off, landing, and the flight itself. In the background data, no distinction is made between these different phases, only in the total distance travelled. Furthermore, differences in environmental impact occur when allocating impacts to the product between belly freight and a dedicated freight plane. Especially in the case of belly freight, the allocation between passengers and goods is based on several assumptions, which, may not always fully capture the complexities of real-world conditions. The TS is aware that the current approach may result in a disproportionate impact on landlocked countries and those in the Global South, and acknowledges that this could lead to challenges in accurately reflecting the unique circumstances of these regions in distributing fresh produce.

The IPCC acknowledges that the Global Warming Potentials are not adequate to describe the climate impacts of aviation on climate change. In literature, several recommendations are made to include the radiative forcing index of emissions in the higher atmosphere; these are not included in the EF impact assessment, but might be included in the future (e.g., based on PEFCR for Aviation, Drones and EVTOLs).

3.8.1 Comparisons and comparative assertions

The results of any environmental footprint study based on the FreshProducePEFCR may be used for various applications, including supply chain management, product design, optimisation, and comparative assertions within the sub-category fruits or vegetables. The FreshProducePEFCR is explicitly not designed to support comparative claims between the sub-categories fruits and vegetables, or between these products and those that are out of the scope of the FreshProducePEFCR.

4 Most relevant impact categories, life cycle stages, processes and elementary flows

This chapter lists the most relevant EF impact categories, most relevant life cycle stages, most relevant processes and most relevant direct elementary flows. These were based on an assessment that was carried out following the guidance in Section 6.3 of Annex I of the recommendation on the use of the Environmental Footprint methods from the European Commission (2021). The assessment was based on the findings from the PEF-RP studies for fruits and vegetables (Weststrate et al., 2025a, 2025b) and has been verified against two (confidential) supporting studies.

4.1 Most relevant EF impact categories

According to the PEF method, 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 impact categories that cumulatively contribute to at least 80% to the total environmental impact. This shall start from the largest to the smallest contributions.

The most relevant impact categories for the sub-category fruits within the scope of the FreshProducePEFCR are the following:

- Acidification
- Climate change
- Ecotoxicity, freshwater
- Eutrophication, freshwater[12]
- Eutrophication, marine[12]
- Particulate matter
- Resource use, fossils
- Resource use, minerals and metals and
- Water use.

The most relevant impact categories for the sub-category vegetables within the scope of the FreshProducePEFCR are the following:

- Acidification
- Climate Change
- Ecotoxicity, freshwater[13]
- Eutrophication, freshwater
- Eutrophication, marine
- Particulate matter
- Resource use, fossils
- Resource use, mineral and metals and
- Water use.

More impact categories may be added to the list of the most relevant ones but none shall be deleted.

[12] This impact category was not above the 80% threshold in the PEF-RP study for the sub-category fruits. It has been added to be consistent with the most relevant impact categories identified for the sub-category vegetables.

[13] This impact category was not above the 80% threshold in the PEF-RP study for the sub-category vegetables. It has been added to be consistent with the most relevant impact categories identified for the sub-category fruits.

4.2 Most relevant life cycle stages

According to the PEF guidance, the most relevant life cycle stages are the ones that together contribute at least 80% to any of the most relevant impact categories identified. This shall start from the largest to the smallest contributions.

On the basis of the RP study of fruits the most relevant life cycle stages for the sub-category fruits in scope of the FreshProducePEFCR are the following:
- Stage 1. Raw materials, pre-processing and starting materials
- Stage 2. Cultivation
- Stage 3. Post-harvest treatment, storage and handling
- Stage 4. Distribution
- Stage 5. Consumer packaging
- Stage 7. Use stage.

On the basis of the RP study of vegetables, the most relevant life cycle stages for the sub-category vegetables in scope of the FreshProducePEFCR are the following:
- Stage 1. Raw materials, pre-processing and starting materials
- Stage 2. Cultivation
- Stage 3. Post-harvest treatment, storage, and handling
- Stage 4. Distribution
- Stage 5. Consumer packaging
- Stage 7. Use stage.

Since the use stage does not exceed 50% of the total impact in any most-relevant impact category, the procedure is not rerun without the use stage.

More life cycle stages to the list of the most relevant ones may be added but none shall be deleted.

4.3 Most relevant processes

According to the PEF method, 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 collectively contribute at least 80% to any of the most relevant 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 environmental footprint report together with the respective life cycle stage (or multiple life cycle stages if relevant) and the contribution in %. The most relevant processes for the sub-category fruits and vegetables in scope of the FreshProducePEFCR are listed in Table 10 and Table 11, respectively.

More processes to the list of the most relevant ones may be added but none shall be deleted.

4.4 Most relevant direct elementary flows

According to the PEF guidance each most relevant process shall be further investigated by identifying the most relevant direct elementary flows. Most relevant direct elementary flows are defined as those direct elementary flows contributing cumulatively at least with 80% of the process, for each most relevant impact category. The analysis shall be limited to the direct emissions of the level-1 disaggregated datasets. 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 most relevant direct elementary flows for the sub-category fruits and vegetables within the scope of the FreshProducePEFCR are listed in Table 10 and Table 11, respectively.

More direct elementary flows to the list of most relevant ones may be added but none shall be deleted.

Table 10 *List of the most relevant impact categories, life cycle stages, processes and direct elementary flows for fruits*

Damage category	[%]	Life cycle stage	[%]	Process	[%]	Most relevant direct elementary flows	[%]	Compartment
Water use	24.27	Stage 2. Cultivation RP Fruits	69.83	Stage 2a. Cultivation oranges {ES}	37.11	Water, river, ES	59.19	Raw
						Water, well, ES	31.64	Raw
				Stage 2. Cultivation watermelons {ES}	13.62	Water, unspecified natural origin, ES	100	Raw
				Stage 2. Cultivation strawberries {ES}	12.56	Water, unspecified natural origin, ES	100	Raw
		Stage 7. Use stage RP Fruits	11.77	Stage 2. Cultivation watermelons {ES}	6.00	Water, unspecified natural origin, ES	100	Raw
				Stage 2a. Cultivation oranges {ES}	3.74	Water, river, ES	59.19	Raw
						Water, well, ES	31.64	Raw
		Stage 3. Post-harvest handling and storage RP Fruits		Stage 2a. Cultivation oranges {ES}	10.02	Water, river, ES	59.19	Raw
						Water, well, ES	31.64	Raw
Climate change	19.81	Stage 4. Distribution RP Fruits	56.48	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	32.65			
				Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	13.97			
				Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling | Cut-off, S	3.99			
				Heat, central or small-scale, natural gas {Europe without Switzerland}| market for heat, central or small-scale, natural gas | Cut-off, S	1.93			
				Transport, passenger car {RER}| transport, passenger car | Cut-off, S	0.87			
				Electricity, low voltage {RER}| market group for electricity, low voltage | Cut-off, S	0.69			
		Stage 7. Use stage RP Fruits	14.87	Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	4.28			
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	4.00			

<table>
<tr><th>Damage category</th><th>[%]</th><th>Life cycle stage</th><th>[%]</th><th>Process</th><th>[%]</th><th>Most relevant direct elementary flows</th><th>[%]</th><th>Compartment</th></tr>
<tr><td></td><td></td><td></td><td></td><td>Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling | Cut-off, S</td><td>1.18</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S</td><td>0.77</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Corrugated board box {RoW}| corrugated board box production | Cut-off, S</td><td>0.65</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 2. Cultivation RP Fruits</td><td>7.66</td><td>Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S</td><td>4.23</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Stage 2. Cultivation bananas {EC}</td><td>0.87</td><td>Dinitrogen monoxide</td><td>54.62</td><td>Air</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Carbon dioxide, fossil</td><td>45.35</td><td>Air</td></tr>
<tr><td></td><td></td><td>Stage 3. Post-harvest handling and storage RP Fruits</td><td>7.60</td><td>Corrugated board box {RoW}| corrugated board box production | Cut-off, S</td><td>1.83</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Fungicide, at plant {RER} Economic, S</td><td>1.41</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S</td><td>0.98</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Corrugated board box {RER}| corrugated board box production | Cut-off, S</td><td>0.75</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 5. Consumer packaging and handling RP Fruits</td><td></td><td>Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S</td><td>1.95</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Corrugated board box {RER}| corrugated board box production | Cut-off, S</td><td>1.58</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S</td><td>1.10</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 6. Retail RP Fruits</td><td></td><td>Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S</td><td>0.69</td><td></td><td></td><td></td></tr>
<tr><td>Resource use, fossils</td><td>11.51</td><td>Stage 4. Distribution RP Fruits</td><td>58.27</td><td>Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S</td><td>33.35</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off, S</td><td>14.51</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling | Cut-off, S</td><td>3.89</td><td></td><td></td><td></td></tr>
</table>

Damage category	[%]	Life cycle stage	[%]	Process	[%]	Most relevant direct elementary flows	[%]	Compartment
				Heat, central or small-scale, natural gas {Europe without Switzerland}| market for heat, central or small-scale, natural gas | Cut-off, S	2.19			
				Electricity, low voltage {RER}| market group for electricity, low voltage | Cut-off, S	1.26			
				Transport, passenger car {RER}| transport, passenger car | Cut-off, S	0.89			
		Stage 7. Use stage RP Fruits	14.36	Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	4.44			
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	4.09			
				Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling | Cut-off, S	1.15			
		Stage 3. Post-harvest handling and storage RP Fruits	7.78	Fungicide, at plant {RER} Economic, S	2.10			
				Corrugated board box {RoW}| corrugated board box production | Cut-off, S	1.72			
				Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S	0.89			
		Stage 5. Consumer packaging and handling RP Fruits		Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S	2.12			
				Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S	1.77			
				Corrugated board box {RER}| corrugated board box production | Cut-off, S	1.57			
		Stage 2. Cultivation RP Fruits		Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	4.13			
Ecotoxicity, freshwater	10.47	Stage 2. Cultivation RP Fruits	71.87	Stage 2. Cultivation strawberries {ES}	53.00	Chloropicrin	56.55	Soil
						Chloropicrin	39.76	Water
				Stage 2a. Cultivation apples {PL}	10.78	Lambda-cyhalothrin	41.88	Water
						Tebuconazole	32.97	Soil
						Mancozeb	6.77	Water
				Stage 2. Cultivation fresh grapes {IT}	2.99	Tau-fluvalinate	46.34	Water

Damage category	[%]	Life cycle stage	[%]	Process	[%]	Most relevant direct elementary flows	[%]	Compartment
						Methiocarb	34.81	Water
				Stage 2a. Cultivation apples {PL}	1.44	Lambda-cyhalothrin	41.88	Water
						Tebuconazole	32.97	Soil
						Mancozeb	6.77	Water
		Stage 4. Distribution RP Fruits	10.83	Stage 2. Cultivation strawberries {ES}	4.19	Chloropicrin	56.55	Soil
						Chloropicrin	39.76	Water
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	1.76			
		Stage 7. Use stage RP Fruits		Stage 2. Cultivation strawberries {ES}	1.75	Chloropicrin	56.55	Soil
						Chloropicrin	39.76	Water
				Stage 2a. Cultivation apples {PL}	1.36	Lambda-cyhalothrin	41.88	Water
						Tebuconazole	32.97	Soil
						Mancozeb	6.77	Water
		Stage 3. Post-harvest handling and storage RP Fruits		Stage 2a. Cultivation apples {PL}	1.49	Lambda-cyhalothrin	41.88	Water
						Tebuconazole	32.97	Soil
						Mancozeb	6.77	Water
		Stage 1. Raw materials RP Fruits		Trellis system, wooden poles, soft wood, tar impregnated {RoW}| trellis system construction, wooden poles, soft wood, tar impregnated | Cut-off, S	1.15			
		Stage 6. Retail RP Fruits		Stage 2. Cultivation strawberries {ES}	1.20	Chloropicrin	56.55	Soil
						Chloropicrin	39.76	Water
Particulate matter	6.1	Stage 4. Distribution RP Fruits	48.74	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	30.50			
				Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	11.74			
				Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling | Cut-off, S	1.91			
				Transport, passenger car {RER}| transport, passenger car | Cut-off, S	0.82			

<table>
<tr><th>Damage category</th><th>[%]</th><th>Life cycle stage</th><th>[%]</th><th>Process</th><th>[%]</th><th>Most relevant direct elementary flows</th><th>[%]</th><th>Compartment</th></tr>
<tr><td></td><td></td><td>Stage 2. Cultivation RP Fruits</td><td>17.40</td><td>Stage 2a. Cultivation apples {PL}</td><td>4.00</td><td>Ammonia, PL</td><td>95.38</td><td>Air</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S</td><td>2.93</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Stage 2. Cultivation bananas {EC}</td><td>2.35</td><td>Ammonia, EC</td><td>100</td><td>Air</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Stage 2a. Cultivation oranges {ES}</td><td>2.23</td><td>Ammonia, ES</td><td>100</td><td>Air</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Stage 2. Cultivation watermelons {ES}</td><td>2.21</td><td>Ammonia, ES</td><td>100</td><td>Air</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Stage 2. Cultivation strawberries {ES}</td><td>1.34</td><td>Ammonia, ES</td><td>100</td><td>Air</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Stage 2b. Cultivation apples {IT}</td><td>1.01</td><td>Ammonia, IT</td><td>100</td><td>Air</td></tr>
<tr><td></td><td></td><td>Stage 7. Use stage RP Fruits</td><td>15.55</td><td>Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S</td><td>3.74</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off, S</td><td>3.60</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Corrugated board box {RoW}| corrugated board box production | Cut-off, S</td><td>1.04</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Stage 2. Cultivation watermelons {ES}</td><td>0.97</td><td>Ammonia, ES</td><td>100</td><td>Air</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Stage 2. Cultivation bananas {EC}</td><td>0.83</td><td>Ammonia, EC</td><td>100</td><td>Air</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, S</td><td>0.73</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 3. Post-harvest handling and storage RP Fruits</td><td></td><td>Corrugated board box {RoW}| corrugated board box production | Cut-off, S</td><td>2.94</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Corrugated board box {RER}| corrugated board box production | Cut-off, S</td><td>0.82</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Stage 2a. Cultivation oranges {ES}</td><td>0.60</td><td>Ammonia, ES</td><td>100</td><td>Air</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Fungicide, at plant {RER} Economic, S</td><td>0.60</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 5. Consumer packaging and handling RP Fruits</td><td></td><td>Corrugated board box {RER}| corrugated board box production | Cut-off, S</td><td>1.73</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S</td><td>0.79</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 6. Retail RP Fruits</td><td></td><td>Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S</td><td>0.64</td><td></td><td></td><td></td></tr>
</table>

Damage category	[%]	Life cycle stage	[%]	Process	[%]	Most relevant direct elementary flows	[%]	Compartment
Resource use, minerals and metals	5.32	Stage 4. Distribution RP Fruits	36.34	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	17.19			
				Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	10.17			
				Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling | Cut-off, S	2.03			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S	1.80			
				Electricity, low voltage {RER}| market group for electricity, low voltage | Cut-off, S	1.46			
				Transport, passenger car {RER}| transport, passenger car | Cut-off, S	1.33			
		Stage 5. Consumer packaging and handling RP Fruits	27.02	Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grad e | Cut-off, S	22.76			
				Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S	1.36			
				Electricity, low voltage {IT}| market for electricity, low voltage | Cut-off, S	1.17			
				Corrugated board box {RER}| corrugated board box production | Cut-off, S	0.89			
		Stage 7. Use stage RP Fruits	12.54	Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	3.11			
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	2.11			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S	1.53			
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	0.74			

Damage category	[%]	Life cycle stage	[%]	Process	[%]	Most relevant direct elementary flows	[%]	Compartment
				Inorganic nitrogen fertiliser, as N {RoW}| nutrient supply from ammonium sulfate | Cut-off, S	0.65			
		Stage 1. Raw materials RP Fruits	9.53	Inorganic nitrogen fertiliser, as N {RoW}| nutrient supply from ammonium sulfate | Cut-off, S	1.83			
				Inorganic nitrogen fertiliser, as N {GLO}| nutrient supply from calcium nitrate | Cut-off, S	1.08			
				NPK (15-15-15) fertiliser {RER}| NPK (15-15-15) fertiliser production | Cut-off, S	0.90			
				Ammonium nitrate {RER}| ammonium nitrate production | Cut-off, S	0.65			
		Stage 3. Post-harvest handling and storage RP Fruits		Fungicide, at plant {RER} Economic, S	1.11			
				Corrugated board box {RoW}| corrugated board box production | Cut-off, S	0.91			
				Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S	0.68			
		Stage 2. Cultivation RP Fruits		Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	4.05			
				Electricity, low voltage {ES}| market for electricity, low voltage | Cut-off, S	0.98			
Acidification	3.91	Stage 4. Distribution RP Fruits	41.09	Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling | Cut-off, S	15.82			
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	13.43			
				Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	6.17			
				Electricity, low voltage {RER}| market group for electricity, low voltage | Cut-off, S	0.82			
				Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, S	0.61			
				Transport, passenger car {RER}| transport, passenger car | Cut-off, S	0.59			
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	0.57			
		Stage 2. Cultivation RP Fruits	17.91	Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	6.47			

Damage category	[%]	Life cycle stage	[%]	Process	[%]	Most relevant direct elementary flows	[%]	Compartment
				Stage 2a. Cultivation apples {PL}	5.72	Ammonia, PL	88.38	Air
				Stage 2. Cultivation bananas {EC}	3.91	Ammonia, EC	100	Air
		Stage 7. Use stage RP Fruits	17.08	Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling | Cut-off, S	4.66			
				Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	1.89			
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	1.65			
				Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, S	1.58			
				Stage 2. Cultivation bananas {EC}	1.38	Ammonia, EC	100	Air
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	1.18			
				Stage 2a. Cultivation apples {PL}	0.72	Ammonia, PL	88.38	Air
				Corrugated board box {RoW}| corrugated board box production | Cut-off, S	0.62			
		Stage 3. Post-harvest handling and storage RP Fruits	9.35	Corrugated board box {RoW}| corrugated board box production | Cut-off, S	1.77			
				Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S	1.46			
				Fungicide, at plant {RER} Economic, S	1.19			
				Stage 2a. Cultivation apples {PL}	0.79	Ammonia, PL	88.38	Air
				Corrugated board box {RER}| corrugated board box production | Cut-off, S	0.69			
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	0.69			
		Stage 5. Consumer packaging and handling RP Fruits		Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S	2.92			
				Corrugated board box {RER}| corrugated board box production | Cut-off, S	1.46			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S	0.92			
		Stage 1. Raw materials RP Fruits		NPK (15-15-15) fertiliser {RER}| NPK (15-15-15) fertiliser production | Cut-off, S	0.58			

Table 11 *List of the most relevant impact categories, life cycle stages, processes and direct elementary flows for vegetables*

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
Climate change	24.23	Stage 4. Distribution RP Vegetables	45.26	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	40.32			
				Transport, passenger car {RER}| transport, passenger car | Cut-off, S	1.36			
		Stage 2. Cultivation RP Vegetables	16.74	Stage 2. Cultivation white mushroom {NL}	4.44	Dinitrogen monoxide	54.33	Air
						Carbon dioxide, peat oxidation	42.10	Air
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	3.56			
				Stage 2. Cultivation green bean {FR}	3.45	Carbon dioxide, land transformation	82.81	Air
				Electricity, low voltage {NL}| market for | Cut-off, S	1.54			
				Stage 2. Cultivation cabbage {PL}	0.79	Carbon dioxide, fossil	56.45	Air
						Dinitrogen monoxide	43.50	Air
		Stage 5. Consumer packaging and handling RP Vegetables	10.44	Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S	5.75			
				Extrusion of plastic sheets and thermoforming, inline {RoW}| extrusion of plastic sheets and thermoforming, inline | Cut-off, S	2.45			
				Electricity, low voltage {RER}| market group for electricity, low voltage | Cut-off, S	1.09			
		Stage 1. Raw materials RP Vegetables	10.09	Transport, freight, lorry >32 metric ton, EURO6 {RER}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	4.71			
				Calcium ammonium nitrate {RER}| calcium ammonium nitrate production | Cut-off, S	0.72			
		Stage 7. Use stage RP Vegetables		Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	4.07			
		Stage 3. Post-harvest handling and storage RP Vegetables		Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S	1.63			
				Transport, freight, lorry >32 metric ton, EURO6 {RER}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	0.97			

<table>
<tr><th>Most relevant impact categories</th><th>[%]</th><th>Most relevant life cycle stages</th><th>[%]</th><th>Most relevant processes</th><th>[%]</th><th>Most relevant direct elementary flows</th><th>[%]</th><th>Compartment</th></tr>
<tr><td></td><td></td><td></td><td></td><td>Stage 2. Cultivation green bean {FR}</td><td>0.72</td><td>Carbon dioxide, land transformation</td><td>82.81</td><td>Air</td></tr>
<tr><td></td><td></td><td>Stage 6. Retail RP Vegetables</td><td></td><td>Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S</td><td>1.00</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 8. End-of-life RP Vegetables</td><td></td><td>Waste plastic, mixture {GLO}| treatment of waste plastic, mixture, municipal incineration | Cut-off, S</td><td>1.87</td><td></td><td></td><td></td></tr>
<tr><td>Resource use, fossils</td><td>13.69</td><td>Stage 4. Distribution RP Vegetables</td><td>47.01</td><td>Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S</td><td>42.37</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Transport, passenger car {RER}| transport, passenger car | Cut-off, S</td><td>1.43</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 5. Consumer packaging and handling RP Vegetables</td><td>18.02</td><td>Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S</td><td>11.36</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Extrusion of plastic sheets and thermoforming, inline {RoW}| extrusion of plastic sheets and thermoforming, inline | Cut-off, S</td><td>2.43</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Electricity, low voltage {RER}| market group for electricity, low voltage | Cut-off, S</td><td>2.05</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 1. Raw materials RP Vegetables</td><td>11.66</td><td>Transport, freight, lorry >32 metric ton, EURO6 {RER}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S</td><td>5.74</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 2. Cultivation RP Vegetables</td><td>8.69</td><td>Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S</td><td>3.57</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Natural gas, low pressure {NL}| market for natural gas, low pressure | Cut-off, S</td><td>2.70</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Electricity, low voltage {NL}| market for | Cut-off, S</td><td>1.69</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 7. Use stage RP Vegetables</td><td></td><td>Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S</td><td>4.28</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 3. Post-harvest handling and storage RP Vegetables</td><td></td><td>Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S</td><td>1.53</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Transport, freight, lorry >32 metric ton, EURO6 {RER}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S</td><td>1.19</td><td></td><td></td><td></td></tr>
<tr><td>Resource use, minerals and metals</td><td>12.1</td><td>Stage 5. Consumer packaging and handling RP Vegetables</td><td>65.86</td><td>Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S</td><td>63.87</td><td></td><td></td><td></td></tr>
</table>

