1st Draft Product Environmental Footprint Category Rules for Fruits and Vegetables

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WAGENINGEN
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1st Draft Product Environmental Footprint Category Rules for fresh Fruits and Vegetables

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Abstract

The primary objective of this FreshProducePEFCR is to fix a consistent and specific set of rules to calculate the relevant environmental information of fresh fruits and vegetables. An important objective is to focus on what matters most for this specific product category to make environmental footprint studies easier, faster and less costly. An equally important objective is to enable comparisons and comparative assertions in all cases where this is feasible, relevant and appropriate. Comparisons and comparative assertions are allowed only if environmental footprint studies are conducted in compliance with harmonised LCA methodology, like a PEFCR. An LCA study for fruits or vegetables can be conducted following this document. This PEFCR – Product Environmental Footprint Category Rules for fresh Fruits and Vegetables – is the report that is developed as much as possible in alignment with the most recent guidance for developing Product Environmental Footprint Category Rules (EC, 2021). It is however not fully compliant to the PEF method, as it is developed outside of the official PEF framework and connecting to the official EF datasets (for background data) is not possible.

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

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Preface

The Technical Secretariat headed by Freshfel Europe would like to offer you the 1st draft of the FreshProducePEFCR - Product Environmental Footprint Category Rules - report that is developed for two product categories:

Fresh fruits sold at the European market;
Fresh vegetables sold at the European market.

The European Commission launched the Product Environmental Footprint (PEF) method over 10 years ago, with the aim to harmonise Life Cycle Assessment (LCA) methodology, make outcomes more comparable and provide less space for false claims. Besides 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.

This document is being developed outside of the official PEF framework, as there is currently no opening to develop new PEFCRs. The fresh produce sector in Europe, however, does not wish to wait for an opening, and has started the development of this harmonised methodology, which is developed to the best extent in compliance with the most recent version of the PEF-method (EC, 2021). This document, which has been prepared by a group of international experts, is offered to professionals that take part in the 1st Open Public Consultation. The development of this draft was informed by the development of the Representative Product (PEF-RP) studies: RP study for Fruits (Weststrate et al., 2024a) and RP study for vegetables (Weststrate et al., 2024b).

The following objectives are met when developing the FreshProducePEFCR:

- to fix a consistent and specific set of rules to calculate the relevant environmental information;
- to enable comparisons between environmental footprinting studies which are conducted in compliance with this PEFCR.

This PEFCR document is structured following the PEFCR template as provided in the guidelines of the European Commission (EC, 2021) and to a large extent follows the process of developing a new PEFCR as stipulated in the guidelines. This process started with arranging a Technical Secretariat (TS), which is the consortium responsible for developing the FreshProducePEFCR. The TS decided upon the representative products (RP) to be analysed and conducted the RP studies. These studies have informed the development of the 1st draft of the FreshProducePEFCR. The firsts drafts of both RP studies and the FreshProducePEFCR are now published for Open Public Consultation from 2 April 2024 to 30 April 2024. Comments will be processed. Thereafter the FreshProducePEFCR will be tested in two (confidential) supporting studies with companies and external consultants. The learnings will be covered in the updated 2nd draft of the FreshProducePEFCR. This 2nd draft of the FreshProducePEFCR will be reviewed by an external review panel, prior to being presented for the 2nd Open Public Consultation.

The development of this 1st draft of the FreshProducePEFCR started with the publication of HortiFootprint Category Rules in 2020 (Helmes et al., 2020) and the FloriPEFCR in 2024 (Broekema et al., 2024). The HortiFootprint Category Rules contain rules for calculating an environmental footprint of horticultural products for both ornamentals and fruits and vegetables. For ornamentals a PEFCR was developed during the PEF's transition phase (FloriPEFCR). Developing this FreshProducePEFCR means a further refinement of the HortiFootprint Category Rules at a European level very much aligned with the 'Product Environmental Category Rules (PEFCR)' of the European Commission.

A word of thanks goes to several professionals that helped the team in reviewing and discussing the interim versions of this document. 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.