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
		Stage 4. Distribution RP Vegetables	17.19	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	11.43			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S	3.64			
		Stage 2. Cultivation RP Vegetables		Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	1.83			
Particulate matter	10.89	Stage 2. Cultivation RP Vegetables	39.86	Stage 2. Cultivation white mushroom {NL}	25.32	Ammonia, NL	100.00	Air
				Stage 2. Cultivation carrot {NL}	2.77	Ammonia, NL	100.00	Air
				Stage 2b. Cultivation tomato {ES}	2.42	Ammonia, ES	100.00	Air
				Stage 2a. Cultivation tomato {IT}	2.30	Ammonia, IT	100.00	Air
				Stage 2. Cultivation green bean {FR}	1.71	Ammonia, FR	100.00	Air
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	1.69			
				Stage 2. Cultivation cabbage {PL}	1.66	Ammonia, PL	100.00	Air
		Stage 4. Distribution RP Vegetables	31.55	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	25.80			
				Stage 2. Cultivation white mushroom {NL}	2.03	Ammonia, NL	100.00	Air
		Stage 1. Raw materials RP Vegetables	9.03	Transport, freight, lorry >32 metric ton, EURO6 {RER}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	5.50			
		Stage 7. Use stage RP Vegetables		Stage 2. Cultivation white mushroom {NL}	2.83	Ammonia, NL	100.00	Air
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	2.61			
		Stage 5. Consumer packaging and handling RP Vegetables		Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S	2.81			
				Extrusion of plastic sheets and thermoforming, inline {RoW}| extrusion of plastic sheets and thermoforming, inline | Cut-off, S	1.77			
Acidification	9.24	Stage 2. Cultivation RP Vegetables	59.61	Stage 2. Cultivation white mushroom {NL}	46.50	Ammonia, NL	100.00	Air

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
				Stage 2. Cultivation carrot {NL}	5.08	Ammonia, NL	100.00	Air
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	2.81			
				Stage 2. Cultivation cabbage {PL}	1.66	Ammonia, PL	100.00	Air
				Heat from CHP, natural gas {NL}	1.24			
		Stage 4. Distribution RP Vegetables	15.28	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	8.57			
				Stage 2. Cultivation white mushroom {NL}	3.72	Ammonia, NL	100.00	Air
		Stage 7. Use stage RP Vegetables	9.40	Stage 2. Cultivation white mushroom {NL}	5.19	Ammonia, NL	100.00	Air
		Stage 5. Consumer packaging and handling RP Vegetables		Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S	2.47			
				Extrusion of plastic sheets and thermoforming, inline {RoW}| extrusion of plastic sheets and thermoforming, inline | Cut-off, S	1.22			
		Stage 1. Raw materials RP Vegetables		Transport, freight, lorry >32 metric ton, EURO6 {RER}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S	1.17			
		Stage 3. Post-harvest handling and storage RP Vegetables		Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S	1.26			
Eutrophication, marine	4.53	Stage 2. Cultivation RP Vegetables	66.92	Stage 2. Cultivation white mushroom {NL}	30.14	Nitrate, NL	91.10	Water
				Stage 2. Cultivation cabbage {PL}	9.91	Nitrate, PL	98.23	Water
				Stage 2b. Cultivation tomato {ES}	5.95	Nitrate, ES	95.69	Water
				Stage 2. Cultivation carrot {NL}	5.44	Nitrate, NL	94.61	Water
				Stage 2a. Cultivation tomato {IT}	5.01	Nitrate, IT	95.13	Water
				Stage 2. Cultivation green bean {FR}	4.44	Nitrate, FR	95.91	Water
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	3.02			
				Heat from CHP, natural gas {NL}	1.50			
		Stage 4. Distribution RP Vegetables	11.85	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	5.35			
				Stage 2. Cultivation white mushroom {NL}	2.41	Nitrate, NL	91.10	Water

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
		Stage 7. Use stage RP Vegetables	9.22	Stage 2. Cultivation white mushroom {NL}	3.37	Nitrate, NL	91.10	Water
				Stage 2. Cultivation cabbage {PL}	2.47	Nitrate, PL	98.23	Water
		Stage 5. Consumer packaging and handling RP Vegetables		Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S	1.33			
Water use	4.29	Stage 2. Cultivation RP Vegetables	73.29	Stage 2b. Cultivation tomato {ES}	41.25	Water, river, ES	100.00	Raw
				Stage 2a. Cultivation tomato {IT}	27.75	Water, unspecified natural origin, IT	100.00	Raw
				Stage 2. Cultivation green bean {FR}	2.93	Water, well, FR	100.00	Raw
		Stage 4. Distribution RP Vegetables	9.98	Stage 2b. Cultivation tomato {ES}	3.26	Water, river, ES	100.00	Raw
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	3.15			
		Stage 5. Consumer packaging and handling RP Vegetables		Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S	3.83			
Eutrophication, freshwater	3.97	Stage 2. Cultivation RP Vegetables	40.65	Stage 2. Cultivation white mushroom {NL}	17.84	Phosphorus	100.00	Soil
				Stage 2. Cultivation green bean {FR}	4.60	Phosphorus	100.00	Soil
				Stage 2b. Cultivation tomato {ES}	4.02	Phosphorus	100.00	Soil
				Stage 2a. Cultivation tomato {IT}	3.14	Phosphorus	100.00	Soil
				Electricity, low voltage {NL}| market for | Cut-off, S	3.05			
				Stage 2. Cultivation carrot {NL}	2.80	Phosphorus	100.00	Soil
				Stage 2. Cultivation cabbage {PL}	2.63	Phosphorus	100.00	Soil
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off, S	1.82			
		Stage 4. Distribution RP Vegetables	17.63	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S	10.81			
				Stage 2. Cultivation white mushroom {NL}	1.43	Phosphorus	100.00	Soil
		Stage 5. Consumer packaging and handling RP Vegetables	13.57	Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade | Cut-off, S	4.57			

<table>
<tr><th>Most relevant impact categories</th><th>[%]</th><th>Most relevant life cycle stages</th><th>[%]</th><th>Most relevant processes</th><th>[%]</th><th>Most relevant direct elementary flows</th><th>[%]</th><th>Compartment</th></tr>
<tr><td></td><td></td><td></td><td></td><td>Extrusion of plastic sheets and thermoforming, inline {RoW}| extrusion of plastic sheets and thermoforming, inline | Cut-off, S</td><td>3.87</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Electricity, low voltage {RER}| market group for electricity, low voltage | Cut-off, S</td><td>3.86</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 3. Post-harvest handling and storage RP Vegetables</td><td>10.06</td><td>Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S</td><td>7.42</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Stage 2. Cultivation green bean {FR}</td><td>0.97</td><td>Phosphorus</td><td>100.00</td><td>Soil</td></tr>
<tr><td></td><td></td><td>Stage 7. Use stage RP Vegetables</td><td></td><td>Stage 2. Cultivation white mushroom {NL}</td><td>1.99</td><td>Phosphorus</td><td>100.00</td><td>Soil</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Electricity, low voltage {PL}| market for electricity, low voltage | Cut-off, S</td><td>1.63</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off, S</td><td>1.09</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Biowaste {GLO}| treatment of biowaste, municipal incineration | Cut-off, S</td><td>1.00</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Stage 1. Raw materials RP Vegetables</td><td></td><td>Transport, freight, lorry >32 metric ton, EURO6 {RER}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off, S</td><td>1.27</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Electricity, low voltage {NL}| market for | Cut-off, S - Copied from ecoinvent</td><td>0.85</td><td></td><td></td><td></td></tr>
</table>

5 Life cycle inventory

This chapter specifies which data needs to be collected to conduct an environmental footprint study according to the FreshProducePEFCR. It specifies processes for which mandatory company-specific data shall be collected as well as rules for collecting any other company-specific data (Section 5.1 and 5.2). Company-specific data enhance the quality of the environmental footprint study. Data quality requirements and calculation of the Data Quality Rating (DQR) are explained (Section 5.3 and 5.6, respectively). The Data Needs Matrix, to be used to evaluate which data are needed for processes outside the list of mandatory company-specific data, is explained (Section 5.4). This chapter also elaborates on which secondary datasets to use (Section 5.5). Furthermore, modelling rules are elaborated for allocation in case of multifunctional processes (Section 5.7), electricity modelling (Section 5.8), climate change modelling (Section 5.9) and modelling of end-of-life and recycling (Section 5.10).

In some cases, a sampling procedure to limit the data collection is needed. Sampling is not mandatory and any user of the FreshProducePEFCR may decide to collect the data from all the plants or farms, without performing any sampling. Sampling may be applicable when cultivation of a certain type of fruit or vegetable occurs in several different farms or when raw materials are produced in multiple different sites. When sampling is used, it shall be done according to the requirements defined in Section 4.4.6 of Annex I, the PEF method (European Commission, 2021). The population and the selected sample used for the environmental footprint study shall be clearly described in the environmental footprint report.

Additional to the requirements defined in Section 4.4.6 of Annex I, the PEF method (European Commission, 2021) the following requirements apply:

- Practitioner shall clearly report on all possible distinctive technologies/farm practices, climate zones, regions (i.e., country), soil types, and classes of capacity of companies when defining a sub-population and the considerations made.
- Reviewer shall verify the considerations made for defining sub-populations for the aspects listed here above.
- Practitioner shall select the sites from highest to lowest contributing to the production volume (in mass) of a sub-population for at least 50%.

Attributional modelling is adopted in this FreshProducePEFCR. This reflects process-based modelling intended to provide a static representation of average conditions, excluding market-mediated effects.

5.1 List of mandatory company-specific data

The following section describes the processes for which mandatory company-specific data (i.e., activity data and direct elementary flows)[14] shall be collected to conform to this FreshProducePEFCR. For all other processes, the Data Needs Matrix is applicable, as explained in Chapter 5.4.

To offset fluctuations due to seasonal differences, cultivation activity data shall be collected and averaged for at least 3 consecutive years. However, this requirement has proven to be a challenge in comparable LCA methodologies related to horticulture, e.g., FloriPEFCR and HortiFootprint Category Rules (Broekema et al., 2024; Helmes et al., 2020). Yield, fertiliser and manure application, and energy use shall always be obtained for three consecutive years. If data cannot be obtained for three consecutive years for the other mandatory company-specific data points, these data points shall be calculated using the average of the available data or extrapolated based on expert judgment, using at least one year of available data. In the LCI it shall be

[14] Note that the direct elementary flows listed shall be aligned with the nomenclature used by the EF reference package 3.1, available at: http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

clearly indicated what data are collected (and for what time period), and what data extrapolated (including details on the extrapolation method).

The user of the FreshProducePEFCR shall collect company-specific data related to:

- Raw material acquisition, pre-processing and starting materials
  - Starting material or young plant input
  - Growing media use
  - Material use
  - Fertilisers and manure
  - Crop protection products;
- Cultivation emissions and resources
  - Yield data of main-product and co-products
  - Product losses (including moisture losses)
  - Use of resources (e.g., land and water)
  - Peat soils
  - Direct emissions from fertilisers and crop protection (calculated)
  - Combined Heat and Power (CHP) unit
  - CO_2 enrichment
  - Geothermal heat
  - Heat use from third parties and
  - Fuel and energy use for on-farm activities (e.g., electricity, diesel use).
- Post-harvest treatment, storage and handling
  - Chemicals and gases used (including refrigerants)
  - Utility use and
  - Product losses (including moisture losses).
- Distribution
  - Identification of transport from farm to DC (qualitative)
  - Largest transport distance between farm and DC (quantitative) and
  - Transport mode.
- Consumer packaging
  - Packaging type, material and amount and
  - Percentage of recycled material.

A data collection template has been developed to aid the data collection process for company-specific data. See Excel file named 'FreshProducePEFCR – Life cycle inventory' for the list of all company-specific data to be collected.

5.2 List of processes expected to be run by the company

Processes carried out by the company for a large part depend on the type of company performing the EF study. For example, growers may run the cultivation of starting materials in addition to the fruit or vegetable cultivation. Retailers will run certain distribution legs and retail operations but might also run consumer packaging.

Therefore, the rules of the Data Needs Matrix (Chapter 5.4) are to be followed by users of the FreshProducePEFCR for company-specific processes which have not been identified as mandatory in Chapter 5.1. Several additional processes may be expected to be run by the company, but will vary greatly depending on the company running the PEF study. Therefore, no further description of processes is given in the FreshProducePEFCR.

Companies in Situation 1- Option 1 and Situation 2- Option 1 of the Data Needs Matrix (Chapter 5.4), shall collect activity data, resources and elementary flows, following guidance given in the corresponding life cycle stage in Chapter 6 of the FreshProducePEFCR.

5.3 Data quality requirements

The data quality of each dataset and the total EF study shall be calculated and reported. The calculation of the DQR shall be based on the following formula with four criteria:

$$DQR = \frac{TeR+GR+TiR+P}{4} \quad \text{Equation 2}$$

where TeR is technological representativeness, GR is geographical representativeness, TiR is time representativeness, and P is precision. The representativeness (technological, geographical and time-related) characterises to what degree the processes and products selected are depicting the system analysed, while the precision indicates the way the data is derived and related level of uncertainty.

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

5.3.1 Company-specific datasets

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. The most relevant direct elementary flows are defined as those contributing at least 80% cumulatively to the total impact of all direct elementary flows.
2. Calculate the DQR criteria TeR, TiR, GR and P for each of the most relevant activity data and each of the most relevant direct elementary flows. The values of each criterion shall be assigned based on Table 12.
   a. Each of the most relevant direct elementary flows consists of the amount and elementary flow naming (e.g., 40 g carbon dioxide). For each of the most relevant elementary flows, the user of the PEFCR shall evaluate the 4 DQR criteria named TeR-EF, TiR-EF, TeR-EF, P-EF. For example, the user of the PEFCR shall evaluate the timing of the flow measured, for which technology the flow was measured and in which geographical area.
   b. For each of the most relevant activity data, the 4 DQR criteria shall be evaluated (named TiR-AD, P-AD, GR-AD, TeR-AD) by the user of the PEFCR.
3. 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 TeR, TiR and GR cannot be higher than 2 (The DQR score shall be ≤1.5).
4. Calculate the environmental contribution of each of the most relevant activity data (through linking to the appropriate sub-process) and 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).
5. Calculate the TeR, TiR, GR 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 of the most relevant activity data and direct elementary flow calculated in step 3.
6. The user of the PEFCR shall calculate the total DQR of the newly developed dataset using $DQR=\frac{TeR+GR+TiR+P}{4}$ Equation 2, where $\overline{TeR}$, $\overline{GR}$, $\overline{TiR}$ and $\overline{P}$ are the weighted average calculated as specified in point (4).

Table 12 *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	GR-EF and GR-AD
1	Measured/calculated and externally verified	The data refer to the most recent annual administration period with respect to the EF report publication date. Data for cultivation should be the average of 3 years for annual plants or 3 full cultivations cycles.	The elementary flows and the activity data exactly reflect the technology of the newly developed dataset	The activity data and elementary flows reflect the exact geography where the process modelled in the newly created dataset takes place
2	Measured/calculated and internally verified, plausibility checked by reviewer	The data refer to maximum 2 annual administration periods with respect to the EF report publication date. Data for cultivation should be the average of 3 years for annual plants or 3 full cultivations cycles.	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 where the process modelled in the newly created dataset takes place
3	Measured/calculated/literature and plausibility not checked by reviewer OR Qualified estimate based on calculations plausibility checked by reviewer	The data refer to maximum three annual administration periods with respect to the EF report publication date. Data for cultivation should be the average of 3 years for annual plants or 3 full cultivations cycles.	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**; GR-EF**: Geographical representativeness for elementary flows; **GR-AD:** Geographical representativeness for activity data.

5.4 Data Needs Matrix (DNM)

All processes required to model the product and outside the list of mandatory company-specific data (listed in Section 5.1) shall be evaluated using the Data Needs Matrix (DNM) (see Table 13). The user of the FreshProducePEFCR shall apply the DNM to evaluate which data is needed and shall be used within the modelling of its EF, depending on the level of influence the user of the FreshProducePEFCR (company) has on the specific process. The following three cases are found in the DNM and are explained below:

1. **Situation 1**: the process is run by the company applying the FreshProducePEFCR.
2. **Situation 2**: the process is not run by the company applying the FreshProducePEFCR but the company has access to (company-)specific information.
3. **Situation 3**: the process is not run by the company applying the FreshProducePEFCR and this company does not have access to (company-)specific information.

Disaggregated datasets shall be used when applying the DNM.

Table 13 *Data Needs Matrix (DNM)*[15]

<table>
<tr><th></th><th></th><th>Most relevant process</th><th>Other process</th></tr>
<tr><td rowspan="2">Situation 1: process run by the company using the FreshProducePEFCR</td><td>Option 1</td><td colspan="2">Provide company-specific data (as requested in the FreshProducePEFCR) and create a company-specific dataset, in aggregated form (DQR≤1.5).
Calculate the DQR values (for each criterion + total).</td></tr>
<tr><td>Option 2</td><td></td><td>Use default secondary dataset in FreshProducePEFCR, in aggregated form (DQR≤3.0).

Use the default DQR values.</td></tr>
<tr><td rowspan="3">Situation 2: process not run by the company using the FreshProducePEFCR but with access to company-specific information</td><td>Option 1</td><td colspan="2">Provide company-specific data (as requested in the FreshProducePEFCR) and create a company-specific dataset, in aggregated form (DQR≤1.5).
Calculate the DQR values (for each criterion + total).</td></tr>
<tr><td>Option 2</td><td>Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤3.0).

Re-evaluate the DQR criteria within the product-specific context.</td><td></td></tr>
<tr><td>Option 3</td><td></td><td>Use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤4.0).

Use the default DQR values.</td></tr>
<tr><td rowspan="2">Situation 3: process not run by the company using the FreshProducePEFCR and without access to company-specific information</td><td>Option 1</td><td>Use default secondary data set in aggregated form (DQR≤3.0).

Re-evaluate the DQR criteria within the product-specific context</td><td></td></tr>
<tr><td>Option 2</td><td></td><td>Use default secondary dataset in aggregated form (DQR≤4.0).

Use the default DQR values.</td></tr>
</table>

Grey fields are not applicable.

5.4.1 Processes in situation 1

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 the FreshProducePEFCR 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 the FreshProducePEFCR applies company-specific data. The DQR of the newly developed dataset shall be evaluated as described in Section 5.3.1.

Situation 1/Option 2
For the non-most relevant processes only, if the user of the FreshProducePEFCR decides to model the process without collecting company-specific data, then the user shall use the secondary dataset listed in the FreshProducePEFCR together with its default DQR values listed here.

If the default dataset to be used for the process is not listed in the FreshProducePEFCR, the user of the FreshProducePEFCR shall take the DQR values from the metadata of the original dataset.

[15] The options described in the DNM are not listed in order of preference.

5.4.2 Processes in situation 2

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

1. The user of the FreshProducePEFCR has access to extensive supplier-specific information and wants to create a new background dataset (Option 1).
2. The company has some supplier-specific information and wants to make some minimum changes (Option 2) (only for most relevant processes).
3. The process is not in the list of most relevant processes and the company wants to make some minimum changes (option 3) (only for processes not indicated as most relevant).

Situation 2/Option 1
For all processes not run by the company and where the user of the FreshProducePEFCR applies company-specific data, the DQR of the newly developed dataset shall be evaluated as described in Section 5.3.1.

Situation 2/Option 2
The user of the FreshProducePEFCR shall use company-specific activity data for transport and shall substitute the sub-processes used for electricity mix and transport with supply-chain specific datasets from the required background database, starting from the default secondary dataset provided in the FreshProducePEFCR. Please note that the FreshProducePEFCR lists all dataset names. For this situation, the disaggregated version of the dataset is required.

The user of the FreshProducePEFCR shall make the DQR context-specific by re-evaluating TeR and TiR using the Table 14. The criteria GR shall be lowered by 30% and the criteria P shall keep the original value.

Situation 2/Option 3
The user of the FreshProducePEFCR shall apply company-specific activity data for transport and shall substitute the sub-processes used for electricity mix and transport with supply-chain specific datasets from the required background database, starting from the default secondary dataset provided in the FreshProducePEFCR.

Please note that the FreshProducePEFCR lists all dataset. For this situation, the disaggregated version of the dataset is required.

In this case, the user of the FreshProducePEFCR shall use the default DQR values. If the default dataset to be used for the process is not listed in the FreshProducePEFCR, the user of the FreshProducePEFCR shall take the DQR values from the original dataset.

Table 14 *How to assess the value of the DQR criteria when secondary datasets are used*

	TiR	TeR	GeR
1	The EF report publication date occurs within the time validity of the dataset	The technology used in the EF study is exactly the same as the one in scope of the dataset	The process modelled in the EF study takes place in the country the dataset is valid for
2	The EF report publication date occurs no later than 2 years beyond the time validity of the dataset	The technologies used in the EF study is included in the mix of technologies in scope of the dataset	The process modelled in the EF study takes place in the geographical region (e.g., Europe) the dataset is valid for
3	The EF report publication date occurs no later than 4 years beyond the time validity of the dataset	The technologies used in the EF study are only partly included in the scope of the dataset	The process modelled in the EF study takes place in one of the geographical regions the dataset is valid for
4	The EF report publication date occurs no later than 6 years beyond the time validity of the dataset	The technologies used in the EF study are similar to those included in the scope of the dataset	The process modelled in the EF 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 EF report publication date occurs later than 6 years after the time validity of the dataset	The technologies used in the EF study are different from those included in the scope of the dataset	The process modelled in the EF study takes place in a different country than the one the dataset is valid for

5.4.3 Processes in situation 3

If a process is not run by the company using the FreshProducePEFCR 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 the FreshProducePEFCR shall make the DQR values of the dataset used context-specific by re-evaluating TeR, TiR and GR, using the table(s) provided. The criteria P shall keep the original value.

Situation 3/Option 2
For the non-most relevant processes, the user of the FreshProducePEFCR shall apply the corresponding secondary dataset listed in the FreshProducePEFCR together with its DQR values.

If the default dataset to be used for the process is not listed in the FreshProducePEFCR, the user of the FreshProducePEFCR shall take the DQR values from the original dataset.

5.5 Datasets to be used

The FreshProducePEFCR has been developed independently of the official PEF framework established by the European Commission. In accordance with the restrictions set forth in the end-user license agreement (EULA) for the accompanying EF database, its use is not authorised in context of the FreshProducePEFCR. Therefore, this FreshProducePEFCR prescribes datasets that shall be used for PEF studies carried out in compliance with this PEFCR. These datasets, hereafter referred to as 'the list of recommended datasets' are listed in the accompanying excel file named 'FreshProducePEFCR – List of recommended datasets'. Datasets are retrieved from the following databases:

1. ecoinvent 3.10, with the 'allocation, cut-off by classification' system model
2. Growing Media Europe LCI database
3. Agri-footprint 6.3, economic allocation

Whenever a dataset is needed to calculate the PEF-profile that is not within the list of recommended datasets, the user shall choose between the following options (in hierarchical order):

4. Use another dataset in the list of recommended datasets that is considered to be a good proxy. In such a case this information shall be included in the 'limitations' section of the EF report. Users of the FreshProducePEFCR shall clearly state in the PEF report for which dataset this option is applied.
5. Use a dataset not included in the list of recommended datasets from the following databases:
   a. ecoinvent 3.10, with the 'allocation, cut-off by classification' system model
   b. Agri-footprint 6.3, economic allocation.
      Users of the FreshProducePEFCR shall clearly state in the PEF report for which dataset this option is applied.
6. If none of the aforementioned criteria is satisfied, and no dataset is available that can provide the necessary information, it shall be excluded from the PEF study. This shall be clearly stated in the PEF report as a data gap and validated by the PEF study and verifiers. Additionally, the user of the FreshProducePEFCR should inform the developers of the FreshProducePEFCR about the missing dataset.

If a more recent version of the databases referenced above is/becomes available, it may be used, provided that its application is documented in the PEF report. This documentation should include details on the version used, any relevant updates or changes, and their potential impact on the PEF results.

5.6 How to calculate the average DQR of the study

To calculate the average DQR of the PEF study, the user of the FreshProducePEFCR shall calculate separately the TeR, TiR, GeR and P for the PEF study as the weighted average of all most relevant processes, based on their relative environmental contribution to the total single overall score. The calculation rules explained in Section 4.6.5.8 of Annex I shall be used (European Commission, 2021).

5.7 Allocation rules for multifunctional processes

If a process provides more than one function, i.e., it delivers several '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. In case of multifunctional processes allocation shall be applied according to the allocation rules specified in Table 15. If the process is not described in this table, the guidance in Section 4.5 of Annex I of the recommendation on the use of the Environmental Footprint methods from the European Commission (2021) shall be followed.

Table 15 *Allocation rules*

Process	Allocation rule	Modelling instructions	Allocation factor
Allocating organic fertiliser use, green manure and compost in annual open field rotation systems	Organic manure is divided over all crops in the crop rotation scheme on the basis of share in area, except for the mineral N fraction, which is allocated solely to the crop of application	If organic fertiliser is applied in a crop rotation scheme, the following calculation rules apply for fertilisation of N (BSI, 2012). Formula 1 (Calculating N application to a crop as part of a crop rotation scheme) Total N from organic fertiliser applied to the plot where crop A stands (in kg N/area unit) = NmOA + NcrA +aA/aT x (NoOT+NcrT) Where: • NmOA = mineral nitrogen from organic fertiliser applied to crop A (kg N/area unit) • NcrA = nitrogen from residues of crop A (kg N/ area unit) • aA = area of crop A (area unit) • aT = total area of rotation system (area unit) • NoOT = organic nitrogen from organic fertiliser applied on all area (kg N/ area unit) • NcrT = nitrogen from crop residues of green manure on all area (kg N/ area unit) All other fertilising elements supplied using organic fertilisers, including green manure, are calculated by formula 2. Formula 2: (Calculating fertiliser application to a crop as part of a rotation scheme) Fapplied to crop A = aA/aT x (FOT) Where: • Fapplied to crop A = fertliser applied to crop A • aA = area of A (area unit) • aT = total area of rotation system (area unit) • FOT = organic fertiliser applied on all area (kg F/area unit)	

Process	Allocation rule	Modelling instructions	Allocation factor
Organic fertilisers	Manure used in conventional farming is considered as a zero-burden product unless farmers need to pay a price for the manure that exceeds transport costs. Manure is then treated as a co-product where economic allocation shall be used. If the animal farmer needs to pay a price to the party receiving the manure, it is treated as residual product. Economic allocation shall be applied for all other organic fertilisers originating from industrial processes.	For manure, as a zero-burden product, all activities needed after storage at the animal farm to application on the horticulture crop are included (thus including transport and processing if occurring). If manure has a price, then the price will be based on the revenues for the animal farmer (excluding transport costs) or the price will be based on a shadow price derived from equivalent quantities of artificial fertiliser needed.	
Energy use, cleaning and other generic operations in cultivation	Land occupation	When multiple crops are grown within the same system (plot/greenhouse), the relative land occupation of each crop shall be applied to allocate the interventions related to the inputs for which it cannot be specified. When possible, the system shall first be broken down into sub-systems, for instance into separated compartments within a greenhouse. Land occupation per crop shall be obtained by specific data for the analysed time period (this will include any changes in land occupation due to differences with planning, differences in production, etc.). When not available, the average land occupation per crop shall be used. This shall be calculated by adding together the land occupation per crop per phase using the following equation: LO = Sum over phases (p) (GTp / PDp) Where: LO = land occupation (yr*m^2) GTp = growing time of phase p (yr) PDp = crop density of phase p (kg / m^2)	
Combined heat and power systems (CHP) in Greenhouse Cultivation	Energy content (energy allocation)	The impact of CHP for the horticultural system shall be calculated by subdividing the heat and electricity produced, based on the energy produced through both. No environmental impact shall be attributed to the production of CO_2 output from the CHP. However, the environmental impacts of the purification process shall be attributed to the produced CO_2. If CHP is turned on for electricity only, then heat should be attributed to the product (see section 6.2.4.3). For the limitations related to this approach see section 3.8.	
(European Commission, 2021)Storage to single product	Volume and time	Only part of the emissions and resources emitted or used at storage systems shall be allocated to the product stored. This allocation shall be based on the space (in m^3) and time (in weeks) occupied by the product stored. For this the total storage capacity of the system shall be known, and the product-specific volume and storage time shall be used to calculate the allocation factor (as the ratio between product-specific volume*time and storage capacity volume*time). Further guidance on emission and resource allocation from storage can be found in European Commission (2021).	

Process	Allocation rule	Modelling instructions	Allocation factor
(co-)products	Economic allocation or cut-off	If the sending party receives a price for (co-)products allocated to the processing industry that exceeds the transport costs, economic allocation shall be applied. Conversely, if the price does not exceed the transport costs, the (co-)product shall be considered a residual by-product, and a cut-off criterion shall be applied. Co-products refer to any material generated during the production of the primary product (e.g., wood produced during orange cultivation) or the primary product itself, which is considered unsuitable for direct human consumption without further processing (e.g., oranges intended for juice production). The physical separation between the main product and the co-product is likely to occur in a life cycle phase subsequent to cultivation. However, the environmental impacts shall be allocated to the cultivation phase. For example, apples are sorted into first-class apples for direct human consumption and those allocated for industrial use (e.g., juice production). If the price of apples directed to industry exceeds the transport costs, economic allocation shall be applied within the cultivation phase.	

5.8 Electricity modelling

The following electricity mix shall be used in hierarchical order:

1. Supplier-specific electricity product shall be used if for a country there is a 100% tracking system in place, or if:
   a. available, and
   b. the set of minimum criteria to ensure the contractual instruments are reliable is met.
2. The supplier-specific total electricity mix shall be used if:
   a. available, and
   b. the set of minimum criteria to ensure the contractual instruments are reliable is met.
3. 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).
4. As a last option, the average EU residual grid mix, consumption mix (EU-28 +EFTA), or region representative residual grid mix, consumption 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 environmental footprint 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 PEF 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 the FreshProducePEFCR 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.

The list of criteria below is based on the criteria of the GHG Protocol Scope 2 Guidance – An amendment to the GHG Protocol Corporate Standard – Mary Sotos – World Resource Institute. 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 characterised as having the environmental attributes of the country residual consumption mix where the facility is located, or shall be characterised by corresponding purchased attributes (e.g., guarantees of origin).

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 (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.

Allocation rules: Please refer to Section 5.7.

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:
1. 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.

2. 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.
3. If all the products produced in the specific plant are supplied with a publicly available environmental footprint study, the company wanting to make the claim shall make all environmental footprint studies available. The allocation rule applied shall be described in the environmental footprint study, consistently applied in all environmental footprint 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

For the specific case of combined heat and power providing, electricity, heat and/or CO_2 to the farmer, this FreshProducePEFCR provides specific modelling rules that are described in Section 6.2.4. On-site electricity generation using any other technology exclusive for electricity generation, shall be modelled following the steps described below.

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 multifunctional 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 environmental footprint study).
2. If not possible, direct substitution shall be used. The country-specific residual consumption electricity mix shall be used as substitution.[16]

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

5.9 Climate change modelling

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

1. **Climate change – fossil**: This sub-category includes emissions from peat and calcination/carbonation of limestone. The emission flows ending with '(fossil)' (e.g., 'carbon dioxide (fossil)' and 'methane (fossil)') shall be used, if available.

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, biofuels or aboveground plant residues, such as litter and dead wood. Carbon exchanges from native forests[17] shall be modelled under sub-category 3 (including connected soil emissions, derived products, residues). The emission flows ending with '(biogenic)' shall be used.

   A simplified modelling approach shall be used when modelling foreground emissions.

[16] For some countries, this option is a best case rather than a worst case.
[17] Native forests – represents native or long-term, non-degraded forests. Definition adapted from Table 8 in Annex V C(2010)3751 to Directive 2009/28/EC.

Only the emission 'methane (biogenic)' is modelled, while no further biogenic emissions and uptakes from atmosphere are included. 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**: 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. This sub-category includes biogenic carbon exchanges from deforestation, road construction, or other soil activities (including soil carbon emissions). For native forests, all related CO_2 emissions are included and modelled under this sub-category (including connected soil emissions, products derived from native forest[18], and residues), while their CO_2 uptake is excluded. The emission flows ending with 'land use change' shall be used.

For land use change, all carbon emissions and removals shall be modelled following the modelling guidelines of PAS 2050:2011 (BSI, 2011) and the supplementary document PAS2050-1:2012 (BSI, 2012) for horticultural products. PAS 2050:2011: 'Large emissions of GHGs can result as a consequence of land use change' (BSI, 2011). 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 recognised 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 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.

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 emissions arising from the product shall be assessed on the basis of the default land use change values provided in PAS 2050:2011 Annex C, unless better data is available. For countries and land use changes not included in this annex, the emissions arising from the product shall be assessed using the included GHG emissions and removals occurring as a result of direct land use change in accordance with the relevant sections of the (IPCC, 2006). 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 total GHG emissions and removals arising from direct land use change over the period shall be included in the quantification of GHG emissions of products arising from this land on the basis of equal allocation to each year of the period.[19]

1. Where it can be demonstrated that the land use change occurred more than 20 years prior to the assessment being carried out, no emissions from land use change should be included in the assessment.
2. Where the timing of land use change cannot be demonstrated to be more than 20 years, or a single harvest period, prior to making the assessment (whichever is the longer), it shall be assumed that the land use change occurred on 1 January of either:
   the earliest year in which it can be demonstrated that the land use change had occurred; or on 1 January of the year in which the assessment of GHG emissions and removals is being carried out.

The following hierarchy shall apply when determining the GHG emissions and removals arising from land use change occurring not more than 20 years or a single harvest period, prior to making the assessment (whichever is the longer):

1. where the country of production is known and the previous land use is known, the GHG emissions and removals arising from land use change shall be those resulting from the change in land use from the previous land use to the current land use in that country (additional guidelines on the calculations can be found in PAS 2050-1:2012)

[18] Following the instantaneous oxidation approach in IPCC 2013 (Chapter 2).
[19] In case of variability of production over the years, a mass allocation should be applied.

2. where the country of production is known, but the former land use is not known, the GHG emissions arising from land use change shall be the estimate of average emissions from the land use change for that crop in that country (additional guidelines on the calculations can be found in PAS 2050-1:2012)
3. where neither the country of production nor the former land use is known, the 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.'

The sum of the three sub-categories shall be reported.

The sub-category 'Climate change-fossil' should be reported separately.

The sub-category 'Climate change-biogenic' should be reported separately.

The sub-category 'Climate change-land use and land transformation' should be reported separately.

Carbon storage
Currently, credits associated with temporary and permanent carbon storage and/or delayed emissions shall not be considered in the calculation of the climate change indicator. This means that all emissions and removals shall be considered as emitted 'now', and there is no discounting of emissions over time (in line with EN ISO 14067:2018). Developments will be considered in order to keep the method updated with scientific evidence and expert-based consensus. Soil carbon storage may be modelled, calculated and reported as additional environmental information.

Offsets
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 on 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.

As per EF methods from the European Commission (2021), offsets shall not be included in the impact assessment of a PEF study, but may be reported separately as additional environmental information.

5.10 Modelling of end of life and recycled content

Modelling of end of life
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 section provides rules on how to model the end of life of products as well as the recycled content.

Circular Footprint Formula (CFF)
The Circular Footprint Formula (CFF) is used to model the end of life of products as well as the recycled content and is a combination of 'material + energy + disposal', i.e.:

Material

$$(1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$$ Equation 3 (material)

Energy $$(1-B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$ Equation 4 (energy)

Disposal $$(1-R_2-R_3) \times E_D$$ Equation 5 (disposal)

With the following parameters

- **A:** allocation factor of burdens and credits between supplier and user of recycled materials.
- **$AE_{recycled}$:** specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.
- **B:** allocation factor of energy recovery processes. It applies both to burdens and credits. It shall be set to zero for all PEF studies.
- **Q_{sin}:** quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.
- **Q_{sout}:** quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.
- **Q_p:** quality of the primary material, i.e. quality of the virgin material.
- **R_1:** it is the proportion of material in the input to the production that has been recycled from a previous system.
- **R_2:** it is the proportion of the material in the product that will be recycled (or reused) in a subsequent system. R_2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R_2 shall be measured at the output of the recycling plant.
- **R_3:** it is the proportion of the material in the product that is used for energy recovery at EoL.
- **$E_{recyclingEoL}$:** specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process.
- **E_v:** specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material.
- **E^*_v:** specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.
- **E_{ER}:** specific emissions and resources consumed (per functional unit) arising from the energy recovery process (e.g., incineration with energy recovery, landfill with energy recovery, etc.).
- **$E_{SE,heat}$ and $E_{SE,elec}$:** specific emissions and resources consumed (per functional unit) that would have arisen from the specific substituted energy source, heat and electricity, respectively.
- **E_D:** specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery.
- **$X_{ER,heat}$ and $X_{ER,elec}$:** the efficiency of the energy recovery process for both heat and electricity.
- **LHV:** lower heating value of the material in the product that is used for energy recovery.

Guidance and default values for CFF

At several life cycle stages product losses and packaging waste occurs, while some materials are recycled or reused, as is elaborated per life cycle stage in Chapter 6. The circular footprint formula applies in these situations.

This chapter does not apply to the end-of-life situation for the use of purified CO_2, organic fertilisers, and reutilisation of growing media (including stone-wool). In these specific cases the guidance in Section 6.2.4.4, Section 6.2.7, Section 6.2.9, and Section 6.8 of FreshProducePEFCR should be applied, respectively.

The default parameters to use in modelling the circular footprint formula are provided in Annex C Transition Phase[20] of the PEF method (European Commission, 2021). In case a specific A value is not in Annex C Transition Phase, the following procedure shall be followed:

1. Check in Annex C the availability of an application-specific A value which fits the FreshProducePEFCR,
2. If an application-specific A value is not available, the material-specific A value in Annex C shall be used.
3. If a material-specific A value is not available, the A value shall be set equal to 0.5.

[20] https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

The FreshProducePEFCR refers to Chapter 4.4.8.1 of Annex I, the PEF method (European Commission, 2021) on CFF on how to deal with alternative parameters to the once provided in Annex C. This applies to all the parameters of equation 3, 4 and 5.

Modelling recycled content

The following part of the CFF is used to model the recycled content:

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

Equation 3a

The R_1 values applied shall be supply-chain specific or default as provided in annex C of the PEF method, in relation with the DNM. Material-specific values based on supply market statistics are not accepted as a proxy and therefore shall not be used. The applied R_1 values shall be subject to verification.

When using supply-chain specific R_1 values other than 0, traceability throughout the supply chain is necessary. The following guidelines shall be followed when using supply-chain specific R_1 values:

1. The supplier information (through, e.g., statement of conformity or delivery note) shall be maintained during all stages of production and delivery at the converter;
2. Once the material is delivered to the converter for production of the end products, the converter shall handle information through their regular administrative procedures;
3. The converter for production of the end products claiming recycled content shall demonstrate through its management system the (%) of recycled input material into the respective end product(s);
4. The latter demonstration shall be transferred upon request to the user of the end product. In case an environmental footprint profile is calculated and reported, this shall be stated as additional technical information of the environmental footprint profile;
5. Company-owned traceability systems may be applied as long as they cover the general guidelines outlined above.

Industry systems may be applied as long as they cover the general guidelines outlined above. In that case, the text above may be replaced by those industry-specific rules. If not, they shall be supplemented with the general guidelines above.

6 Life cycle stages

The following subsections describe the life cycle stages covered in the scope of the FreshProducePEFCR. They cover all modelling- and data requirements and assumptions to be applied by the user of this FreshProducePEFCR. Most of the rules are applicable to both sub-categories. In case different rules are applicable for either one of the sub-categories, this is specified.

6.1 Raw material acquisition, pre-processing and starting material

This section lists all technical requirements and assumptions for modelling raw material acquisition, pre-processing and starting material to be applied by the user of the FreshProducePEFCR. This life cycle stage considers the materials acquired for the cultivation stage. Materials acquired are plant input material, growing media, capital goods, materials (e.g., trellis systems), crop protection products, biological pest control, fertilisers (synthetic and mineral, organic and CO_2), and heat.

All data are collected per gross area of farm plots being part of the study. By combining yields, allocation data (e.g., prices of co-products) and the other data points, the data are transferred to data per unit of product.

For transport of raw materials to the farm, primary data should be used (if available). In case no primary data is available, the default scenarios outlined in Table 16, shall be used.

Table 16 *Default transport scenarios*

Transport mode	Distance (km)	Default process to be used
For manure:		
Truck	30	Transport, freight, lorry >32 metric ton, EURO6 {RER}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off
For packaging materials:		
Truck	230	Transport, freight, lorry >32 metric ton, EURO6 {RER}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off
Train	280	Transport, freight train {Europe without Switzerland}| market for transport, freight train | Cut-off
Barge	360	Transport, freight, inland waterways, barge {RER}| transport, freight, inland waterways, barge | Cut-off
For all other inputs:		
Truck	130	Transport, freight, lorry >32 metric ton, EURO6 {RER}| transport, freight, lorry >32 metric ton, EURO6 | Cut-off
Train	240	Transport, freight train {Europe without Switzerland}| market for transport, freight train | Cut-off
Barge	270	Transport, freight, inland waterways, barge {RER}| transport, freight, inland waterways, barge | Cut-off

6.1.1 Starting material

Plant input material can be seeds, seedlings, cuttings (or other) or young plants. For the plant input material, the following data shall be collected:

- number of seeds, seedlings and/or young plants needed per area
- transport mode, distance and mass of plant input materials
- mass of starting material (as delivered to farm)

For the production of starting material secondary data may be used. In case there is no exact match with a background process, a proxy shall be used. This shall be listed in the limitations section of the PEF study. The selection of the proxy shall involve both the product itself and the production system (e.g., heated or non-heated).

6.1.2 Growing media

A growing medium is a material, other than soil in situ, in which plants or mushrooms are grown. Growing media is used to support the development of plants (e.g., rooting environment, water absorption an retention, supply of nutrients). A growing media product can be a mix of constituents or a mono-material. The quantity of growing media used shall be collected (in volume) on an annual basis. If growing media are used for a longer period than a year, the annual usage shall be defined by dividing the amount of growing media by the years of usage.

Growing media composition
Data regarding the composition and additional ingredients (i.e., additives) of the growing media shall be collected and documented in the PEF report. All constituents shall add up to a total of 100% volume/volume for a fresh mix. The exact composition of the growing media shall be used, no proxy is allowed. The fresh bulk density (in kg/m^3) and the moisture content (in weight %) shall be specified as delivered to the farm. The fresh bulk density should be measured according to the EN 12580 standard (NEN, 2022). The composition of the growing media shall be based on the weighted average composition that takes into account time-related variation and the variation of geographical origin for supply (see Section 5.1).

Product losses in volume when mixing growing media constituents shall be accounted for. This is particularly important for growing media mixes composed of various constituents with varying densities. To ensure accurate accounting of constituent usage, a mass balance of the required constituents and the total mix shall be provided. Any losses incurred during the mixing process shall be reported and factored into the amount of product delivered to the farm.

When modelling the growing media, the user of this PEFCR shall use the correct moisture contents and bulk densities of all the constituents to avoid inadvertent overestimates or underestimates of material input when integrating the mix for calculation. When the moisture content and/or bulk density of a constituent at production changes before the final mix, this shall be registered and considered in the mass balance before calculating the amount of material required for the final growing media.

The use of additives in the growing media mix shall be recorded, based on the use by mass per m^3 of growing media (kg/m^3). The complete list of additives shall be provided, no additive shall be left out. If the additive is a fertiliser, the nutrient content has to be indicated as per here below.

Growing media or additives may contain nutrients. C, peat C, N, P, K, limestone, dolomite, urea, moisture content and density shall be collected and shall be considered when modelling N, P and CO_2 emissions during cultivation (Sections 6.2.7 and 6.2.9).

For the production of growing media constituents secondary data may be used (e.g., Growing Media Europe LCI Database). If company specific data is used to model the production of growing media constituents, this shall be done in accordance with the guidance given in the Growing Media Environmental Footprint Guidelines V2.0 (Growing Media Europe, 2024).

Data on utility use in mixing/processing operations and the packaging of growing media should be collected directly from the production plant and shall be modelled as per Section 5.8, 6.2.3, 6.2.4 and 6.2.5.