General Director Social Sciences Group (SSG)	Chair of the Technical Secretariat of the FreshProducePEFCR
Wageningen University & Research	Freshfel Europe

Abbreviations

Abbreviation	Explanation
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
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
GR	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
OCAP	organic CO_2 for assimilation by plants
P	precision
PCR	Product Category Rules
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
PEF-RP	PEF study of the representative product
RP	representative product
SS	supporting study
TeR	technological representativeness
TiR	time representativeness
TS	Technical Secretariat
UNEP	United Nations Environment Programme
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

Definitions

Activity data - information which is associated with processes while modelling Life Cycle Inventories (LCI). The aggregated LCI results of the process chains, which represent the activities of a process, are each multiplied by the corresponding activity data[1] and then combined to derive the environmental footprint associated with that process.

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

Synonym of 'non-elementary flow'.

Acidification – EF impact category that addresses impacts due to acidifying substances in the environment. Emissions of 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.

Additional environmental information – environmental information outside the EF impact categories that is calculated and communicated alongside 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 – next to the elementary flows (and possibly not relevant amounts of waste flows and radioactive wastes) – itemises only the product(s) of the process as reference flow(s) in the input/output list, but no other goods or services.

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

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

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

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

Average Data – production-weighted average of specific data.

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

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

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

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. 1 Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute, 2011). 8

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 to 'primary data'. To determine the level of representativeness a sampling procedure may be applied.

Company-specific dataset – refers to a dataset (disaggregated or aggregated) compiled with company-specific data. In most cases the activity data is company-specific while the underlying sub-processes are datasets derived from background databases. 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. 9

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, etc.).

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 (for example, 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 11 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**).

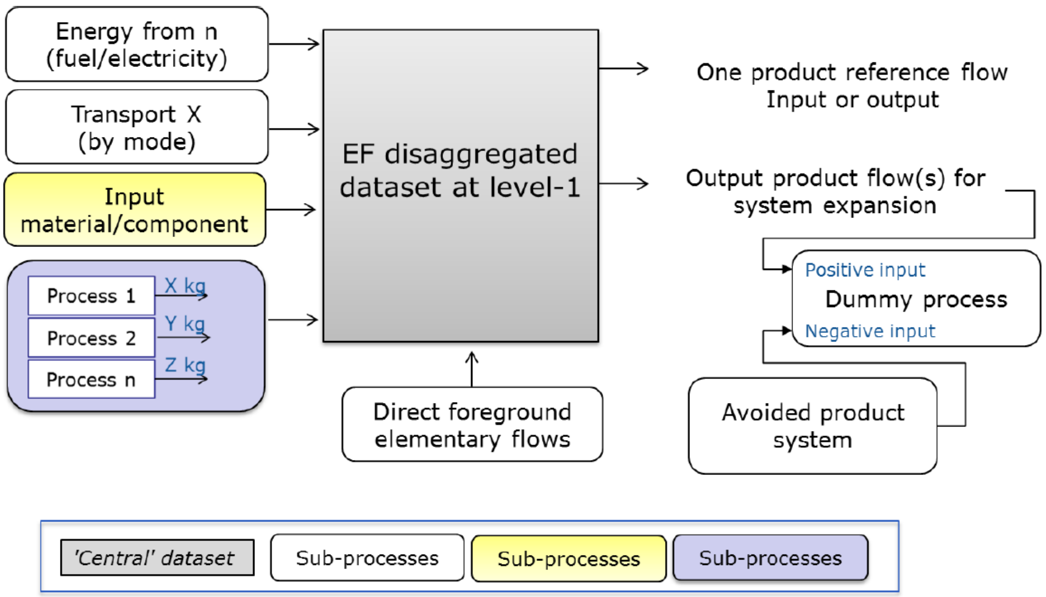

Figure 1 *Example of a dataset partially disaggregated at level-1*

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].

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.

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.

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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

Summary

The Product Environmental Footprint Category Rules for fresh Fruits and Vegetables (FreshProducePEFCR) is the report that is developed to the best extent in alignment with Annex I and II of the recommendation on the use of the Environmental Footprint methods from the European Commission (EC, 2021). It provides technical guidance to the fresh produce sector on how to perform environmental footprint studies of fresh produce belonging to the following categories: (fresh) Fruits and Vegetables. The FreshProducePEFCR is intended for practitioners to monitor their environmental impact, identify hotspots in the life cycle of their products and recognise areas for improvement of their environmental performance.

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. The document is structured along the template as required by the PEF-method (EC, 2021). It documents how stakeholders and experts have been involved in the process, specifies the functional unit of the analysis, guidelines for environmental footprinting studies in this product category and results of Representative Product (RP-PEF) studies as required by the PEF Guidance. This 1st draft FreshProducePEFCR report is released for the 1st Open Public Consultation through which feedback is requested. The comments are addressed in the next round of revision and thereby continuous development and improvement of this document will take place.