Inbound transport of the constituents to growing media processing plant and inbound transport to farm shall be modelled according to the guidance given in Section 6.1.

6.1.3 Capital goods

According to Annex I of the PEF method (European Commission, 2021), 'capital goods (including infrastructures) and their end of life should be excluded, unless there is evidence from previous studies that they are relevant.' Kan et al. (2020) provide evidence for the inclusion of greenhouses. Greenhouses often have a large contribution to the environmental footprint of horticultural products (Kan et al., 2020). Thus, greenhouse constructions used in the cultivation of fruit and vegetable products shall be included by users of this FreshProducePEFCR. Other capital goods used in cultivation, or parts of greenhouses not used for cultivation activities, do not need to be included in PEF studies adopting this FreshProducePEFCR.

Practitioner may collect primary data when available. An overview of the data that needs to be collected is provided in Memo on capital goods modelling, see Kan et al. (2020) (Table 6 and Table 7). Many greenhouses around the world have been designed using the 'CASTA/Kassenbouw' programme (TNO, n.d.). CASTA reports can contain relevant information to retrieve primary data on the greenhouse structure. If primary data on greenhouses is not available, Kan et al. (2020) provide default data to be used for a few greenhouse types (Table 3 and Table 5).

Greenhouse depreciation shall be taken into account in all cases. Linear depreciation shall be used. The expected service life of the greenhouse shall be taken into account. By combining the material bill of the greenhouse, the total size, and the expected lifetime of the greenhouse, the material use per greenhouse shall be established. If there is no specific information on the lifetime of the greenhouse, a default lifetime of 15 years (Montero et al., 2011) shall be assumed. To calculate the input of greenhouse per unit of product, the total yield shall be divided by the size of the greenhouse, the expected lifetime of the greenhouse and, in case of different crops grown after each other, the share of cropping time it takes to grow the product.

$$AGH_p = (AGH_T * CT_p / CT_T) / (LTGH * YGH) \quad \text{Equation 6}$$

Where:
- AGH_p = the area of the greenhouse per FU (ha)
- AGH_T = the total area of the greenhouse (ha)
- CT_p = the cropping time (length of the cropping period) of crop p (weeks)
- CT_T = the total cropping time (weeks)
- LTGH = the life time of the greenhouse (yr)
- YGH = the yield of the product for the entire greenhouse (t/yr)

When multiple crops are grown within one capital good, the bill of materials needs to be allocated between the crops using the allocation rules provided in Table 15.

6.1.4 Materials use

There can be a wide variety of material use at a farm. The following types shall be added in the inventory, if applicable: materials used for crop covering and for guiding plants. If materials are used multiple times, the total amount used shall be distributed proportionally over the number of uses.

6.1.4.1 Materials used for crop covering

Materials used for crop covering may be relevant in open field and protected farm systems. It concerns the use of natural materials such as mulch or straw and synthetic materials such as plastics.

6.1.4.2 Materials used for guiding plants

Some plants are led and supported. For this purpose, a wide variety of constructions are developed consisting of a range of materials, such as wood, steel and plastics. This includes trellis systems used in fruit cultivation.

6.1.5 Crop protection products

Crop protection products are products that aim to protect crops or desirable/useful plants from pests and diseases. They are primarily used in the agricultural sector but also in forestry, horticulture, amenity areas and in home gardens. They contain at least one active substance and have one of the following functions (European Commission, 2021);

- protect plants or plant products against pests/diseases, before or after harvest
- influence the life processes of plants (such as substances influencing their growth, excluding nutrients)
- preserve plant products
- destroy or prevent growth of undesired plants or parts of plants.

Company-specific data shall be collected on all use of crop protection products such as herbicides, insecticides, fungicides, biocides, soil fumigants in cultivation and storage. This data involves the specific active ingredient and its CAS number, the application rate in grams per year per area unit or per crop weight unit for the crop under study. In case the application rate is not available in weight units, a conversion from volume (e.g., litre) to weight units (e.g., grams) shall be made based on the density of the specific active ingredient. The active ingredients can be organic or inorganic chemicals such as S and Cu compounds.

For the production of crop protection products secondary data may be used. Wherever possible, product type specific datasets shall be used. If this is not available, a pesticide 'unspecified' dataset shall be used. The background dataset may include water as inert ingredient for pesticide formulation, the user of the FreshProducePEFCR shall take this into consideration. Transport of crop protection products to farm shall be omitted, as well as packaging for the crop protection product.

The rules for modelling of the emissions resulting from the application of crop protection products in the field is documented in Section 6.2.6.

Secondary data on biological pest control are not readily available for use within LCA studies. As a result, biological pest control does not need to be considered within the current scope of the FreshProducePEFCR. If biological pest control is used, this shall be reported as additional technical information together with the type of biological pest control (Section 3.6).

6.1.6 Fertilisers

6.1.6.1 Synthetic and mineral fertilisers

For synthetic and mineral fertilisers data shall be collected on the application of macro elements (N, P, K), meso elements (Ca, Mg, S) and micro elements (B, Cu, Fe, Mn, Mo, Si, Zn) as illustrated in Fout! Verwijzingsbron niet gevonden.. Data on N fertilisers shall be split in urea and other N compounds. For N, P, K and Ca fertilisers, data shall also be collected on compounds use for more precise calculations. The data shall be specified in weight per area for the crop under study. Transport distance shall also be modelled.

Table 17 *fertiliser use activity data collection table*

Activity data	Unit per gross area per year	Quantity	Source and method of measurement
Fertiliser brand or type name and composition	Kg/ha		
Urea	Kg N/ha		
Calculated N use	Kg N/ha		
Calculated P use	Kg P/ha		
Calculated K use	Kg K/ha		
CaO use	Kg CaO/ha		
$CaCO_3$ use	Kg $CaCO_3$/ha		
Mg use	Kg Mg/ha		
S use	Kg S/ha		
B use	Kg B/ha		
Cu use	Kg Cu/ha		
Fe use	Kg Fe/ha		
Mn use	Kg Mn/ha		
Mo use	Kg Mo/ha		
Si use	Kg Si/ha		
Zn use	Kg Zn/ha		

For the production of synthetic and mineral fertilisers secondary data may be used.

6.1.6.2 Organic fertilisers

Organic fertilisers are products originating from a wide range of sources, such as animal manure, co-products from industry and compost. The following data shall be collected on organic fertilisers:

- Fertiliser type (e.g., animal type, compost, industry)
- Fertiliser composition: water, total N, organic bound N, mineral N, P, K, Cd, Zn, Cu and
- transport mode, distance and mass of fertilisers.

For the composition of N, P, and K and fertiliser type primary data shall be used. For the production and transport of organic fertilisers to farm, secondary data may be used, as well as for the composition of trace elements Cd, Zn, and Cu.

Organic fertilisers may also be used in bulk as one-time amendments to improve soil quality and increase soil organic carbon rather than being used primarily for nutrients provision. In such case, allocating impacts from composting production to the crop in scope can lead to a disproportionate environmental footprint. In order to derive a more representative footprint, the composting impacts would have to be amortised over a given time. The recommended option is to amortise the impacts of compost production by the number of years of expected usage, in accordance with what indicated for growing media in Section 6.2.1.If it is not possible to know the expected usage or in the case that amendments are only applied once, the maximum number of years to be used to amortise impacts is 20 (IPCC, 2019).

6.2 Cultivation

The cultivation stage considers all activities related to the cultivation, including, but not limited to: plot preparation, planting/sowing, growing, and harvesting the fruits and vegetables. Emissions from (the use of) crop protection products, fertilisers, growing media, land use and land use change, and peat oxidation are considered in this life cycle stage. The additional quantity to be cultivated for products that are going to the processing industry is accounted for in this life cycle stage. Energy used for cultivation activities and CO_2 generation via CHP on site are in this stage as well.

6.2.1 Time period to consider for data collection of cultivation stage

Note: this section should be read in conjunction with Section 5.1

For all cultivation data it is important to carefully define the average performance of the production system considering the variation in inputs and outputs related to climate variation. For perennial plants it is crucial to have a representative contribution of the different growth phases in the production system.

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 annual and seasonal differences:

- 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 grown in greenhouses shall be considered as annual crops, 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 are cultivated and harvested over a longer period through the year are considered as annual crops.
- 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.[21] The non-productive years, whether during the establishment or destruction phase, shall be accounted for.
- 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.
- 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.

6.2.2 Land occupation and land use change

Data on land use and direct land use change (LUC) shall be collected. This shall be country-specific. Land use per FU is calculated from collected data on yield per hectare of land. If no data on land use (i.e. land occupation type) is available, the following data shall be used:

- Open field, in soil: occupation, arable OR permanent crops, [country-specific suffix]
- Open field, outside soil: occupation, arable OR permanent crops, [country-specific suffix]
- Protected, in soil: occupation, arable, greenhouse, [country-specific suffix]
- Protected, outside soil: occupation, arable, greenhouse, [country-specific suffix]

For the farm plots where the crop(s) under study are grown, data shall be collected on area use and on the history of the plot if a specific LUC calculation is done. If the farm (plots) have a proven history of no LUC for more than 20 years this means that there is no GHG impact of LUC and/or land transformation flows. All carbon emissions and removals shall be modelled following the modelling guidelines of PAS 2050:2011 (BSI, 2011) and the supplementary document PAS2050-1:2012 (BSI, 2012) for horticultural products. See Section 5.9 for more information on the modelling of the GHG impact of land use and LUC.

[21] 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 time 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 and more (e.g., in case of fruit and nut trees).

6.2.3 Water

Data on blue water use shall be collected according to Table 18. This includes among others, irrigation water[22], tap water, surface/groundwater etc. Rainwater, unless sourced via surface or groundwater resources, is not to be considered. Rainwater captured at the roof of a greenhouse, stored (e.g., in a basin) and later used in the greenhouse is seen as irrigation water and shall be accounted for. The elementary flow 'water, unspecified natural origin', shall be used in such cases.

Irrigation water is crop-specific. The flow of irrigation water can be measured/estimated with several methods. The source and method of measurement shall be recorded. In case (drainage) water from the crop under study is reused, this shall be reported as well as the recirculation percentage. The specific water-flow entering the cultivation plot shall be corrected by deducting the recirculation percentage from the total water use. Any form of water treatment before reuse should be considered.

The user of this FreshProducePEFCR shall report the source of the irrigation water (e.g., well, canal/river, lake, tap water) and the country in which it is used and extracted. All water use should be calculated back to the FU.

Table 18 *Water use activity data collection*

Activity data	Unit per gross area per year per crop	Quantity	Water source (well, canal/river, lake, tap water)	Country of extraction	Source and method of measurement
Irrigation water	m^3 per ha, kg crop or farm per year				
Other water use	m^3 per ha, kg crop or farm per year				
Water discharge	m^3 per ha, kg crop or farm per year				
Recirculation	%		n/a	n/a	

6.2.4 Electricity, heat, and purified CO_2

6.2.4.1 Purchased electricity

Electricity consumed during cultivation shall be collected according to the electricity modelling in Section 5.8.

Electricity from a CHP system in a farm shall be modelled as described in Section 6.2.4.3. Electricity from a CHP system to a greenhouse of the same owner may be calculated from the CHP efficiency and electricity deliveries to the grid.

6.2.4.2 Purchased heat

For heat, data shall be collected on the energy use per hectare during cultivation. For purchased heat secondary data may be used.

For the production of heat from a CHP system located in a farm (own or neighbour), primary data of suppliers shall be used. Heat flows from a CHP to a greenhouse of the same owner may be calculated from the CHP efficiency and heat delivered to third parties (see Section 6.2.4.3).

[22] Using the volume of water used for irrigation instead of blue water consumption will potentially lead to an overestimation of water related impacts. Blue water consumption only accounts for the volume of irrigated water consumed for transpiration and evaporation. Water volumes in the soil, resulted to the system, or lost during conveyance are not included (Mialyk et al., 2024).

6.2.4.3 Combined heat and power (CHP) systems

A combined heat and power (CHP) system can provide heat, electricity, and purified CO_2 to a farm. In case a farmer has a CHP system, activity data from the operation inputs and outputs of the CHP system shall be gathered. A CHP system shall be modelled according to the following hierarchy:

1. By subdivision, i.e., by dividing the CHP unit to the smallest unit possible, being 1) the cultivation activities, 2) the CHP system and 3) the flue gas cleaning system.
2. If subdivision is not feasible, activity data shall be collected on the CHP including the flue gas cleaning system and the cultivation separately.
3. If subdivision between CHP and cultivation is not feasible, a theoretical subdivision shall be constructed by calculating all unknown energy inputs and output from the CHP from the known energy flows.

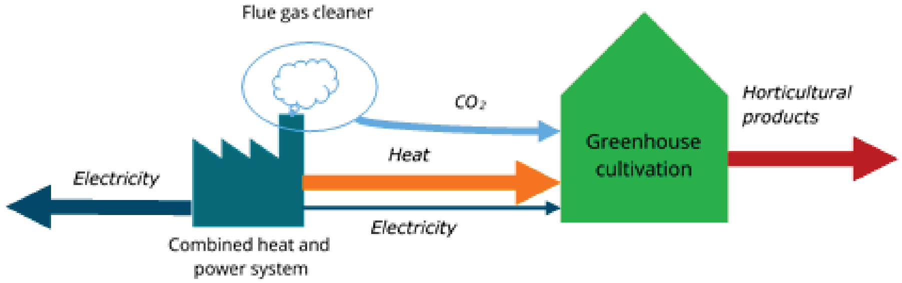

Figure 5 *Graphical representation of the heated greenhouse processes, subdivided into three unit process and the product flows*

Activity data for the CHP unit shall include:

1. The type and quantity of fuel used by the CHP per unit of electricity and heat produced. The amount and type of fuel shall be connected to appropriate secondary data for fuel production.

2. The environmental interventions related to the CHP unit, shall be calculated. This shall be done by applying the following provisions:
   a. Carbon dioxide (CO_2) emissions to air shall be determined in the following order of preference:
      i. The emission shall be collected from direct measurement or a documented prior measurement of the CHP unit considered.
      ii. If direct measurement is not available, the emission shall be collected from a data source specific to the installation, such as a technical specification document.
      iii. If a data source specific to the installation is not available, a public source, clearly stating average emissions from CHPs in general representative for the country of cultivation shall be used.
      iv. If a public source is not available, secondary data from scientific papers or LCA databases can be used.
   b. All emissions for different cases within the same study shall be from the same type of data source. Note that CO_2 may be used in the cultivation process, however CO_2 is considered a direct emission of the CHP heat and electricity production and shall not be attributed to any other stage in the cultivation process. As per 6.1.6, if CO_2 is used as fertiliser, the flue gas cleaning activities for the purification of CO_2 can be attributed to the production of CO_2 and its use as fertiliser in the cultivation process.
3. Methane (CH_4) emissions to air from natural gas should be directly measured from CHP unit operation considering mg of C loss per m^3 of natural gas, assuming all C lost is CH_4. If no measurement is available, a default worst case scenario of methane slip of 500 mg CH_4 Nm^3 (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2025). The CO_2 emitted from the combustion of natural gas in the CHP unit should be adjusted to account for the unburned methane. Methane emissions from combustion of fuels

other than natural gas shall be determined using the specific fuel heating value and carbon emission factors per energy unit.

a. Nitric oxide (NO_x) emissions to air shall be calculated using the EMEP/EEA Tier 1 approach mg emission per MJ of fuel.
b. Sulphur dioxide (SO_2) emitted to air shall be calculated using the EMEP/EEA Tier 1 approach mg emission per MJ of fuel.

4. Electricity and heat output per unit of fuel used shall be recorded. The activity data and environmental interventions from CHP shall be allocated to the heat and electricity outputs as per indication provided in Section 5.7.

Urea used for flue gas cleaning shall be recorded in weight units per unit of fuel used by the CHP. The amount of urea used shall be connected to appropriate secondary data for fuel production. Default urea use for flue gas cleaning is based on expert judgment and considered to be 1.75 ml/kWh. This value shall be applied if no primary data is available.

Urea use shall be allocated to the heat and electricity outputs as per indication provided in Section 6.1.6.

6.2.4.4 CO_2 as a fertiliser

CO_2 is used as a fertiliser in greenhouses. It can either be produced by farmers themselves in a CHP or fuel boiler, or purchased from a third party (e.g., OCAP). Guidance related to the production of CO_2 in a CHP can be found in Section 6.2.4.

If CO_2 is purchased from a third-party supplier the inputs required to capture, process (e.g., purifying), store, and transport the CO_2 to the greenhouse shall be included. Data shall be collected on the quantity in weight unit per area unit for the area where the crop under study is grown. The source of CO_2 used in greenhouse crops should be clearly defined in the EF study. Data, sources and assumptions used for modelling the impact should be recorded and reported. In case no company-specific data is available, secondary data may be used.

CO_2 emissions resulting from the application of purchased CO_2 at greenhouse shall be omitted. The application and emissions of CO_2 during the production of fruits and vegetables is considered as a delayed emission of the providing industry and should be accounted for by that industry.

6.2.4.5 Geothermal energy

Geothermal energy refers to the thermal energy stored beneath the earth's surface in the form of heat. This energy can be utilised for heating applications, such as in greenhouses or other facilities (e.g., warehouse, office). Geothermal energy is typically extracted from hot water contained within porous sand and rock layers located in the subsurface. As a renewable energy source, it offers a sustainable alternative to traditional heating methods reliant on coal or natural gas, given that heat is continually generated within the earth.

The emissions associated with the extraction and use of geothermal energy are attributable to several factors:

- The construction and establishment of the geothermal infrastructure
- The electricity consumption in the geothermal installation
- The combustion of formation gas, often referred to as 'by-catch.'

In case geothermal energy is generated on-site, the following rules apply.

Construction and establishment of the geothermal installation infrastructure

The input of geothermal infrastructure per unit of heat produced (i.e. extracted) (GI_h) in MJ can be calculated as:

$$GI_h = 1 / (AHPGI * LTGI) \qquad \text{Equation 7}$$

Where:
GI_h = the input of geothermal infrastructure per unit of heat product in MJ per year
AHPGI = annual heat production of the geothermal heat installation in MJ
LTGI = lifetime in years of the geothermal heat installation infrastructure in years

If there is no specific information on the lifetime of the geothermal heat installation available, a default lifetime of 30 years shall be assumed (Vlaar, 2013). GI_h shall be connected to the background dataset given in Table 19.

Electricity consumption in the geothermal installation
The electricity consumption in the installation per unit of produced heat shall be determined by dividing the total annual electricity usage (in kWh) by the annual heat output (in MJ). In the absence of specific data, a default value of 0.0253 kWh (per MJ heat output) shall be used (based on Vlaar, 2013) (Table 19). The electricity use shall be further modelled according to the Electricity modelling rules described in Section 5.8.

Combustion of formation gas
During the extraction of water from the subsurface, emissions due to the combustion of formation gas can occur ('by-catch'). This 'by-catch' can be flared or used in a natural gas boiler to heat the greenhouse. In case the 'by-catch' is being flared, the related emissions shall be fully allocated to the extraction of geothermal heat. The exact emission is based on the composition of the formation gas and this differs per geothermal heat location. Since more detailed information on the composition is lacking and to simplify modelling, a default emission factor for flared by-catch of 0.0562 kg CO_2 per MJ geothermal heat is considered (country specific EF of natural gas for the Netherlands (Rijksdienst voor Ondernemend Nederland, 2024)) (Table 18). The user of this FreshProducePEFCR may adjust this with an EF for the country where the geothermal heat is extracted. This emission shall be modelled as emissions to air. In case the by-catch is being used in the natural gas boiler or CHP-system, the modelling rules in Section 6.2.4.3 apply.

In case the geothermal heat is not the only source of heat during the year, co-firing or other sources of heat shall be considered according to the guidance given in other sub-sections of Section 6.2.4.

Table 19 *geothermal heat activity data collection for 1 MJ heat*

Inputs and outputs for 1 MJ of geothermal heat			
Output	**Quantity**	**Unit**	**Comment**
Heat, from geothermal	1	MJ	
Inputs from technosphere	**Quantity**	**Unit**	**Comment**
Geothermal power plant, 5.5MWel | Geothermal power plant construction | Cut-off	2E-10	P	The input of geothermal infrastructure, per MJ
Electricity use, low voltage | Cut-off	0.0253	kWh	Electricity for geothermal heat operation, per MJ
Emission to air	**Quantity**	**Unit**	**Comment**
Carbon dioxide, fossil	0.0562	kg	Proxy for flared by-catch. This value shall only be considered in case the by-catch is being flared. sub-compartment: air

6.2.4.6 Heat from third parties
Numerous third parties (e.g., industries, data centres, electricity power plants) generate substantial quantities of heat available at favourable temperatures for, e.g., growers. This heat can be transferred via a District Heating Network (DHN) to organisations in the fruit and vegetable supply chain for the purpose of heating greenhouses or other facilities. For these facilities, heat from third parties typically constitutes the primary energy source, with supplementary energy types used as needed.

Within this FreshProducePEFCR, three distinct categories of heat from third parties are identified:
Category 1: Heat originating from a third party, primarily generated for the purpose of supplying heat to external parties.
Category 2: Heat originating from a third party, where heat is produced as a co-product at a third party, for use by external parties.

Category 3: Heat originating from a third party, where heat is released as a residual (i.e., waste) product, for use by external parties.

Heat as described in category 1 shall be accounted for in accordance with Section 6.2.4.2. The environmental impacts associated with heat from third parties as described in categories 2 and 3, shall be calculated following the guidelines outlined below.

To begin, the user of the FreshProducePEFCR shall determine whether the heat being used qualifies as residual heat (i.e., 'waste' heat) or co-product. In this context, the definition of residual heat follows that of the Renewable Energy Directive, which describes waste heat as 'unavoidable heat generated as a by-product in industrial or power generation installations, or in the tertiary sector, which would dissipated unused in air or water without access to a district heating system, where a cogeneration has been used or will be used, or where cogeneration is not feasible.' For heat to be considered residual heat, all four cumulative criteria, as specified in Table 20, must be satisfied. These criteria are derived from the Europeans Commissions Communication 'Guidance on heating and cooling aspects in Articles 15a, 22a, 23 and 24 of Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources as amended by Directive (EU) 2023/2413'.

Table 20 *Criteria to define whether heat can be qualified as residual heat or not*

Criteria	Description
Unavoidable	Waste heat shall be *unavoidable*. This means that it cannot reasonably (technically and economically) be avoided or internally consumed or reduced (at all stages) through technical and energy efficiency improvements. Example: excess heat reused inside a plant is accounted as an energy efficiency improvement and therefore cannot be considered as waste heat.
By-product	The generation of waste heat shall be a 'by-product'. This means that the primary aim of the process shall not be to generate the specific fraction of heat that is being used by the product under study. In order to determine whether the heat is a by-product, the user of this PEFCR may for example refer to the purpose of the installation or to the type of operating permit obtained by the plant. Example: the *direct* heat output of a cogeneration process, whose primary purpose is to co-produce heat and electricity, is defined as 'useful' heat and is not seen as by-product. Some other *indirect* heat streams of cogeneration processes (e.g., heat extracted from a condenser) could potentially be defined as a by-product.
Location of heat generation	The generation of waste heat shall take place in industrial or power generation installation, or in the tertiary sector.
Connection to a DHN	The heat 'would be dissipated unused, without access to a DHN.'[23] This means that the heat stream has to be delivered to a DHN. Excess heat recovery without access to a DHN, for instance on-site or to a single building cannot is therefore not seen as waste.

In addition to those four cumulative criteria, for a heat stream to be classified as residual heat, the definition of waste heat stipulates an overarching requirement to prioritise the 'cogeneration'. In this context, the definition cogeneration follows that of Directive 2012/27/EU (THE EUROPEAN PARLIAMENT & THE COUNCIL OF THE EUROPEAN UNION, 2012), which describes cogeneration as 'the simultaneous generation in one process of thermal energy and electrical energy'. The user of this FreshProducePEFCR shall prioritise cogeneration of both electricity and heat before considering heat-only production, otherwise the heat shall not be considered as residual product.

A decision tree is included in in Figure 6 to determine whether heat can be classified are residual product or not. Based on the decision tree, two situations can occur:
Situation 1: the heat is qualified as residual product
Situation 2: the heat is qualified as co-product
Here below, guidance is given on how to deal with situation 1 and 2.

[23] The FreshProducePEFCR adopts the definition of district heating system from the Renewable Energy Directive: 'the distribution of thermal energy in the form of steam or hot water, from central or decentralised sources of production through aa network to multiple buildings or sites, for the use of space or process heating.'

Situation 1: the heat is qualified as residual product
If all criteria in Table 20 and the overarching principle of cogeneration are satisfied, the heat is classified as a residual product, and no upstream burdens shall be allocated to the product under study. If not all of the criteria are met, but also no price is paid by the user of heat for the heat itself, the heat is classified as a residual product as well. In both cases no upstream burdens shall be allocated to the product under study. The environmental impacts associated with the production and operation of the DHN shall be accounted for as per below.

Situation 2: the heat is qualified as co-product
If not all criteria and the overarching principle of cogeneration are met, the heat shall be considered as a co-product and one of the following situations can occur:

- If a price is paid by the user of heat for the heat itself, the heat is classified as a co-product and an economic allocation of the upstream burden shall be applied for the heat by using the relative value of heat compared to the other products produced during the production process by the producer of heat. The environmental impacts associated with the production and operation of the DHN shall be accounted for.
- If a price is paid by the user of heat only for using the DHN and not for the heat itself, the heat is classified as a residual product and only the environmental impacts associated with the production and operation of the DHN shall be accounted for.

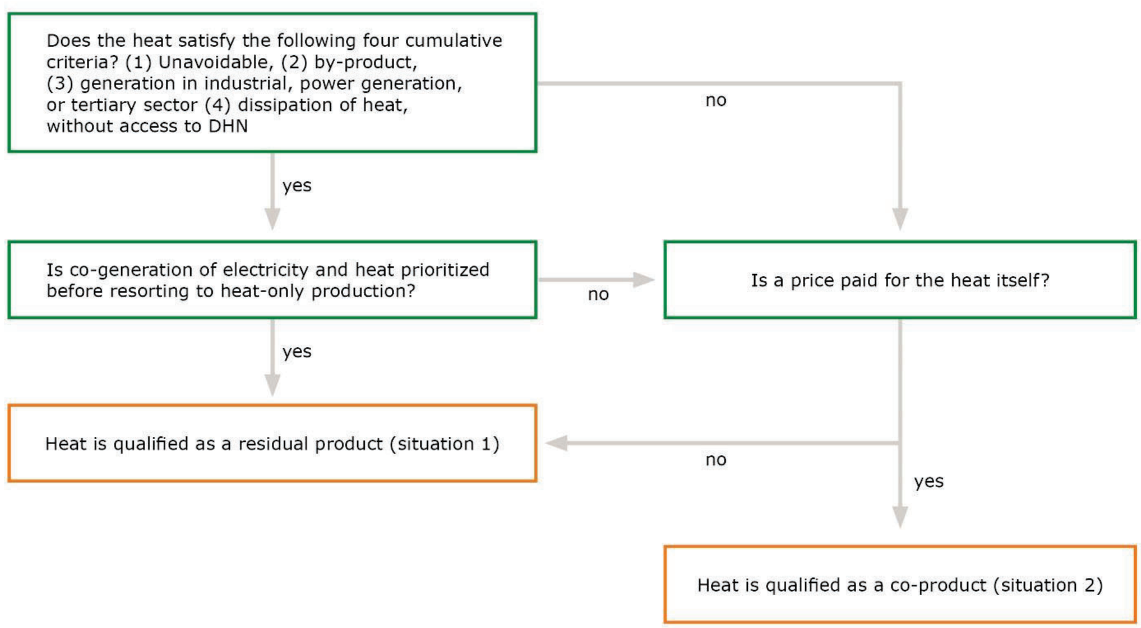

Figure 6 *Decision tree heat from third parties*

Production and operation of DHN
In case heat from third parties is used, the user of this FreshProduceEPFCR shall account for both the production and operation of the DHN.

The production of the DHN shall be accounted for using the dataset: *Pipeline, natural gas, high pressure distribution network {RoW}| pipeline construction, natural gas, high pressure distribution network | Cut-off.* The length of the DHN depends on various factors, such as if the DHN is part of a larger cluster, the density of the cluster and the fuel type. If no primary data is available, an average length of 15 kilometres shall be used as a default, based on Planbureau voor de leefomgeving (2012) and Jaspers (n.d.).

The operations of the DHN encompass all activities required to utilise the heat at the point of use. If no primary data is available, an average electricity use of the DHN installation of 0.0018 MJ_e/MJ_{th}*(length of pipeline) shall be used as a default, based on Muller et al. (2021).

In some cases, the temperature of the waste heat may be too low and is subsequently upgraded using a booster heat pump. The additional heat shall be accounted for in the inventory. To prevent double counting, the amount of auxiliary energy used should not be considered as residual heat. Please also note that the heat in a DHN doesn't necessarily classify as residual heat. It could also be generated by, e.g., a CHP. Whether it's residual heat or not, should be justified in the study.

In case heat from a third party is being used, the following activity data shall be gathered:
- The source of heat being used (e.g., type and name), including short description
- Length of pipeline (in km)
- Annual heat use from third parties (in MJ)
- Electricity use of DHN installation (in kWh).

6.2.5 Fuels

Unless it is clearly documented that operations are carried out manually, field operations shall be accounted for through total fuel consumption and its combustion emissions or through inputs of specific machinery, transports to/from the field, energy for irrigation, etc.

For data on fuel use not captured in other activities with dedicated modelling, e.g., for use of machinery at farm, data shall be collected per area unit and shall include:
- Fuel type
- Energy content of the fuel specified in Higher Heating Value (HHV) or Lower Heating Value (LHV)
- Fuel mix (for instance if biogenic fuels are mixed in) in relative shares of fuels in the total amount of fuel used
- Quantity of the fuel in weight and energy units.

This information shall be used to match the most adequate secondary datasets for production of fuels and combustion of fuels. In deviation from other inputs (e.g. fertilisers), the production of fuels shall be included in the life cycle stage cultivation given the compatibility with the available background datasets.

6.2.6 Emissions from use of crop protection products

Here, only the emissions resulting from the application of crop protection products is described. Modelling rules for the production of crop protection products is documented in Section 6.1.5.

Pesticide emissions shall be modelled as specific active ingredients. The use of background datasets with a default pesticide application mix is not allowed. As a default approach, pesticides applied on the field shall be modelled as 90% emitted to the agricultural soil compartment, 9% emitted to air, and 1% emitted to water (European Commission, 2021).

The fate of crop protection active ingredients (i.e., environmental compartment destination post-application) depends on the farm system, climate conditions, the distance to surface area, the spraying technology, etc. In this FreshProducePEFCR, no specific emission model is recommended that differentiates fate factors based on these parameters. The TS is aware of the Pest-LCI 2.0 and Greenhouse Emission Model approaches for open field and protected cultivation, respectively, which are the most progressive to overcome the current limitations of the current modelling of pesticides here proposed. Future versions of the FreshProducePEFCR will continue to explore emission models that can overcome these limitations.

If the active ingredient is not characterised in the EF LCIA method, the active ingredient shall be omitted and be listed separately as not characterised substance in the EF report.

6.2.7 Fertilisers

In this section, carbon, nitrogen, and phosphorus related emissions are calculated from C, N, and P inputs as synthetic fertiliser, manure, growing media and other organic fertilisers. How much C, N, and P inputs shall be allocated to a specific crop in case of a rotation scheme is described in Chapter 5.7 of this FreshProducePEFCR.

For this FreshProducePEFCR a preference level approach shall be followed when modelling C, N, and P emissions caused by the application of fertilisers. The preference is determined by the data that can be made available:

1. Direct measurement
2. Preferred modelling
3. Default modelling.

Direct measurement of the emissions is the most accurate method to indicate the emissions provided that the measurement complies with given conditions.

The **preferred modelling** is based on calculation rules derived from existing models, whereas some principals are applied to select the most relevant model/method. These principals are:

- The calculation rule must be publicly accessible and free of charge from a model.
- Transparency: some models are not transparent in the use of calculation rules.
- The calculation rule should not be too complex, in other words data needed should be easily available for a farmer/grower. This means that if data should be obtained based on very frequent measurements (e.g., daily basis) or a large amount/high density of data on farm level is needed (for instance 10 soil samples per ha), the model is considered too complex to be used for the purpose of this FreshProducePEFCR.
- The model must be applicable on a global scale.

The **default modelling** shall be applied if direct measurement and preferred modelling cannot be performed. The most important criteria for the default modelling is, that it should be applicable even if only minor information on cultivation is known. The default modelling shall always be used for modelling emissions from growing media nutrients and additives, in order to align with the Growing Media Environmental Footprint Guidelines (Growing Media Europe, 2024).

During the verification (compulsory for PEF studies) it shall be checked whether an improved preference level could be met. Improved preference levels might not always be applicable due to factors such as missing data points. In such cases, applying a lower preference level is considered valid.

This preference level approach implies that comparability is more important than precision.[24] In other words, preferred modelling only uses one method, instead of several regional models, although this might imply less accurate results for certain regions. This means that by default PEFCR modelling prefers IPCC TIER 1 above the IPCC TIER 2 approach, because the TIER 1 approach results in a comparable approach for each situation, whereas when choosing for the IPCC TIER 2 approach, the method will differ between countries which results in less comparable results.

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

- NH_3 to air, i.e. ammonia volatilisation (from N fertiliser application)
- NO_x to air (from N fertiliser application)
- N_2O to air (direct and indirect) (from N fertiliser application)
- CO_2 to air (from lime, urea, and urea-compounds application)
- NO_3 to water unspecified (leaching from N fertiliser application)
- PO_4 to water unspecified or freshwater (leaching and run-off of soluble phosphate from P fertiliser application)
- P to water unspecified or freshwater (soil particles containing phosphorous, from P fertiliser application).

[24] The use of the default approach, although allowing comparability, may not extend to specific country or region as no country-specific emission factors are applied. This is acknowledged as a limitation of the PEFCR approach as only comparability of applied N is possible.

The LCI for N emissions shall be modelled as the amount of emissions after it leaves the field (soil) and ending up in the different air and water compartments per amount of fertilisers applied. N emissions to soil shall not be modelled. The N emissions shall be calculated from N fertiliser applications on the field and excluding external sources (e.g., rain deposition).

Combining these three preference levels (direct measurement, preferred modelling, and default modelling) with the above-mentioned list of emissions related to fertilisers results in the overview as presented in Table 21. Note that for some combinations a distinction is made between soil and soilless[25] cultivation systems.

The remainder of this section is structured according to the overview in Table 21. Each of the following subsections describes the preference levels for emission modelling, including the formulas and corresponding parameters. The general parameters and constants that are relevant for several emissions are presented in Table 22.

Table 21 *Overview of emission modelling per preference level*

Section	Emission	Compart-ment	Direct measurement	Preferred modelling	Default modelling
6.2.7.1	**Ammonia (NH_3)**	Air	Yes, applicable	Model based on fertiliser use compliant to Bouwman et al. (2002)	IPCC (2019) Tier 1
6.2.7.2	**Nitrogen oxides (NO_x)**	Air	Yes, applicable	Model based on EEA 2016 (if no default modelling for NH_3)	Default modelling for NH_3 includes NO_x
6.2.7.3	**Nitrate (NO_3)**	Water	**Soilless**: Yes, direct measurement applicable only for closed recirculation **Soil**: No, direct measurement not applicable	**Soilless**: not applicable **Soil**: model run-off to surface water and leaching to ground water (Miterra, Velthof et al. (2007))	IPCC (2019) Tier 1
6.2.7.4	**Nitrous oxide (N_2O)**	Air	No, direct measurement not applicable	IPCC (2019) Tier 1 (no supra national models available)	IPCC (2019) Tier 1
6.2.7.5	**Carbon dioxide (CO_2)**	Air	No, direct measurement not applicable	IPCC (2019) Tier 1 (no supra national models available)	IPCC (2019)Tier 1 for urea and lime
6.2.7.6	**Phosphate (PO_4) and Phosphorus (P)**	Water	**Soilless**: direct measurement only for closed recirculation (all discharged water is monitored) **Soil**: No, direct measurement not applicable	No recommended model: use direct measurement or default modelling	EC (2021)

Table 22 *Overview of general parameters and constants used in emission modelling*

Parameter	Unit	Description
N_{fert}	kg N	Total amount of N (kg) applied to soil or growing media as synthetic fertiliser
N_{org}	kg N	Total amount of N (kg) applied to soil or growing media as organic fertiliser (compost, animal manure, sewage sludge and other organic nitrogen)
$N_{applied}$	kg N	Total amount of N (kg) applied to soil or growing media as synthetic or organic fertiliser
17/14	-	Conversion constant from NH_3-N to NH_3
46/14	-	Conversion constant from NO_x-N to NO_x
62/14	-	Conversion constant from NO_3-N to NO_3
44/28	-	Conversion constant from N_2O-N to N_2O
44/12	-	Conversion constant from CO_2-C to CO_2

[25] We assume that a soilless system is a protected system (e.g., a greenhouse) or an open field situation where the soil is completely covered by a material that prevents water flowing to the soil and cultivation takes place in a growing medium on top of this material.

6.2.7.1 Ammonia (NH_3) emissions

The main source for ammonia (NH_3) emissions at horticulture systems is via application of nitrogen in synthetic and organic fertiliser (animal manure, compost, sewage sludge, etc.). Other sources of ammonia volatilisation as standing crops and crop residues are recognised but modelling these emissions as a robust and usable methodology covering various cultivation systems in different regions is not yet possible (European Environment Agency, 2016). Nevertheless in some situations these sources are modelled and included in inventories, as for instance ammonia volatilisation from crop residues in The Netherlands which is included as source in the National Inventory (Vonk et al., 2018a). In this methodology ammonia volatilisation from N-application through synthetic and organic fertiliser is being considered.

Airborne ammonia emissions have different characterisation factors for acidification and eutrophication, marine and terrestrial, per country. For this reason, the user of this FreshProducePEFCR shall specify in which country the emissions take place.

Users of this FreshProducePEFCR must follow the preferred modelling in case the data needed can be collected (see Table 23 and Table 24). If not, the default modelling based on IPCC, Tier 1 (IPCC, 2019) may be used instead (see Table 23).

Synthetic N-fertilisers solely based on nitrate do not have any volatilisation at application (European Environment Agency, 2016).

Table 23 *Preferred and default emission modelling for ammonia (NH_3) volatilisation*

Preferred modelling: Formula 1	**NH_3 (kg) = NH_3 rate * $N_{applied}$ * 17/14** **NH_3 rate = $Exp^{crop + fert + appl + pH + CEC + climate}$**	**Bouwman et al. (2002)**
CNH_3 rate	NH_3 fraction (0 – 1) of N application emitted as ammonia	Formula 1 (see above)
crop	Type of crop	Choose ‘upland’ in Table 24
fert	Type of fertiliser (e.g., urea)	Primary data and Table 24 or country average[1]
appl	Type of application (e.g., broadcast)	Primary data and Table 24
pH	pH of the soil	Primary data and Table 24
CEC	Cation-Exchange-Capacity of soil	Primary data and Table 24
climate	Climate (temperate or tropical)	Primary data and Table 24
Default modelling: Formula 2	**NH_3 (kg) = ($Frac_{vols}$ * N_{fert} + $Frac_{volo}$ * N_{org}) * 17/14**	**IPCC (2019) Tier 1**
$Frac_{vols}$	Fraction of N from synthetic fertiliser that volatilises as NH_3 and NO_x	$Frac_{vols}$ = 0.11
$Frac_{volo}$	Fraction of N from organic fertiliser (compost, animal manure, sewage sludge and other organic nitrogen) that volatilises as NH_3 and NO_x	$Frac_{volo}$ = 0.21

1 In case that no information is available on which N-fertilisers are used the weighted average value for N-fertiliser use determined per country (see table A.3 in Appendix 4) may be used as default.

Table 24 *The values for the parameters to calculate the ammonia volatilisation rate in the preferred formula 1 of Table 22 according to Bouwman et al. (2002)*

parameter		**value**
crop type	upland	-0.045
fertiliser	Ammonium sulfate (AS)	0.429
	Urea	0.666
	Ammonium nitrate (AN)	-0.35
	Calcium Ammonium nitrate (CAN)	-1.064
	Anhydrous Ammonia (AA)	-1.151
	Other straight N	-0.507
	Nitrogen solutions	-0.748
	Ammonium phosphates (mono-ammonium and diammonium phosphate)	0.065
	other compound NP	0.0014
	compound NK	-1.585
	compound NPK	0.014
	Ammonium Bicarbonate	0.387
	Animal manure	0.995
application	broadcast	-1.305
	broadcast to floodwater	-1.305
	incorporated	-1.895
	solution	-1.292
	broadcast and then flooded	-1.844
	incorporated and then flooded	-1.844
	broadcast to floodwater at panicle initiation	-2.465
soil pH	< 5.5	-1.072
	5.5 > pH ≤ 7.3	-0.933
	7.3 > pH ≤ 8.5	-0.608
	> 8.5	0
soil CEC	≤ 16	0.088
in cmol/kg	16 < CEC ≤ 24	0.012
	24 < CEC ≤ 32	0.163
	> 32	0
Climate	Temperate < 20 ºC	-0.402
	Tropical ≥ 20 ºC	0

6.2.7.2 Nitrogen oxides (NO_x)

The preferred methodology for nitrogen oxides (NO_x) emissions depends on the way ammonia volatilisation is calculated. If ammonia volatilisation is calculated using the fall-back option (conform IPCC Tier 1, see Section 6.2.7.1), nitrogen oxides emissions are not to be included separately, because in the IPCC ammonia approach (IPCC, 2006) the NO_x emissions are included. Table 25 provides an overview of preferred nitrogen oxides emissions modelling.

Table 25 *Preferred emission modelling for nitrogen oxides (NO_x)*

Preferred modelling: Formula 3	NO_x **(kg) =** $N_{applied}$ ***** EF_{nox} *** 46/14**	EEA (2019)
EF_{nox}	Emission factor NO_x in kg NO_x per kg N applied	EF_{nox} = 0.04
Default modelling	If NH_3 used default modelling: NO_x already included in IPCC Tier 1 so no need to account for these emissions	

Airborne emissions of nitrogen oxides have different characterisation factors for acidification and eutrophication, marine and terrestrial, per country. For this reason, the user of this FreshProducePEFCR shall specify in which country the emissions take place.

6.2.7.3 Nitrate emissions (NO_3)

Nitrate emissions (NO_3) to groundwater and surface water originate from nitrogen surplus of external inputs from, for instance, fertiliser, nitrogen fixation, crop residues, deposition. Nitrate emissions shall be preferably calculated using either 'measurement' or the preferred modelling method. If insufficient data are available, then default rules documented in Section 4.4.1.5 of the PEF method (Annex I) (European Commission, 2021) shall be applied. The choice of modelling shall be reported in the PEF study report. In the preferred method a distinction is made between run-off to surface water and leaching to ground water.

The ILCD impact methodology for marine eutrophication allows for making a distinction between nitrogen to soil and nitrate to fresh water. Ground water is not an emission compartment as such and also the human toxicological effects of nitrate in ground water are not considered. The user of this FreshProducePEFCR shall consider both run off to surface water and leaching to ground water as a direct emission of nitrate to fresh water. Both emission pathways are separated in the emissions flows of the preferred modelling approach so that later on, when LCA methodology develops and separate impact factors become available, this can be applied easily.

The remainder of this subsection describes additional information on direct measurements, the preferred modelling approach, and the default modelling approach.

Direct measurements for soilless cultivation

Nitrate emission measurements are only representative/accurate in completely closed water systems which are applied in soilless systems. In these systems, all discharged water is monitored on nitrate content. In that case the nitrate emissions are calculated as volume discharged water times the measured nitrate concentration. This implies that for cultivations in the soil, regardless of if it is protected, measurements of nitrate emissions are not applicable.

In some countries, it is mandatory to measure and report the annual amount of discharged water (to surface water or the sewage system) and nitrate concentration for greenhouse cultivation on growing media to the authorities. This annual measured and reported quantity for nitrate in discharged water should be taken as nitrate emission. If it can be proven that the water recirculation system is closed, and no water is discharged at all, the nitrate leaching can be taken as zero. This zero discharge of water must be confirmed by the relevant legal authority.

Preferred modelling for cultivation in soil

The preferred modelling of nitrate emissions is based on the Miterra-Europe model (Velthof et al., 2007, 2009). This model has a proven track record in European studies (de Vries et al., 2011; Leip et al., 2014; Oenema et al., 2009; Velthof et al., 2014) and data needed for calculation of nitrate emissions is rather easily available at farm level.