The methodological choices are described in the main part of the document under respective sections. Previously, several methodological approaches for horticultural crops were pre-tested in 2018-2019 during the development of Hortifootprint Category Rules (Helmes et al., 2020), which is the starting point for the development of first the FloriPEFCR and now the FreshProducePEFCR. On the basis of six cases in 2020 (rose, phalaenopsis, tulip bulbs but also other relevant crops like bananas, apples, tomatoes) and later on the basis of several confidential studies (tomato from the Netherlands, Morocco and Tunisia, oranges from Egypt and onions from the Netherlands) the HortiFootprint Category Rules were tested.

Chapters 1 and 2 provide a general introduction and information about the FreshProducePEFCR, describing the consortium that participated in the development of the methodology and the stakeholder engagement process.

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 Representative Product (RP) studies have been conducted to gain more experience with calculating the environmental impact according to the PEF guidance. The RP studies were also important to make methodological decisions and the learnings from the two RP studies were used for drafting this version of the FreshProducePEFCR. One RP study was conducted for fruits and one for vegetables. For both RP studies a virtual product was analysed. This virtual (i.e. non-existing) product is a mix of real products and is considered to represent the diversity of the products on the market for the two product categories.

For fruits, a virtual product was constituted based on six real products from various countries of cultivation. These products are selected to represent six main groups of fruits as follows:

- Apples, from Poland and Italy, is chosen to represent pomme- and stone fruits.
- Oranges, from Spain and South-Africa, is chosen to represent citrus fruits.
- Banana, from Ecuador, is chosen to represent tropical- and subtropical fruits.
- Watermelon, from Spain, is chosen to represent melons.

- Fresh grape, from Italy, is chosen to represent table grapes.
- Strawberries, from Spain, is chosen to represent berries.

The virtual representative product for vegetables is composed of five real products, from various countries of cultivation. These products are selected to represent five main groups of vegetables as follows:

- Tomato, from Italy, Spain and the Netherlands, is chosen to represent fruit bearing vegetables. This selection also includes various production techniques: open field, shade nets, glass greenhouses.
- Cabbage, from Poland, is chosen to represent leafy- or stem vegetables.
- Carrot, from Germany, is chosen to represent root- bulb- and tuberous vegetables.
- Green bean, from France, is chosen to represent green leguminous vegetables.
- White mushroom, from the Netherlands, is chosen to represent mushrooms.

Chapter 4 relates to the results obtained from Representative Product studies (Weststrate et al., 2024a; Weststrate et al., 2024b), such as the most relevant impact categories, life cycle stages, processes and direct elementary flows, as well as limitations.

In Chapter 5 the document lists the processes to be modelled with mandatory company-specific data (i.e. activity data and direct elementary flows). Most of the mandatory company-specific data will come from growers and access to these data is required to perform a study which is compliant to the FreshProducePEFCR. There are horticulture service providers that have access or manage data from growers that are expected to be able to perform such a study. Also there are owners of certification schemes which already manage a lot of the data from growers and are expected to be able to perform such a study. 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.

In 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.

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 programmes.

This FreshProducePEFCR is developed to the best extent possible in compliance with 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 (EC, 2021). It is however 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 (2024) no opening in the official PEF framework to develop new PEFCRs. Since having harmonised category rules in a sector provide great advantages and opportunities, the Fresh Produce sector has chosen to develop a PEFCR outside of the official PEF framework and align to best extent possible. Hereafter, this document is referred to as FreshProducePEFCR.

For all requirements not specified in the FreshProducePEFCR, the user of the FreshProducePEFCR shall refer to the documents the FreshProducePEFCR is in conformance with (see chapter 2.7).

The compliance with the present FreshProducePEFCR is optional for PEF in-house applications, whilst it is mandatory whenever the results of an environmental footprinting study or any of its content is intended to be communicated.

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 has to 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.

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
Greenyard	Fresh produce company	Frederic Rosseneu
Dole PLC	Fresh produce company	Vincent Dolan
Wageningen Economic Research (TS support)	Research organisation	Jeroen Weststrate Roline Broekema
PRé Sustainability	LCA Consultancy	Marisa Vieira Ellie Williams
Blonk Sustainability	LCA Consultancy	Meike Hopman
Fresh Produce Centre (GroentenFruit Huis)	Trade association	Richard Schouten Nikki Hulzebos

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
- Representative product studies
- 1st Draft FreshProducePEFCR
- 1st public consultation
- Supporting studies
- 2nd draft FreshProducePEFCR
- 2nd public consultation
- Final FreshProducePEFCR

After the representative product studies, the current 1st draft of the FreshProducePEFCR is laying before you. The 1st public consultation with stakeholders takes place from 2 April 2024 to 30 April 2024.

2.3 Review panel and review requirements

During the 1st Public Consultation in the development of the FreshProducePEFCR, the FreshProducePEFCR is reviewed by a third-party review panel (Table 2).

Table 2 *Review panel of the 1st draft of the FreshProducePEFCR*

Name of the member	Affilliation	Role
Johannes Lijzen	RIVM National Institue for Public Health and the Environment	Chair
Anne Hollander		Member
Alan Forrester	Doff Consulting	Member
Judith Brouwer	Milieu Centraal	Member

The reviewers are asked to verify that the following requirements are 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 (EC, 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.

The public review reports of this 1st draft of this FreshProducePEFCR will be made publicly available in due time.

2.4 Review statement

Not applicable for this version of the FreshProducePEFCR.

2.5 Geographic validity

The FreshProducePEFCR is valid for products in scope sold or consumed in the European Union + EFTA + UK.

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):

- 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 (EC, 2021). The recommendations are followed to the best extent possible, as this PEFCR is developed outside of the official PEF framework;
- FloriPEFCR (Broekema et. al, 2024), was used as a starting point;
- Hortifootprint Category Rules (Helmes et al., 2020) were used as a starting point;
- Growing Media Environmental Footprint Guideline V1.3 was used as much as possible for the modelling approach for production and emissions for growing media (GME, 2021).

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 methods to be used. Furthermore, the additional technical and environmental information which shall be provided when conducting an EF 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 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 in Table 3.

Table 3 *CPA codes for the products included in the FreshProducePEFCR.*

CPA code	Coverage
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 dries avocados	
0803 10 10 Plantains, fresh	
0803 90 10 Bananas, fresh (excl plantains)	
0804 10 00 Fresh or dried dates	
0804 20 10 Fresh figs	
0804 30 00 Fresh or dried pineapples	
0804 50 00 Fresh or dried guavas, mangoes and mangosteens	
0807 20 00 Fresh pawpaws “papayas”	
0810 60 00 Fresh durians	
01.23 Citrus fruits	
0805 40 00 Fresh or dried grapefruit	
0805 50 10 Fresh or dried lemons “citrus limon, Citrus limonum”	
0805 10 90 Fresh or dried limes “Citrus aurantifolia, Citrus Latifolia”	
0805 10 20 Fresh sweet oranges	
0805 10 80 Fresh or dries oranges (excl. fresh sweet oranges)	
0805 20 10 Fresh or dried clementines	
0805 20 30 Fresh or dried monreales and satsumas	
0805 20 50 Fresh or dries mandarins and wilkings	
0805 20 70 Fresh or dried tangerines	
0805 20 90 Fresh or dried tangelos, ortaniques, malaquinas and similar citrus hybrids (excl. clementines, monreales, satsumas, mandarins, wilkings and tangerines)	
0805 90 00 Fresh or dried citrus fruit (excl. oranges, lemons, limes, grapefruit, mandarins, incl tangerines and satsumas, clementines, wilkings and similar citrus hybrids)	
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)	

CPA code	Coverage
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-perrenial 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	
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	
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 capsicin or capsicum oleoresin dyes	
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	

CPA code	Coverage
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.s.	
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, flap mushrooms, mushrooms of the genus “Agaricus” and truffles	Not covered
01.13.9 Vegetables, fresh	
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.

3.2 Representative product(s)

Two representative products are considered in the FreshProducePEFCR; one for Fruits and one for Vegetables. Both representative products are virtual (i.e. non-existing) products, that reflects the average consumption of fruits or vegetables (in kg/year/capita) at 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 (in weight units), not what is produced within the European Union. For products that are mostly exported from, or imported to the EU, 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 fruits at the European market (in kg/capita/year);
- The average consumption of 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 criteria for fruits and vegetables, since sales-weighted characteristics are deemed to not represent the environmental footprint correctly. Other agri-food related PEFCRs (e.g. feed and marine fish) also adopted a mass/volume based approach.