Two pathways for nitrate losses can be distinguished: runoff to surface water and leaching to groundwater (which indirectly can end up in surface water). Preferred emission modelling for both pathways is described in Table 26. Note that these formulas are only applicable to cultivation in soil. For soilless cultivation, direct measurements or default modelling is applicable (see Table 29).

Table 26 *Preferred emission modelling for nitrate (NO_3) runoff and leaching for cultivation in soil*

Preferred modelling		**Total NO_3 (kg) = (N_{runoff} + N_{leach}) * 62/14**	**See Formula 4 and 5**
Runoff to surface water: Formula 4		N_{runoff} (kg) = (N_{fert} + N_{org}) * LF_{runoff_max} * min(f_p, f_{rc}, f_s)	Velthof et al (2007, 2009)
LF_{runoff_max}		Maximum runoff fraction based on the slope of the soil	Primary data and Table 27
f_p, f_s, f_{rc}		Fractions based on precipitation surplus, soil type, and depth to rock	Primary data and Table 27
Leaching to groundwater: Formula 5		N_{leach} (kg) = LF * $correction_{dep}$ * $N_{soil\_surplus}$	Velthof et al (2007, 2009)
LF (leaching fraction)		= $LF_{soiltype\_max}$ * min(f_p, f_r, f_t, f_c)	
	$LF_{soiltype\_max}$	Maximum leaching fraction based on soil type	Primary data and Table 28
	f_p, f_r, f_t, f_c	Fractions based on precipitation surplus, rooting depth, temperature, and soil organic C content	Primary data and Table 28
$correction_{dep}$[1]		= 1 – (N_{dep} / (N_{fert} + N_{org} + N_{fix} + N_{dep})) Correction factor for share of N_{dep} in total N input	See parameters below
	N_{fix}	Amount of nitrogen input from N-fixation in specific N fixating crops (e.g., legumes like lupine) in kg N	N_{fix} = 0 (if N_{fert}+N_{org}≥N_{harv}) N_{fix} = N_{harv} (otherwise)
	N_{dep}	Amount of nitrogen input from N-deposition (kg N)	Country specific data (e.g., via EMEP)
$N_{soil\_surplus}$		= (N_{fert} + N_{org} + N_{fix} + N_{dep}) minus (N_{harv} + NH_3-N + NO_x-N + N_{runoff} + direct N_2O-N) Difference of N inputs[2] and N outputs (kg N available to leach)	See parameters below
	N_{fix}, N_{dep}	See above as part of $correction_{dep}$	
	N_{harv}	Amount of nitrogen in harvested crop (main and co-products) in kg N = N-content (kg N/tonne product) * $product_{harv}$ (tonne)	$Product_{harv}$: primary data N-content: primary data or Table A.4 in Appendix 4
	NH_3-N	Amount of NH_3-N (kg) from synthetic and organic fertilisers	See Formula 1 or 2 in Table 23
	NO_x-N	Amount of NO_x-N (kg) from synthetic and organic fertilisers	See Formula 3 in Table 24
	N_{runoff}	Amount of N emitted as nitrate by runoff to surface water	See Formula 4 in Table 26
	Direct N_2O-N	Amount of N_2O-N (kg) from synthetic and organic fertilisers	See Formula 7 in Table 30

1 N_{dep} is included in $N_{soil\_surplus}$ but is considered as 'background input' for which the farmer is not directly accountable, although good farming practice is to take the deposition into account in the planning of fertilisation. Therefore, a correction is included, based on the share of N_{dep} in total N input.

2 Nitrogen in crop residues are no external inputs and considered as internal N-flows, so not included in N inputs.

Table 27 *The values for the parameters to calculate the runoff to surface water for cultivation in soil (Formula 4 in Table 26) according to* Velthof et al. (2007) *and* Velthof et al. (2009).

Parameter		**value**
LF_{runoff_max}	Slope 0 to 8%	0.10
	Slope 8 to 15%	0.20
	Slope 15 to 25%	0.35
	Slope > 25%	0.50
f_p	Precipitation surplus > 300 mm	1
	Precipitation surplus 100 to 300 mm	0.75
	Precipitation surplus 50 to 100 mm	0.50
	Precipitation surplus < 50 mm	0.25
f_s	Mineral soils, clay content > 60%	1
	Mineral soils, clay content 35-60%	0.9
	Mineral soils, clay content 18-34%	0.75
	Mineral soils, clay content <18%	0.25
	Peat soils	0.25
f_{rc}	Depth soil to rock ≤ 25 cm	1
	Depth soil to rock > 25 cm	0.8

Table 28 *The values for the parameters to calculate the leaching to groundwater for cultivation in soil (Formula 5 in Table 26) according to* Velthof et al. (2007) *and* Velthof et al. (2009)

Parameter		**value**
$LF_{soiltype\_max}$	Sandy soils	1
	Loamy soils	0.75
	Clay soils	0.5
	Peat soils	0.25
f_p, sand and loam	Precipitation surplus > 300 mm	1
	Precipitation surplus 100-300 mm	0.75
	Precipitation surplus 50-99 mm	0.50
	Precipitation surplus < 50 mm	0.25
f_p, clay and peat	Precipitation surplus > 300 mm	0.50
	Precipitation surplus 100-300 mm	1
	Precipitation surplus 50-99 mm	0.75
	Precipitation surplus < 50 mm	0.25
f_r	Rooting depth < 40 cm	1
	Rooting depth > 60 cm	0.75
f_t	Temperature < 5° C avg annual temp	1
	Temperature 5 - 15° C	0.75
	Temperature > 15° C	0.50
f_c	Soil organic C content < 1%	1
	Soil organic C content 1% - 2%	0.90
	Soil organic C content 2% - 5%	0.75
	Soil organic C content > 5%	0.50

Default modelling for cultivation in soil and for soilless cultivation

Nitrate emissions are calculated according to the 2019 Refinement to the 2006 IPCC Guidelines (IPCC, 2019) whereas 24% of the applied nitrogen is emitted as nitrate. The applied nitrogen is the sum of nitrogen applied with synthetic fertiliser, organic fertiliser (compost, animal manure, sewage sludge, and other organic nitrogen additions to the soil), crop residues, and nitrogen mineralised in organic soils or associated with land use change.

The fraction leached is 24% for situations where soil/growing media water-holding capacity is exceeded, as a result of an excess of rainfall compared to potential evaporation or where irrigation (excluding drip irrigation) is employed. For dry circumstances where evaporation exceeds rainfall or irrigation the 2019 Refinement to the 2006 IPCC Guidelines (IPCC, 2019) prescribe a leaching fraction of 0%, so no leaching takes place at all. This is, however, not in line with the preferred modelling where the reduction factor for a situation with a negative precipitation surplus is still more than 0%. Therefore, in the default modelling the fraction leached is set to 24% for all situations. Table 29 describes the default emission modelling for total nitrate to water (without distinction between runoff and leaching). The default modelling approach is applicable to cultivation in soil and to soilless cultivation.

Table 29 *Default emission modelling for nitrate (NO_3) runoff and leaching for cultivation in soil and for soilless cultivation*

Default modelling	**No distinction between runoff to surface water and leaching to ground water**	
Total nitrate to water: Formula 6	Total NO_3 (kg) = $Frac_{leach}$ * (N_{fert} + N_{org} + N_{cr} + N_{som} + N_{os}) * 62/14	IPCC (2019) Tier 1
$Frac_{leach}$	Fraction of added nitrogen emitted as nitrate through leaching and runoff	$Frac_{leach}$ = 0.24
N_{cr}	**Soil**: total amount of nitrogen in crop residues above and below ground (kg N) **Soilless**: negligible or not relevant[1]	**Soil**: N_{cr} from primary data or Table A.5 in Appendix 4 **Soilless**: N_{cr} = 0
N_{som}	**Soil**: amount of nitrogen mineralised in mineral soils associated with loss of soil carbon from soil organic matter as a result of changes to land use or management **Soilless**: not applicable for fertiliser modelling in soilless cultivation	**Soil**: N_{som} calculated via IPCC (2019) equation 11.8 or choose N_{som} = 0 and acknowledge as limitation **Soilless**: N_{som} = 0
N_{os}	Amount of nitrogen (kg) mineralised from oxidation of organic matter in growing media. See Growing media in Section 6.2.9.	N_{os} = 0 for fertiliser modelling

1 In soilless systems, crop residues are negligible or not relevant because after the cultivation period the crop is either removed together with growing media or the crop remains growing on the growing media for the next production cycle.

6.2.7.4 Nitrous oxide (N_2O) emissions to air (direct and indirect)

The relationship of direct nitrous oxide (N_2O) emissions from N applied is described by the 2019 Refinement to the 2006 IPCC Guidelines (IPCC, 2019). In this model the nitrous oxide emission is not depending on soil, climate, fertiliser type, etc. A more specific modelling in which the relationship of N_2O emissions to those factors is taken into account on a supra national level is not available. For instance, in the Netherlands specific N_2O emission factors are available (depending on soil type, fertiliser type and application method) but these are not applicable for other (EU) countries. For this reason, both the preferred and the default modelling approach for direct and indirect nitrous oxide emissions are based on (IPCC, 2019) Tier 1 (see Table 30), without taking the N input from urine and dung from grazing animals into account. Indirect nitrous oxide emissions are determined by ammonia volatilisation and nitrate leached.

Table 30 *Preferred and default emission modelling for direct and indirect nitrous oxide (N_2O) emissions for cultivation in soil and for soilless cultivation*

Preferred and default modelling approach for direct and indirect N_2O emissions		
Direct N_2O: Formula 7	N_2O direct[1] (kg) = (N_{fert} + N_{org} + N_{cr}) * EF_1 * 44/28	IPCC (2019) Tier 1
N_{cr}	Soil: total amount of nitrogen in crop residues above and below ground (kg N) Soilless: negligible or not relevant[2]	Soil: N_{cr} from primary data or Table A.5 in Appendix 4 Soilless: N_{cr} = 0
EF_1	Emission factor for direct N_2O emissions from nitrogen inputs in kg N_2O-N per kg N	EF_1 = 0.01
Indirect N_2O: Formula 8	N_2O indirect (kg) = ($EF_{ammonia}$ * NH_3-N + $EF_{nitrate}$ * NO_3-N) * 44/28	(IPCC, 2019) Tier 1
NH_3-N (kg)	Amount of nitrogen volatilisation and redeposition as ammonia and nitrogen oxides (kg NH_3-N + kg NO_x-N). *Note that the formulas give the results in kg NH_3, and not in NH_3-N. A conversion factor according to Table 22 shall be applied.*	See Formulas 1, 2, 3 (Table 23 and Table 25)
NO_3-N (kg	Amount of nitrogen leached an runoff as nitrate (kg NO_3-N) *Note that the formulas give the results in kg NO_3, and not in NO_3-N. A conversion factor according to Table 22 shall be applied.*	See Formulas 4, 5, 6 (Table 26 and Table 29)
$EF_{ammonia}$	Emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces in kg N_2O-N/(kg NH_3-N+kg NO_x-N)	$EF_{ammonia}$ = 0.01
$EF_{nitrate}$	Emission factor for N_2O emissions from nitrogen leaching and runoff in kg N_2O-N per kg N leached and runoff	$EF_{nitrate}$ = 0.011

1 Note that direct N_2O emissions also result from nitrogen mineralised in mineral soils associated with loss of soil carbon from soil organic matter as a result of change in land use or management and from nitrogen mineralised from organic soils and growing media. These direct N_2O emissions shall be accounted for in Section 6.2.2 on Land occupation and land use change and in Section 6.2.9 on rowing media.

2 In soilless systems, crop residues are negligible or not relevant because after the cultivation period the crop is either removed together with growing media or the crop remains growing on the growing media for the next production cycle.

6.2.7.5 Carbon dioxide emissions (CO_2) to air from lime, urea, and urea-compounds application

Lime is used to reduce soil acidity and improve plant growth in managed systems, particularly agricultural lands and managed forests. Adding carbonates to soils in the form of lime (e.g., calcic limestone ($CaCO_3$), or dolomite ($CaMg(CO_3)_2$) leads to CO_2 emissions as the carbonate limes dissolve and release bicarbonate ($2HCO_3^-$), which evolves into CO_2 and water (H_2O).

Adding urea to soils during fertilisation leads to a loss of CO_2 that was fixed in the industrial production process of urea. This source category is included because the CO_2 removal from the atmosphere during urea manufacturing is estimated in the Industrial Processes and Product Use Sector (IPPU Sector).

Both the preferred and the default modelling approach for CO_2 emissions from lime and urea follow the 2019 IPCC Refinement to the 2006 IPCC Guidelines (IPCC, 2019) as described in Table 31 below.

Table 31 *Preferred and default emission modelling for carbon dioxide (CO_2) from lime and urea application*

Preferred and default modelling approach for CO_2 emissions from lime application		
CO_2 from lime: Formula 9	CO_2 (kg) = (limestone (kg) * EF_{lime} + dolomite (kg) * EF_{dolo})* 44/12	IPCC (2019) Tier 1
Limestone	Amount of calcic limestone ($CaCO_3$) applied in kg	Primary data
Dolomite	Amount of dolomite ($CaMg(CO_3)_2$) applied in kg	Primary data
EF_{lime}	Emission factor for limestone in kg C per kg limestone	EF_{lime} = 0.12
EF_{dolo}	Emission factor for dolomite in kg C per kg dolomite	EF_{dolo} = 0.13
Preferred and default modelling approach for CO_2 emissions from urea application		
CO_2 from urea: Formula 10	CO_2 (kg) = urea (kg) * EF_{urea} * 44/12	IPCC (2019) Tier 1
Urea	Amount of urea fertilisation as is, in kg	Primary data
EF_{urea}	Emission factor for urea in kg C per kg urea	EF_{urea} = 0.20

6.2.7.6 Phosphorus (P) and phosphate emissions (PO_4) to water

The LCI for phosphorus (P) emissions should be modelled as the amount of P emitted to water after run-off and the emission compartment 'water' shall be used. When this amount is not available, the LCI may be modelled as the amount of P applied on the agricultural field (through manure or fertilisers) and the emission compartment 'soil' shall be used. In this case, the run-off from soil to water is part of the impact assessment method.

In the case of measured amounts of phosphate (PO_4) discharged in wastewater to surface water or sewage system, direct measurements shall be used. Comparable with nitrate, phosphate measurements are only representative/accurate in completely closed recirculation systems, where all discharged water is monitored on phosphate content. In that case the phosphate emissions shall be calculated as volume of discharged water times the measured phosphate concentration. This implies that for cultivations in the soil, regardless of if it is protected, measurements of phosphate emissions are not applicable.

Table 32 describes the default emission modelling approach for phosphorus related emissions according to the PEF method in Annex II of European Commission (2021).

Table 32 *Default emission modelling for phosphorus (P) related emissions*

P emissions: Formula 11	***P (kg) = P_{rate} * $P_{applied}$***	**Recommendation on the use of Environmental Footprint methods**
$P_{applied}$	*Amount of phosphorus applied in kg*	*Primary data*
P_{rate}	*Fraction (0 – 1) of phosphorus application emitted to water*	*P_{rate} = 0.05*

6.2.7.7 Nitrogen (N) and phosphorous (P) balance

To get the full picture of N and P use, the fate of the nutrients and the environmental impact modelling, a balance per area unit shall be made according to Table 33.

Table 33 *N and P nutrient application balance per area unit*

	Nutrient application on the field during cultivation of the crop	Nutrient application due to crop rotation related fertiliser application	Nutrient uptake by the crop (main product plus co-product)	Nutrient uptake by crop residues	Nutrients discharged to surface or sewage water system after recirculation	Remaining nutrients
N						
P						

If a recirculation system is in place farm system emissions to surface water shall be calculated directly from the discharged quantities.

Additionally, the input N from crop residues that stay on the field or are burned (kg residue + N content/ha) shall be included. How to address green manure and cover crops is a topic raised by the TS for discussion at the Agricultural modelling working group. We will wait for their guidance, until then, green manure and cover crops are only considered for the N and P balance.

6.2.8 Heavy metal emissions

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.

The final fate of the heavy metals elementary flows are 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 cultivated for human consumption end up in the plant. Within the EF context, 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.

6.2.9 Growing media

Emissions from the use of growing media constituents and additives shall be modelled according to the guidance given in Section 6.1.6. The default modelling approach shall be used, in order to align with the Growing Media Environmental Footprint Guidelines V2.0 (Growing Media Europe, 2024).

Additional to the rules prescribed in section 6.2.7, the carbon content of peat based constituents shall be assumed to be oxidised into CO_2 at a default oxidation of 5%[26] per year. All emissions due to oxidation of peat carbon shall be modelled as fossil CO_2, in the life cycle stage for cultivation. The remaining peat C content in growing media shall be considered during end-of-life (see Section 6.8) for indoor use. For outdoor use, it shall be assumed that the growing media is not reutilised in a different growing cycle, and that the carbon content of the peat undergoes complete oxidation, meaning all the carbon is allocated to the crop under study.

[26] PAS2050-1:2012 states an annual decomposition rate of 52%. This percentage is deemed unrealistically high by the TS based on available research (Cleary et al., 2005; Sharma et al., 2024) and sector standards (Growing Media Europe, 2024).

6.2.10 Peat soils

This section is only applicable if cultivation of the crop under study takes place on drained peat soils.

Drained peat soils shall include greenhouse gas emissions on the basis of a model that relates the drainage levels to annual oxidation. The 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, chapter 2 should be used to account for these emissions (IPCC, 2013). If no primary data is available, secondary data may be used.

The emissions related to peat oxidation shall be modelled using the following elementary flows:
- Carbon dioxide (CO_2), peat oxidation
- Dinitrogen monoxide (N_2O), peat oxidation
- Methane (CH_4), peat oxidation.

6.2.11 Waste

All waste resulting from the cultivation stage at farm shall be modelled in this life cycle stage. Farm waste can consist of plant and crop remains (organic) and of wasted materials. The modelling of emissions from crop residues left on the field is explained in 6.2.7. Other organic waste should be accounted for and modelled as composting. We refer to Section 5.2.5 of the Growing Media Environmental Footprint Guidelines V2.0 (Growing Media Europe, 2024) for guidelines on composting activities.

For material waste, the waste scenario is included in the Circular footprint formula detailed in Section 5.10.

Moisture losses shall be accounted for by correcting the yield outputs. No physical waste flows shall be accounted for.

Part of the yield might go to the processing industry to make, e.g., fruit juices. The yield outputs should be corrected in the cultivation stage, also if the physical separation takes place in another life cycle stage. Allocation rules as described in Section 5.7 are applicable.

6.2.12 Storage at farm

If any storage operation takes place at the farm, this shall be included in Section 6.3. In case it is not possible to separate the electricity and/or heat use already captured in Section 6.2.4, it shall be included in the respective section. The chosen approach shall be clearly reported in the PEF report, including the reasoning.

6.3 Post-harvest treatment, storage and handling

This life cycle stage encompasses all activities related to the post-harvest treatment, storage (see also Section 6.2.4 and 6.2.12) and handling of the product, including, but not limited to: utility use, waste water treatment, chemical production and use, refrigerant use, intermediate packaging production (primary), and waste (including the additional quantity needed to fulfil the FU).

Text Box 1. Guidance for fresh cuts

The FreshProducePEFCR is about fresh produce. The scope focuses on products from these categories that are marketed as fresh produce directly to the consumer, without processing (i.e., transformation of the product itself). Cutting, slicing, and compiling of products is not seen as processing and therefore within the scope of the FreshProducePEFCR. For modelling of those ‘fresh cut’ products, we refer to the memo on fresh produce handling (Willems et al., 2025).

Activities to be included in this life cycle stage can take place at different locations along the value chain. The user of this FreshProducePEFCR may decide to split this life cycle stage into multiple stages, for example into ‘post-harvest treatment’, ‘storage’, and ‘handling’. The reason(s) for doing this shall be set out in the PEF report. If this is the case, transport between these stages shall be included, if not covered in Section 6.4.

Moisture losses, as well as physical product losses including their waste treatment shall be included. The additional product to compensate for physical product losses shall be accounted for. Treatment of physical product losses shall be modelled by using the default biowaste background process Table 34.

Utility use shall be collected. If applicable, data on amount of leakage of, e.g., refrigerant (per type), and use of other energy sources (per type) shall also be collected. Allocation rules as described in Section 5.7 are applicable.

Fruits and vegetables are metabolically active after harvesting, meaning they undergo different senescence processes that must be controlled in order to maintain their quality. There are various physical, chemical and gaseous treatments to do so. Also, there are several processes to speed up this process. Company-specific data shall be collected on types of chemicals and/or gases used in post-harvest treatments and handling. This data involves the specific active ingredient and its CAS number, the use rate in grams per year per crop weight unit for the crop under study.

For the production of chemicals and gases secondary data may be used. Wherever possible, product type specific datasets shall be used. Transport of these products to location may be omitted.

In case the chemical agent is dissolved into or mixed with water (e.g., via spraying), the chemical agents are assumed to go to wastewater-treatment and shall be modelled as such. Water use for dilution shall be included. More specific data may be used if available.

6.4 Distribution

Transport from location of cultivation, storage or post-harvest treatment to final client (including consumer transport) shall be modelled within this life cycle stage. The final client is defined as the consumer who eats the fruit or vegetable. Transport from farm to in-country handling facilities shall be excluded from the distribution stage because it is to be included in the post-harvest treatment, storage and handling stage. Figure 7 provides a visual representation of how and where to account for the various transport legs.

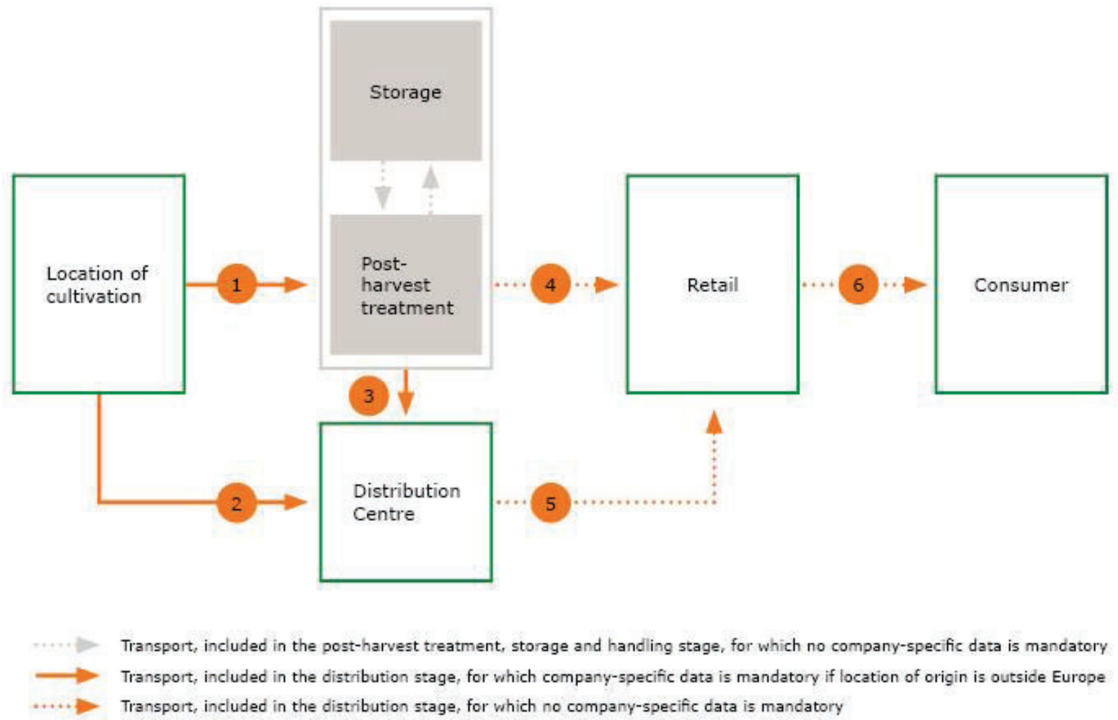

Figure 7 *Overview on transport legs, in which life cycle stages the legs are to be included and which type of data is required*

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

Data on intercontinental transport is a mandatory company-specific process. In case no supply-chain specific information is available, no compliant study according to this FreshProducePEFCR can be conducted. In case no supply-chain specific information is available for the other transport legs, the default scenario, outlined below and in Figure 7 shall be used.

1. X% from farm to post-harvest treatment, storage and handling:
   X% Local supply chain: 1.200 km by lorry with refrigeration machine (7.5 - 16t, EURO 6)
   X% Intracontinental supply chain: 3.500 km by lorry with refrigeration machine (7.5 - 16t, EURO 6)
2. X% from farm to distribution centre (DC):
   X% Local supply chain: 1.200 km by lorry with refrigeration machine (7.5 - 16t, EURO 6)
   X% Intracontinental supply chain: 3.500 km by lorry with refrigeration machine (7.5 - 16t, EURO 6)
3. X% from post-harvest treatment, storage and handling to distribution centre:
   300 km by lorry with refrigeration machine (7.5 - 16t, EURO 6)
4. X% from post-harvest treatment, storage and handling to retail:
   450 km by lorry with refrigeration machine (7.5 - 16t, EURO 6)
5. X% from DC to retail:
   150km by lorry with refrigeration machine (7.5 - 16t, EURO 6)
6. X% from retail to final client
   62%: 5 km, by passenger car (average)
   5%: 5 km, by van (lorry 3.5 - 7.5 t, EURO 6)
   33%: no impact modelled.

It should be noted that for road transport within local supply chains, the emission standard has been updated from EURO 4 to EURO 6. This adjustment is based on the fact that EURO 6 has been the standard in Europe in recent years, although it does not fully align with the PEF method.

In EF 3.1 database, the transport payload is modelled in a parameterised way through the utilisation ratio. The background datasets used in context of this FreshProducePEFCR do not allow for this parametrisation. The used average load factor and gross vehicle weight per lorry size class are shown in Table 34.

Table 34 *Average load factor and gross vehicle weight per lorry size class in tonnes (t)*

Lorry size class	Average load factor	Gross vehicle weight
3.5 – 7.5t	0.98t	4.98t
7.5 – 16t	3.29t	9.29t
16 – 32t	5.79t	15.79t
>32t	15.96t	29.96t

Allocation of the car impact shall be based on volume. The maximum volume to be considered for consumer transport is 0.2 m^3 (around 1/3 of a trunk of 0.6 m^3). For products larger than 0.2 m3 the full car transport impact shall be considered. For products sold through supermarkets, the product volume (including packaging and empty spaces such as between fruits or bottles) shall be used to allocate the transport burdens between the products transported. Default product volumes are presented in Table 36, these shall be used. The allocation factor shall be calculated as the volume of the product transported divided by 0.2 m^3. To simplify the modelling, all other types of consumer transport (like buying in specialised shops or using combined trips) shall be modelled as if sold through a supermarket.

The waste of products during distribution shall be included in the modelling. The waste percentage that shall be applied for fresh fruits and vegetables is dependent on the location of cultivation of the product under study. Table 35 specifies the waste fractions to be applied for specific production regions (FAO, 2011). A list of countries that are included in each region, can be found in Appendix 1 of the respective source (FAO, 2011). Waste fractions are given as consolidated value for transportation, storage and retail place, and shall therefore be corrected for the losses in retail (2.1% correction factor) (Foundation Samen Tegen Voedselverspilling, n.d.). If more specific data is available, this may be used.

Table 35 *Default waste percentages during distribution and retail (FAO, 2011; Foundation Samen Tegen Voedselverspilling, n.d.)*

Production region	Waste percentage (%)	Waste percentage (%), including correction factor
Europe, including Russia	10	7.9
North America and Oceania	12	9.9
Industrialised Asia	8	5.9
Sub-Saharan Africa	17	14.9
North Africa, West and Central Asia	15	12.9
South and Southeast Asia	10	7.9
Latin America	12	9.9

The waste disposal of fresh fruits or vegetables at the distribution centre shall be modelled according to the default scenario for biowaste (Table 36). In case more specific information is available, this may be used. Waste from packaging shall be accounted for following the Circular Footprint Formula, see Section 5.10.

Storage activities consume energy and refrigerant gases. The following default data shall be used, unless better data is available:

- **Energy consumption at distribution centre:** the storage energy consumption is 30 kWh/m^2·year and 360 MJ bought (= burnt in boiler) or 10 Nm^3 natural gas/m^2·year (if using the value per Nm^3, do not forget to consider emissions from combustion and not only production of natural gas). For centres that contain cooling systems, the additional energy use for the chilled or frozen storage is 40 kWh/m^3·year (with an assumed height of 2 m for the fridges and freezers). For centres with both ambient and cooled storage:

20% of the area of the DC is chilled or frozen. Note: the energy for chilled or frozen storage is only the energy to maintain the temperature.
- **Refrigerant gases consumption and leakages at DCs with cooling systems**: gas content in fridges and freezers is 0.29 kg R404A per m^2 (retail OEFSR). A 10% annual leakage is considered (Palandre et al., 2003). The environmental impact of the portion of refrigerant gases remaining in the equipment at end of life is assumed to be negligible, 5% is emitted at end of life and the remaining fraction is treated as hazardous waste.

Only part of the emissions and resources emitted or used at storage systems shall be allocated to the product stored. This allocation shall be based on the space (in m^3) and time (in weeks) occupied by the product stored. For this the total storage capacity of the system shall be known, and the product specific volume and storage time shall be used to calculate the allocation factor (as the ratio between product-specific volume*time and storage capacity volume*time). If no primary data is available, a default storage volume of 3 times the product volume shall be considered. The default storage time at the distribution centre is based on expert judgement and shall be considered to be 2 days in case no more specific data is available. Default product volumes are presented in Table 36, these shall be used.

An average DC is assumed to store 60,000 m^3 of product, out of which 48,000 m^3 for ambient storage and 12,000 m^3 for chilled or frozen storage. For 52 weeks of storage, a default total storage capacity of 3,120,000 m^3*weeks/year shall be assumed.

Table 36 *default product volumes, based on Agribalyse documentation (Asselin-Balençon et al., 2022)*

Name product	Density (kg/l)	Proxy for:
Potato	0.6375	Tubers and roots
Onion	0.6195	Leek, shallot and kohlrabi
Eggplant	0.398	Zucchinini
Cabbage	0.362	Asparagus, artichoke squash, brussels sprouts, pumpkin
Lemon	0.575	Agrumes
French bean	0.271	Long beans (e.g, French beans)
Cauliflower	0.2355	Broccoli and romanesco cauliflower
Cow pea	0.24	Small beans, peas and legumes, corn
Spinach	0.118	Lettuce, endives, cress, sorrel, mushrooms (very light food)
Chili	0.295	Sweet peppers
Pointed gourd	0.447	Cucumber, melon, watermelon, all fruits and berries, celery, rhubarb (water rich fruits and vegetables)

Food losses at the distribution centre, 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 packaging/repacking/unpacking at distribution centre, during transport and at retail place): assumed to be 100% recycled.

Other waste generated at the distribution centre, during transport and at the retailer (except food and product losses) such as repacking/unpacking are assumed to follow the same EoL treatment as for home waste.

6.5 Consumer packaging

This life cycle stage encompasses all processes and emissions related to the production of packaging materials for consumer packaging (primary, secondary, tertiary), utility use for packaging operations, transport of packaging materials to location, and waste of intermediate packaging. Intermediate packaging is all packaging that is not intended to reach the consumer, for example pallet boxes.

Data shall be collected on material type (e.g., PET), weight, transport mode, transport distance, mass of materials, and recycled content per material type. This information will be used to match the most adequate secondary datasets for production of packaging materials (including forming) as shown in Table 37. The user of the FreshProducePEFCR shall account for losses in processes that are subject to a forming process (e.g., PP, PET, HDPE, and PVC). The default losses (recycled in external, open loop) for extrusion of plastic sheets and thermoforming are 0.06 kg per kg of raw material. For example, if an activity requires 1 kg of LDPE, then the user shall list 1/0.94 = 1.0638 kg of the forming process and of the packaging type processed.

Table 37 *Datasets to be used for packaging materials, including forming processes*

Packaging material	Dataset	Forming process
Cardboard	Corrugated board box {RER or RoW}| corrugated board box production	Already included in dataset, not to be included separately.
Paper	Kraft paper {RER or RoW}| kraft paper production	Already included in dataset, not to be included separately.
Expanded polystyrene (EPS)	Polystyrene, expandable {RER or RoW}| polystyrene production, expandable	Already included in dataset, not to be included separately.
Polypropylene (PP)	Polypropylene, granulate {RER or RoW}| polypropylene production, granulate	Extrusion of plastic sheets and thermoforming, inline {RoW}| extrusion of plastic sheets and thermoforming, inline | Cut-off
Polyethylene terephthalate (PET)	Polyethylene terephthalate, granulate, bottle grade {RER or RoW}| polyethylene terephthalate production, granulate, bottle grade	Extrusion of plastic sheets and thermoforming, inline {RoW}| extrusion of plastic sheets and thermoforming, inline | Cut-off
Low density polyethylene (LDPE)	Packaging film, low density polyethylene {RER or RoW}| packaging film production, low density polyethylene	Already included in dataset, not to be included separately.
High density polyethylene (HDPE)	Polyethylene, high density, granulate {RER or RoW}| polyethylene production, high density, granulate	Extrusion of plastic sheets and thermoforming, inline {RoW}| extrusion of plastic sheets and thermoforming, inline | Cut-off
Polyvinylchloride (PVC)	Polyvinylchloride, suspension polymerised {RER or RoW}| polyvinylchloride production, suspension polymerisation	Extrusion of plastic sheets and thermoforming, inline {RoW}| extrusion of plastic sheets and thermoforming, inline | Cut-off
EURO-pallet	EUR-flat pallet {RER}| EUR-flat pallet production	n/a

Utility use for packaging operations shall be considered. Electricity use data shall be collected according to the rules set out in Section 5.8, which implies that a specific consumption mix can be accounted for if the conditions on validation are met.

In case no primary data on transport of packaging materials to packaging location is available, the default scenario in Section 6.1 shall be used.

The raw material consumption of reusable packaging shall be calculated by dividing the actual weight of the packaging by the reuse rate. The reuse rate affects the quantity of transport needed per FU. The transport impact shall be calculated by dividing the one-way trip impact by the number of times this packaging is reused. The processing for potential reuse is not covered in this PEFCR.

The waste of the intermediate packaging materials shall be accounted for. Default waste treatment scenarios per type of packaging material are displayed in Table 35.

6.6 Retail

Activity data for the retail stage can be modelled using default data as provided in the PEF method in Annex I. If retailer-specific data is available, the Data Needs Matrix applies (see Section 5.4).

Storage activities at retail place consume utilities, incl. refrigerant gases. Default parameters to be used to compute product specific utility requirements at retail, are specified in Table 38. These shall be used, unless better data is available.

Table 38 *Utility use at retail place, calculated based on Agribalyse documentation (Asselin-Balençon et al., 2022)*

Type of delivery	Storage volume (volume/product)[27]	Storage time (days)	Energy ($kWh/m^3/day$)	Cooling ($kWh/m^3/day$)	R404a ($kg/m^3/day$)
Ambient	4 times	1.5	4.40	n.a.	n.a.
Chilled	3 times	1.5	1.65	7.83	0.00006

The waste of products during retail shall be included in the modelling. The default is based on Foundation 'Samen Tegen Voedselverspilling' and shall be 2.1% for both fresh fruits and vegetables in case no more specific data is available. Food losses at retail place are assumed to be 50% trashed, 25% composted and 25% methanised.

Any packaging, except for the product primary packaging used by the consumer to bring the product home (e.g., shopping bags) shall not be considered.

6.7 Use stage

Neither product independent (i.e., processes that have no relationship with the way the product is designed or used) nor product dependent (i.e., processes that are directly or indirectly determined or influenced by the product design or are related to instructions for using the product) processes shall be included in the use phase. The reason for excluding these processes is that behaviour (e.g., preparation and storage) varies substantially across consumers and countries, and no sufficient data is available on this behaviour to design a meaningful and accurate default scenario.

Inedible food parts are excluded from the functional unit (see Section 3.3) and shall be included in the use phase. The definition of inedible food parts adopted here is based on the product's physical properties (e.g., whether a part is edible or not) and is not influenced by consumer behaviour. Exclusion of inedible food parts (e.g., banana peel) from the functional unit means additional consumable food parts are needed to fulfil the functional unit. This additional amount shall be included in the use stage. This approach allows comparability between products with different levels of edibility within the product category. Product specific inedible fractions shall be used. Appendix 5 list the inedible fractions that shall be used. In case the product is not available in the list, the nearest proxy within the same category shall be chosen. The inedible fraction of the product is derived from the Agribalyse documentation (Asselin-Balençon et al., 2022), based on De Laurentiis et al. (2018).

The waste treatment of inedible food parts shall be modelled using the default biowaste scenario (Table 40). The waste treatment of primary packaging associated with the inedible food parts shall be accounted for in the EoL.

[27] Default product volumes are presented in Table 36, these shall be used

6.8 End of life

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). For the FreshProducePEFCR, this stage includes consumer packaging (primary). As the functional unit is 1 kg of consumable fresh fruits/vegetables and inedible parts are accounted for in the use stage, no product waste occurs in this stage. Other waste (different from the product in scope) generated during the manufacturing, distribution, retail, use stage or after use shall be included and modelled at the life cycle stage where it occurs.

The end of life of the primary packaging calculation shall include all activity data related to the management of the primary packaging as waste, including transport for collection, utility use and emissions related to incineration, landfill, composting or recycling, based on the local waste management system.

The default values to be used in waste treatment modelling per primary packaging material are displayed in Table 40.

Growing media
Emissions of peat carbon in growing media shall be modelled on remaining carbon content of peat after transferring to end of life, in which case full oxidation of remaining carbon from peat shall be modelled in the case of indoor use. For outdoor use, full carbon oxidation during cultivation is assumed (see also Section 6.2.9). This related to both growing media included in the product (e.g., herbs in soil) as to growing media use in cultivation (e.g., mushrooms).

The user of the FreshProducePEFCR shall report the DQR values (for each criterion + total) for all the datasets used.

The end of life shall be modelled using the Circular Footprint Formula and rules provided in chapter 5.10 of this PEFCR and in the PEF method, together with the default parameters listed in Annex C Transition Phase[28] of the PEF method.

Before selecting the appropriate R_2 value, the user of the PEFCR shall carry out an evaluation for recyclability of the material. The PEF study shall include a statement on the recyclability of the materials/ products. The statement on recyclability shall be provided together with an evaluation for recyclability that includes evidence for the following three criteria (as described by ISO, 1999, Section 7.7.4 'Evaluation methodology'):

1. The collection, sorting and delivery systems to transfer the materials from the source to the recycling facility are conveniently available to a reasonable proportion of the purchasers, potential purchasers and users of the product;
2. The recycling facilities are available to accommodate the collected materials;
3. Evidence is available that the product for which recyclability is claimed is being collected and recycled.

Point 1 and 3 can be proven by recycling statistics (country specific) derived from industry associations or national bodies. Approximation to evidence at point 3 can be provided by applying for example the design for recyclability evaluation outlined in EN 13430 Material recycling (Annexes A and B) or other sector-specific recyclability guidelines if available.[29]

Following the evaluation for recyclability, the appropriate R_2 values (supply-chain specific or default) shall be used. If one criterion is not fulfilled or the sector-specific recyclability guidelines indicate limited recyclability, an R_2 value of 0% shall be applied.

Company-specific R_2 values (measured at the output of the recycling plant) shall be used, if available. If no company-specific values are available and the criteria for the evaluation of recyclability are fulfilled (see below), application-specific R_2 values shall be used as listed below.

[28] https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml
[29] E.g., the EPBP design guidelines (http://www.epbp.org/design-methodlines), or Recyclability by design (http://www.recoup.org/).

- If an R_2 value is not available for a specific country, the European average shall be used.
- If an R_2 value is not available for a specific application, the R_2 values of the material shall be used (e.g., materials average).
- In case no R_2 values are available, R_2 shall be set equal to 0 or new statistics may be generated in order to assign an R_2 value in the specific situation.

The applied R_2 values shall be subject to the EF study verification.

The reuse rate determines the quantity of packaging material (per product sold) to be treated at the end of life. The amount of packaging treated at the end of life shall be calculated by dividing the actual weight of the packaging by the number of times this packaging was reused.

7 Environmental footprint results

The results of the RP studies are provided as characterised results, normalised results, and weighted results, as requested in the PEFCR method. Normalisation and weighting factors are presented in Appendix 1 The results were calculated for each sub-category: fruits and vegetables. In the context of PEF, the results of the RP may be used as a benchmark, a standard or point of reference against which any comparison may be made. The term 'benchmark' refers to the average environmental performance of the representative product sold on the European market.

As a matter of principle, the TS does not question the merits of a benchmark approach as a tool among others to enable final consumers to assess the environmental footprint of products placed on the market. However, the TS considers that, at the current stage of development of the PEF methodology, a mandatory and stringent benchmark approach would be premature, and its immediate implementation might give an inaccurate perception to consumers and a wrong incentive to the industry, due to the diversity of crops and cropping systems used in the fresh produce sector. The results of the supporting studies provide more insight into this diversity. The values listed below should therefore be seen as an indicative guide only.

7.1 Benchmark values for representative product fruits

The results in this sections are derived from the RP study of fruits (Weststrate et al., 2025b).

Table 39 *Characterised values per consumable kg representative product fruits*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	mol H^+ eq	3,44E-03	4,12E-03
Climate change	kg CO_2 eq	5,06E-01	6,16E-01
Ecotoxicity, freshwater	CTUe	4,71E+01	5,21E+01
Particulate matter	disease inc.	3,05E-08	3,66E-08
Eutrophication, marine	kg N eq	2,18E-03	2,70E-03
Eutrophication, freshwater	kg P eq	1,68E-04	1,98E-04
Eutrophication, terrestrial	mol N eq	1,28E-02	1,55E-02
Human toxicity, cancer	CTU_h	4,63E-10	5,71E-10
Human toxicity, non-cancer	CTU_h	7,89E-09	9,12E-09
Ionising radiation	kBq U-235 eq	4,26E-02	4,78E-02
Land use	Pt	2,11E+01	2,51E+01
Ozone depletion	kg CFC11 eq	1,97E-07	2,19E-07
Photochemical ozone formation	kg NMVOC eq	2,40E-03	2,85E-03
Resource use, fossils	MJ	6,32E+00	7,21E+00
Resource use, minerals and metals	kg Sb eq	5,05E-06	5,61E-06
Water use	m^3 depriv.	4,74E+00	5,46E+00

Table 40 *Normalised values per consumable kg representative product fruits*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	person-year	6,18E-05	7,41E-05
Climate change	person-year	6,70E-05	8,15E-05
Ecotoxicity, freshwater	person-year	8,30E-04	9,18E-04
Particulate matter	person-year	5,13E-05	6,14E-05
Eutrophication, marine	person-year	1,11E-04	1,38E-04
Eutrophication, freshwater	person-year	1,05E-04	1,23E-04
Eutrophication, terrestrial	person-year	7,26E-05	8,77E-05
Human toxicity, cancer	person-year	2,68E-05	3,31E-05
Human toxicity, non-cancer	person-year	6,13E-05	7,08E-05
Ionising radiation	person-year	1,01E-05	1,13E-05
Land use	person-year	2,57E-05	3,06E-05
Ozone depletion	person-year	3,77E-06	4,18E-06
Photochemical ozone formation	person-year	5,88E-05	6,97E-05
Resource use, fossils	person-year	9,73E-05	1,11E-04
Resource use, minerals and metals	person-year	7,94E-05	8,81E-05
Water use	person-year	4,13E-04	4,76E-04

Table 41 *Weighted benchmark per consumable kg representative product fruits*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	µPt	3.83	4.60
Climate change	µPt	14.11	17.17
Ecotoxicity, freshwater	µPt	15.94	17.63
Particulate matter	µPt	4.60	5.50
Eutrophication, marine	µPt	3.30	4.08
Eutrophication, freshwater	µPt	2.93	3.45
Eutrophication, terrestrial	µPt	2.69	3.25
Human toxicity, cancer	µPt	0.57	0.71
Human toxicity, non-cancer	µPt	1.13	1.30
Ionising radiation	µPt	0.51	0.57
Land use	µPt	2.04	2.43
Ozone depletion	µPt	0.24	0.26
Photochemical ozone formation	µPt	2.81	3.33
Resource use, fossils	µPt	8.09	9.23
Resource use, minerals and metals	µPt	5.99	6.65
Water use	µPt	35.15	40.49

7.2 Benchmark values for representative product vegetables

The results in this sections are derived from the RP study of vegetables (Weststrate et al., 2025a).