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

Average EU consumption per capita (kg/yr) =
(European production + Export (Extra EU) – Import (intra EU)) / European population

It should be noted that actual 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 or parts may be wasted.

Data is collected for a time period of 5 years (2017-2021), being the latest data available at the time of conduction 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 are 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), processing factors are applied to the production data. These processing factors are delivered by TS lead Freshfel Europe and retrieved from several EC working groups.

Table 4 and Table 5 represent data on the average consumption of fruits and vegetables at the European market per sub-category.

Table 4 *Average consumption of fruits at the European market (2017-2021).*

Sub-categories ***(categorization 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 Table grapes	5.69	7.2
01.25 Other tree and bush fruits	5.13	6.5
Total:	**79.16**	**100.00**

Table 5 *Average consumption of vegetables at the European market (2017-2021).*

Sub-categories ***(categorization according to CPA)***	**Average consumption (in kg/capita/year)**	**Share of total consumption (in %)**
01.13.4 Root, bulb or tuberous vegetables	29.79	41.0%
01.13.3 Other fruit-bearing vegetables	22.70	31.3%
01.13.1 Leafy or stem vegetables	15.85	21.8%
01.11.6 Green leguminous vegetables	2.92	4.0%
01.13.8 Mushrooms	1.18	1.6%
Total:	**72.44**	**100.0**

Within each of the sub-categories listed above, 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 raking in decreasing order of production volume (kg), the 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 Technical Secretariat. Two main questions guided the selection of products within the product groups:
1. Is there any other product in the product group dominating the consumption?
2. Do we expect to miss any relevant calculation rules or other requirements for any other product within the product group?

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 are selected to represent six sub categories of fruits as follows:
- Apples, from Poland and Italy, is chosen to represent pomme- and stone fruits.
- Oranges, from Spain and South-Africa, is chosen to represent citrus fruits.
- Banana, from Ecuador, is chosen to represent tropical- and subtropical fruits.
- Watermelon, from Spain, is chosen to represent melons.
- Fresh grape, from Italy, is chosen to represent table grapes.
- Strawberries, from Spain, is chosen to represent berries.

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.

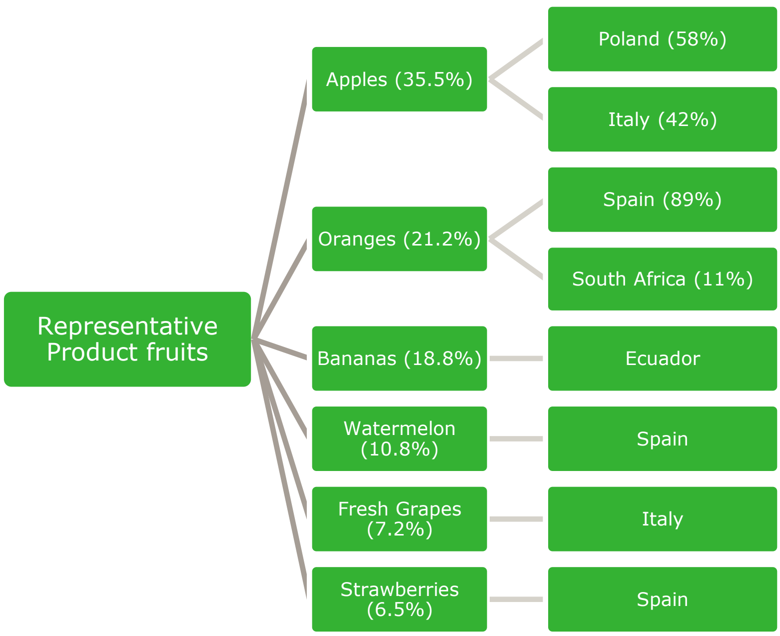

Figure 2 *Composition of the representative product fruits, including market shares that are used to calculate the environmental impact (percentages may not add up to 100% due to rounding). Market shares are based on the average consumption in kilograms, per capita-year at the European market.*

3.2.2 Vegetables

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

- Tomato, from Italy, Spain and the Netherlands, is chosen to represent fruit bearing vegetables. This selection also includes various production techniques: open field, shade nets, glass greenhouses.
- Cabbage, from Poland, is chosen to represent leafy- or stem vegetables.
- Carrot, from Germany, is chosen to represent root- bulb- and tuberous vegetables.
- Green bean, from France, is chosen to represent green leguminous vegetables.
- White mushroom, from the Netherlands, is chosen to represent 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.

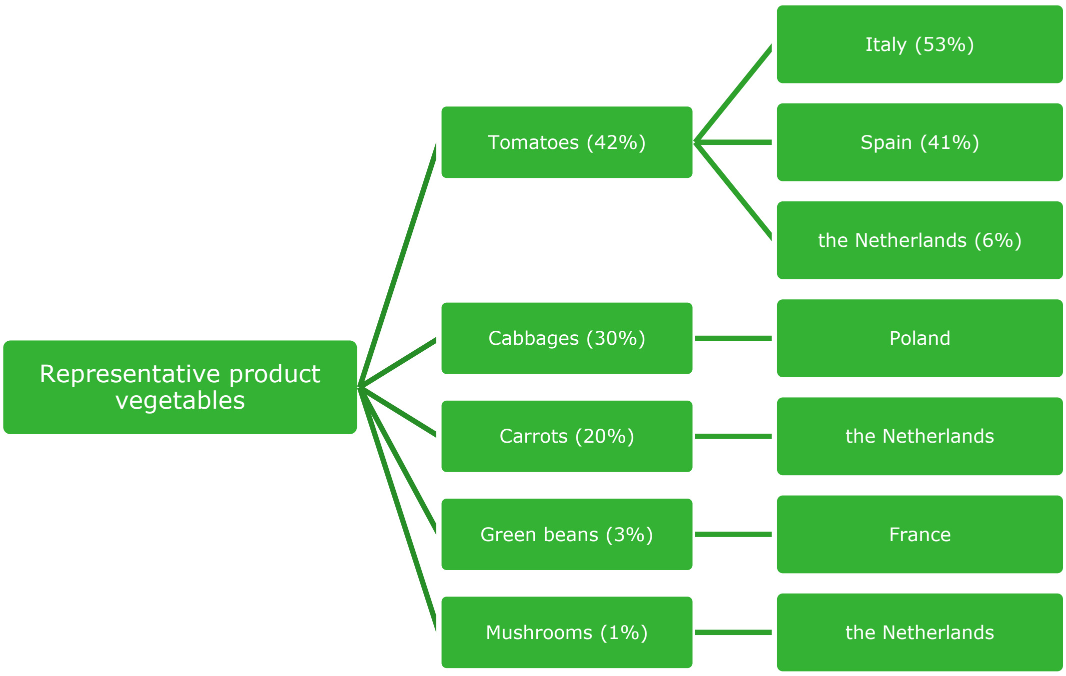

Figure 3 *Composition of the representative product vegetables, including market shares that are used to calculate the environmental impact (percentages may not add up to 100% due to rounding). Market shares are based on the average consumption in kilograms, per capita-year at the European market.*

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 other input and output flows in the analysis quantitatively relate to it.

The functional unit of fruits (FU) is one kilogram of consumable fruit (i.e. excluding inedible parts), excluding preparation

The functional unit of vegetables (FU) is one kilogram of consumable vegetable (i.e. excluding inedible parts), excluding preparation

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

Table 6 provides a description of the functional unit, encompassing its four defining aspects: What? How much? How well? How long?

Table 6 *Key aspects of the functional unit*

Sub-category	Aspect detail	Fruits and vegetables
What?	Function provided	To provide nutrition to humans.
How much?	Magnitude of the function	1 kg of product consistent with system boundary defined (excluding packaging weight). 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 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.

The reference flow is the amount of product needed to fulfil the defined function and shall be measured in 1 kilogram of consumable product (for both fruits and vegetables), in conformance with the system boundaries. All quantitative input and output data collected in the study shall be calculated in relation to this reference flow[6].

The main function of 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. The expected level of quality is related to the amount of inputs needed in all life cycle stages to achieve the specifications of the producer or retailer. The duration of the product provided is related to the expected lifetime of the fruits and vegetables and affects waste fractions the use stage.

Food losses at post-harvest treatment, storage, handling, distribution, consumer packaging and retail shall be quantified. 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.

3.4 System boundary

The following life cycle stages and processes shall be included in the system boundary for all products under the FreshProducePEFCR (see

[6] The reference flow is the amount of product needed to fulfil the defined functional unit.