Table 42 *Characterised values per consumable kg representative product vegetables*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	mol H^+ eq	4,69E-03	5,14E-03
Climate change	kg CO_2 eq	4,32E-01	4,77E-01
Ecotoxicity, freshwater	CTUe	4,94E+00	5,70E+00
Particulate matter	disease inc.	3,43E-08	3,72E-08
Eutrophication, marine	kg N eq	2,30E-03	2,53E-03
Eutrophication, freshwater	kg P eq	1,99E-04	2,18E-04
Eutrophication, terrestrial	mol N eq	1,36E-02	1,48E-02
Human toxicity, cancer	CTU_h	3,51E-10	3,81E-10
Human toxicity, non-cancer	CTU_h	3,12E-09	3,45E-09
Ionising radiation	kBq U-235 eq	3,29E-02	3,43E-02
Land use	Pt	2,14E+01	2,34E+01
Ozone depletion	kg CFC11 eq	1,90E-07	1,99E-07
Photochemical ozone formation	kg NMVOC eq	1,85E-03	2,00E-03
Resource use, fossils	MJ	5,54E+00	5,88E+00
Resource use, minerals and metals	kg Sb eq	5,53E-06	5,78E-06
Water use	m^3 depriv.	5,76E-01	6,04E-01

Table 43 *Normalised values per consumable kg representative product vegetables*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	person-year	8,44E-05	9,24E-05
Climate change	person-year	5,72E-05	6,32E-05
Ecotoxicity, freshwater	person-year	8,72E-05	0,000101
Particulate matter	person-year	5,77E-05	6,25E-05
Eutrophication, marine	person-year	1,18E-04	0,000129
Eutrophication, freshwater	person-year	1,24E-04	0,000136
Eutrophication, terrestrial	person-year	7,69E-05	8,39E-05
Human toxicity, cancer	person-year	2,04E-05	2,21E-05
Human toxicity, non-cancer	person-year	2,43E-05	2,68E-05
Ionising radiation	person-year	7,80E-06	8,14E-06
Land use	person-year	2,61E-05	2,86E-05
Ozone depletion	person-year	3,63E-06	3,80E-06
Photochemical ozone formation	person-year	4,53E-05	4,90E-05
Resource use, fossils	person-year	8,53E-05	9,05E-05
Resource use, minerals and metals	person-year	8,69E-05	9,09E-05
Water use	person-year	5,02E-05	5,27E-05

Table 44 *Weighted benchmark per consumable kg representative product vegetables*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	μPt	5,235227	5,729957
Climate change	μPt	12,04125	13,31035
Ecotoxicity, freshwater	μPt	1,673941	1,930771
Particulate matter	μPt	5,166553	5,600705
Eutrophication, marine	μPt	3,478382	3,83303
Eutrophication, freshwater	μPt	3,461397	3,79552
Eutrophication, terrestrial	μPt	2,852234	3,113387
Human toxicity, cancer	μPt	0,433741	0,47019
Human toxicity, non-cancer	μPt	0,446483	0,493433
Ionising radiation	μPt	0,390861	0,407739
Land use	μPt	2,074824	2,269172
Ozone depletion	μPt	0,22913	0,239887
Photochemical ozone formation	μPt	2,166609	2,342326
Resource use, fossils	μPt	7,094588	7,528903
Resource use, minerals and metals	μPt	6,563258	6,861809
Water use	μPt	4,271067	4,485279

7.3 Environmental footprint profile

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

- full life cycle inventory
- characterised results in absolute values, for all impact categories (as a table)
- normalised results in absolute values, for all impact categories (as a table)[30]
- weighted result in absolute values, for all impact categories (as a table)[31]
- the aggregated single overall score in absolute values.

7.4 Classes of performance

This PEFCR should become an instrument to inform stakeholders, e.g., growers, traders, retailers, and consumers, regarding the product environmental footprint of fruits and vegetables. In this context, communicating EF impact assessment results is not sufficient. Stakeholders need a 'compass' to give them an indication whether the EF results they obtain are good or bad. The most effective approach to classifying performance requires the prior collection of a substantial number of PEF results. Further research and efforts in this sector are necessary to facilitate this process.

[30] The full list of normalisation factors is available in Appendix 1.
[31] The full list of weighting factors is available in Appendix 1.

8 Verification

The verification of a PEF study/report carried out in compliance with this FreshProducePEFCR shall be done in accordance with all the general requirements included in Section 9 of the Annex I in the recommendation on the use of Environmental Footprint methods (European Commission, 2021), including part A of that Annex, and the requirements listed below. Part of these guidance may not be applicable to this FreshProducePEFCR and may be excluded from verification and validation. Verifier(s) shall clearly state what has been excluded, including the reason for exclusion.

The verifier(s) shall verify that the PEF study is conducted in compliance with this PEFCR.

In case policies implementing the PEF method define specific requirements regarding verification and validation of PEF studies, reports and communication vehicles, the requirements in said policies shall prevail.

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

1. The verifier(s) shall check if the correct version of all impact assessments methods was used. For each of the most relevant EF impact categories, at least 50% of the characterisation factors shall be verified, while all normalisation and weight factors of all impact categories shall be verified. In particular, the verifier(s) shall check that the characterisation factors correspond to those included in the EF impact assessment method the study declarers in compliance with. This may also be done indirectly.
2. Cut-offs applied (if any) fulfil the requirements in Section 3.4.
3. All datasets used shall be checked against the data requirements (Section 5.1 – Section 5.4).
4. For at least 80% (in number) of the most relevant processes, the verifier(s) shall validate all related activity data and the datasets used to model these processes. If relevant, CFF parameters and datasets used to model them shall also be validated in the same way. The verifier(s) shall check that the most relevant processes are identified as specified in Section 6.3.3 of Annex I in the recommendation on the use of Environmental Footprint methods (European Commission, 2021).
5. For at least 30% (in number) of all other processes (corresponding to 20% of the processes as defined in Section 6.3.3 of Annex I in the recommendation on the use of Environmental Footprint methods (European Commission, 2021)) the verifier(s) shall validate all related activity data and the datasets used to model these processes.
6. The verifier(s) shall check that the datasets are correctly implemented in the software (i.e., LCIA results of the datasets in the software are within a deviation of 1% of 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.

In particular, verifier(s) shall verify if the DQR of the processes satisfies the minimum DQR as specified in the DNM for selected processes.

These data checks shall include, but should not be limited to, the activity data used, the selection of secondary subprocesses, the selection of the direct elementary flows, and the CFF parameters. For example, if there are 5 processes and each one of them includes 5 activity data, and 5 secondary datasets, then the verifier(s) has to check at least 4 out of 5 processes (70%) and, for each process, (s)he/they shall check at least 4 activity data (70% of the total amount of activity data), and 4 secondary datasets (70% of the total amount of secondary datasets.

The verification of the PEF report shall be carried out by randomly checking enough information to provide reasonable assurance that the PEF report fulfils all the conditions listed in Section 8 of Annex I in the recommendation on the use of Environmental Footprint methods, including part A of this Annex.

Currently, there are several actors developing and updating their tools to adopt the rules for product environmental footprinting documented in this FreshProducePEFCR. Tools can ease the effort and significantly reduce the costs involved in calculating PEF results. In this context, it is important to guarantee that tools claiming compliance with this PEFCR meet a list of requirements. Other verification requirements are product/PEF-study specific.

'The International EPD® System allows the use of pre-verification of LCA and Environmental Product Declaration (EPD) tools to facilitate the development of EPDs. The application of these tools leads to a simplified verification process since certain elements of the LCA cannot be further influenced by those developing the EPD and verification of these elements is needed only once. Please note that while using a pre-verified tool simplifies the procedure for developing an EPD, it does not replace the need for fulfilling verification requirements (…).'[32] The TS took inspiration from the pre-verified tools for EPD development of the International EPD® Systems and identified the verification and validation requirements that can be met by the integration of a specific PEFCR in a software tool. Having this as a pre-requisite would significantly reduce the efforts and costs for verification of specific studies/assessments. For this reason, the TS considers two situations:

- The PEF assessment is **not conducted with a pre-verified tool** (see Section 8.1); and
- The PEF assessment is **conducted in a pre-verified tool**.

8.1 Verification requirements for PEF assessments not conducted in a pre-verified tool

The verifier(s) shall validate the accuracy and reliability of the quantitative information used in the calculation of the study. This shall be done according to the verification requirements documented in section 9 of the Annex I 'Product Environmental Footprint Method' to the Commission Recommendation (EU) 2021/2279 of 15 December 2021.

8.2 Verification requirements for PEF assessments conducted in a pre-verified tool

The TS is presently examining various approaches and governance structures for the verification of PEF assessments conducted using a pre-verified tool. More information can be found at the website of the TS Lead Freshfel Europe.

8.3 Verifier(s)

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 3rd party verifier, they shall not have conflicts of interests on concerned products

[32] https://www.environdec.com/all-about-epds/lca-and-epd-tools

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Appendix 1 List of EF normalisation and weighting factors

Table A.1 *Normalisation factors (NF) for Environmental Footprint (EF) 3.1*

Impact categories	Unit	NF
Acidification	mol H^+ eq./person-year	5.56E+01
Climate change	kg CO_2 eq./person-year	7.55E+03
Ecotoxicity, freshwater	CTU_e/person-year	5.67E+04
EF-particulate matter	disease incidences/person-year	5.95E-04
Eutrophication, freshwater	kg P eq./person-year	1.61E+00
Eutrophication, marine	kg N eq./person-year	1.95E+01
Eutrophication, terrestrial	mol N eq./person-year	1.77E+02
Human toxicity, cancer	CTU_h/person-year	1.73E-05
Human toxicity, non-cancer	CTU_h/person-year	1.29E-04
Ionising radiation	kBq U^{235} eq./person-year	4.22E+03
Land use	pt/person-year	8.19E+05
Ozone depletion	kg CFC-11 eq./person-year	5.23E-02
Photochemical ozone formation	kg NMVOC eq./person-year	4.09E+01
Resource depletion, fossils	MJ/person-year	6.50E+04
Resource depletion, minerals and metals	kg Sb eq./person-year	6.36E-02
Water use	m^3 water eq of deprived water/person-year	1.15E+04

Table A.2 *Weighting factors (WF) for Environmental Footprint (EF) 3.1*

Impact categories	WF [%]
Acidification	6.20
Climate change	21.06
Ecotoxicity, freshwater	1.92
EF-particulate matter	8.96
Eutrophication, freshwater	2.80
Eutrophication, marine	2.96
Eutrophication, terrestrial	3.71
Human toxicity, cancer	2.13
Human toxicity, non-cancer	1.84
Ionising radiation	5.01
Land use	7.94
Ozone depletion	6.31
Photochemical ozone formation	4.78
Resource depletion, fossils	8.32
Resource depletion, minerals and metals	7.55
Water use	8.51

Appendix 2 PEF study template

This is the checklist from the PEF study template as provided in Part E 'PEF Report Template' of Annex II to the Commission Recommendation (European Commission, 2021).

Table of contents
Acronyms
Definitions
1. Summary
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3. Goal of the study
4. Scope of the study
    a. Functional unit and reference flow
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5. Life cycle Inventory Analysis
    a. Screening step (if applicable)
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6. Impact assessment results (confidential, if relevant)
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7. Interpreting EF results
8. Validation statement

References
Annex I Detailed Life Cycle Inventory and assessment of data quality

Appendix 3 Review statement of the FreshProducePEFCR

Validation statement

Title of the PEF study: Product Environmental Footprint Category Rules for Fresh Produce

Version/ date of the PEF study: Draft Final version, February 2025

Commissioner of the PEF study: Technical Secretariat of the FreshProducePEFCR

User of the PEF method as described in *COMMISSION RECOMMENDATION of 16.12.2021 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations* (C(2021) 9332 final), including Annex 1+2

Team members of the review panel:

- Johannes Lijzen (lead) and Anne Hollander, RIVM, NL
- Alan Forrester, DoffConsulting, UK
- Judith Brouwer, MilieuCentraal, NL

We, the review panel, declare not to have conflicts of interest with respect to concerned products and any involvement in previous work (PEFCR development, Technical Secretariat membership, consultancy work carried out for the user of the PEF method) during the last three years.

The objective of this verification/ validation is to check whether the study 'Product Environmental Category Rules for Fresh Produce' has been carried out in compliance with the most updated version of the PEF method and that the information and data included in the study 'Product Environmental Category Rules for Fresh Produce' are reliable, credible and correct.

We, the review panel, following the review procedure, consider:

- This PEFCR report has been developed in accordance with the latest by the EC adopted recommendation on the PEF method. However, as stated in the PEFCR report, it was developed outside of the official PEF framework, and connecting to the official EF datasets (for background data) was therefore not possible.
- Because the official EF datasets could not be used, some adjustments had to be made; these adjustments are reported correctly (e.g. concerning transport).
- The hotspot analysis is applied and reported upon correctly.
- RP studies themselves are not reviewed; still we can confirm that identified LCA data and additional environmental information give a description of the significant environmental aspects associated with this product group as described in the RP studies.
- The secondary datasets for the product groups are appropriate.
- The report provides suggestions for limitations and improvements of the PEFCR study.
- The two supporting studies (on 1. paprika in glass house with residual heat and 2. mangos from Brazil) are confidential. Therefore we were not able to judge if the learning points relevant for the PEFCR have been incorporated.
- The comments given on the draft PEFCR-study were seriously worked on leading to changes or explanations. Overall, the Technical Secretariat of the FreshProducePEFCR has mostly addressed the concerns raised by the review panel with clear and sufficient responses, within the current PEF-guidelines.
- Points of attention and/or limitations of the verification are:
  - In some cases it was not possible to tailor the method for this product group because the description in PEFCR-Guidance is mandatory. It is important to pass these insights through to the EC.
  - Some of the remarks of the review team concerned product group-specific circumstances. To benefit maximally from this information, direct contact in an online meeting between the TS and the review team after the first draft is important.

- The selected products for the RP studies do represent important product groups for fruits and vegetables. Still, data on market shares are not reported, which makes the selection of the virtual product less transparent.
- The product group (sweet) potatoes with a large market share is missing in the vegetable group. We recommend to add this group in a next version of the PEFCR.
- It is important to perform more studies to be able to improve the benchmark values that are reported in the PEFCR for fruits and vegetables over time.
- Because the pesticide use of the selected vegetables is relatively low, the ecotoxicity impact category was not above the 80% cut-off. We support the addition of reporting on the impact category ecotoxicity for vegetables, because for other products than those selected in the RP study this might be relevant, in case they use more and/or other pesticides. Since the reason could also be lack of data for crop protection products, we emphasize the need for data collection on crop protection products.
- As is stated in the PEFCR, biodiversity impact cannot yet be taken into account, apart from additional information. It is important to improve this in the future.

Date of this validation statement: March 11th 2025

Signatures:

Milieu Centraal — Judith Brouwer

DoffConsulting — Alan Forrester

RIVM — Anne Hollander/ Johannes Lijzen

Appendix 4 Parameters fertiliser modelling

The main parameters to be used by the applicant regarding fertiliser modelling are described in the Section 6.2.7. For an increased readability of that respective section, some parameters are included in this Appendix.

Table A.3 *Per country the weighted average value for the parameter fertiliser ('fert') in the equation for ammonia volatilisation (Formula 1), based on the N-fertiliser use given by FAO*

	Country	*Value fertiliser*		Country	*Value fertiliser*
1	Afghanistan	0.637	60	Libya	0.476
2	Albania	0.318	61	Lithuania	-0.160
3	Algeria	0.383	62	Macedonia	-0.150
4	Argentina	0.264	63	Malaysia	0.245
5	Armenia	-0.269	64	Mauritius	0.014
6	Australia	0.311	65	Mexico	0.153
7	Austria	-0.461	66	Moldova Republic of	-0.082
8	Azerbaijan	-0.251	67	Morocco	0.028
9	Bangladesh	0.613	68	Myanmar	0.546
10	Belarus	-0.017	69	Nepal	0.574
11	Belgium	-0.771	70	Netherlands	-0.800
12	Bosnia-Herzegovina	-0.399	71	New Zealand	0.579
13	Brazil	0.346	72	Nicaragua	0.030
14	Bulgaria	-0.163	73	Nigeria	0.514
15	Cameroon	0.488	74	Norway	-0.219
16	Canada	0.030	75	Pakistan	0.504
17	Chile	0.451	76	Paraguay	0.210
18	China	0.251	77	Peru	0.407
19	Colombia	0.373	78	Philippines	0.493
20	Costa Rica	0.136	79	Poland	-0.119
21	Croatia	-0.031	80	Portugal	-0.427
22	Cuba	0.310	81	Qatar	0.574
23	Cyprus	0.097	82	Romania	-0.068
24	Czech Rep.	-0.373	83	Russian Federation	-0.209
25	Czechoslovakia (former)	NA	84	Saudi Arabia	0.491
26	Côte d'Ivoire	0.490	85	Senegal	0.014
27	Denmark	-0.639	86	Serbia	0.056
28	Dominican Republic	0.512	87	Slovak Rep.	-0.371
29	Ecuador	0.460	88	Slovenia	-0.651
30	Egypt	0.396	89	South Africa	0.055
31	El Salvador	0.442	90	Spain	-0.102
32	Estonia	-0.301	91	Sri Lanka	0.632
33	Ethiopia	0.416	92	Sudan	0.615
34	Finland	-0.366	93	Sweden	-0.650
35	Former FSU	NA	94	Switzerland	-0.519
36	France	-0.340	95	Syria	0.413
37	Georgia	-0.285	96	Taiwan China	0.436
38	Germany	-0.373	97	Tajikistan	0.266
39	Greece	-0.044	98	Tanzania	0.293
40	Guatemala	0.478	99	Thailand	0.458
41	Hungary	-0.626	100	Trinidad & Tobago	0.635
42	Iceland	-0.097	101	Tunisia	-0.269

	Country	*Value fertiliser*		Country	*Value fertiliser*
43	India	0.557	102	Turkey	0.065
44	Indonesia	0.559	103	Turkmenistan	0.233
45	Iran	0.578	104	Ukraine	-0.188
46	Iraq	0.606	105	United Kingdom	-0.259
47	Ireland	-0.415	106	United States	-0.385
48	Israel	0.004	107	Uruguay	0.419
49	Italy	0.264	108	Uzbekistan	-0.158
50	Japan	0.151	109	Venezuela	0.472
51	Jordan	-0.099	110	Viet Nam	0.500
52	Kazakhstan	-0.192	111	Yugoslavia (former)	NA
53	Kenya	-0.013	112	Zambia	0.247
54	Korea DPR	0.341	113	Zimbabwe	-0.186
55	Korea Republic	0.210	114	Others Africa	0.155
56	Kuwait	0.593	115	Others East Asia	0.292
57	Kyrgyzstan	-0.303	116	Others Latin America and the Caribbean	0.469
58	Latvia	-0.114	117	Others Oceania	0.042
59	Lebanon	0.192	118	Others West Asia	0.523

Table A.4 *Nitrogen content in harvested products (kg/tonne fresh harvested product), based on van der Schoot & van Dijk (2001)*

Crop	N content (kg/tonne fresh harvested product)
Strawberry	1.2
Cauliflower	2.6
Broccoli	2.0
Chinese cabbage	1.5
Peas	7.5
Celeriac	2.0
Carrot	1.5
Winter carrot	1.6
Leek	3.0
Lettuce	2.0
Iceberg lettuce	1.5
Spinach	3.5
Brussels sprouts	5.5
Green bean	2.2
Onion	2.2
Chicory root	2.3
White cabbage	1.9

Table A.5 *Nitrogen in crop residues (above and below ground) emission factor, based on Vonk et al. (2018b)*

Crop	N in crop residue above ground (kg N/ha)	N in crop residue below ground (kg N/ha)
Strawberry	19	6
Endive	40	6
Asparagus	27	6
Gherkin	78	6
Cauliflower	132	14
Broccoli	156	14
Cabbage	122	14
Celeriac	75	14
Beetroot	95	14
Lettuce	37	6
Leek	82	4
Scorzonera	46	14
Spinach	30	6
Brussels sprouts	170	14
Industrial French Beans	77	13
Runner beans	61	13
Broad beans, green	16	13
Carrot	9	0
Winter carrot (Danvers)	65	0
Chicory	59	0
Other vegetables	78	6
Green manure following arable crop	51.5	14

Appendix 5 Inedible fractions

Table A.6 *Inedible fractions as included in the Agribalyse documentation (Asselin-Balençon et al., 2022), based on Witte et al. (2015) and De Laurentiis et al. (2018)*

Product	Inedible fraction
Vegetables	
Artichoke	0.60
Asparagus	0.40
Avocados	0.30
Basil	0.10
Beetroot	0.10
Broccoli	0.20
Brussels sprout	0.10
Cabbage	0.20
Carrots	0.10
Cassava	0.10
Cauliflower	0.20
Celeriac	0.10
Celery	0.03
Chicory	0.20
Chines or Japanese artichokes	0.10
Coriander	0.10
Cucumber	0.10
Eggplant	0.10
Endive	0.20
Escaroles	0.40
Fennel	0.20
French bean	0.10
Garden cress	0.20
Carden pea	0.20
Green celery	0.03
Green pea	0.00
Jerusalemen artichoke	0.10
Leek	0.20
Lettuce	0.40
Mint	0.10
Mushroom	0.10
Onion	0.10
Parsley	0.10
Pepper	0.03
Pumpkin	0.20
Radish	0.03
Red endive	0.20
Salad	0.40
Salsify	0.20
Shallot	0.10
Spinach	0.03
Tarragon	0.20
Tomatoes	0.03
Turnips	0.20
Fruits	
Apple	0.10

Product	Inedible fraction
Apricot	0.20
Banana	0.30
Blackberry	0.03
Blueberry	0.03
Cherry	0.20
Currant	0.20
Grapefruit (incl. pomelos)	0.30
Lemon	0.30
Mandarin	0.20
Mango	0.20
Melon	0.40
Orange	0.20
Peach	0.20
Pear	0.10
Pineapple	0.50
Plum	0.20
Pomegranate	0.20
Raspberry	0.03
Strawberry	0.03
Table grape	0.10

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The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,700 employees (7,000 fte), 2,500 PhD and EngD candidates, 13,100 students and over 150,000 participants to WUR's Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.