Figure 4 and Table 7). 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

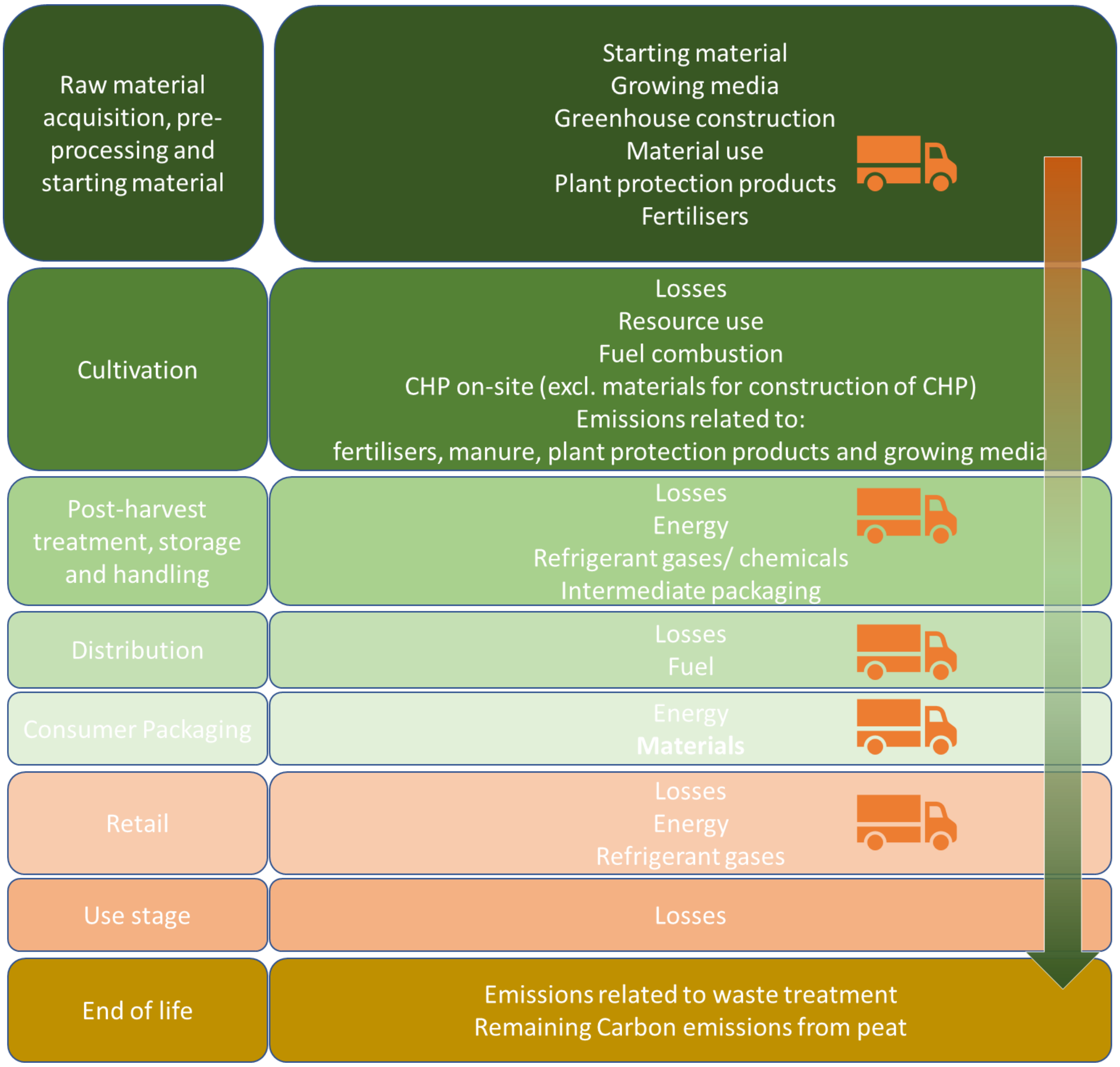

Table 7 *Life cycle stages*

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, fertilizers, plant protection products), incl. transport to farm. This life cycle also includes greenhouse constructions (incl. depreciation and maintenance) and material use (e.g. trellis systems).
Cultivation	Considers all activities related to the cultivation, including, but not limited to: plot preparation, planting/sowing, growing and harvesting the vegetables. Emissions from (the use of) plant protection products, fertilizers, 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 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.
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, refrigerant use, intermediate packaging production, and waste (incl. 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

	center (DC), waste of secondary and tertiary packaging and waste (incl. the additional quantity needed to fulfil the FU).
Retail	This life cycle stage refers to utility use (e.g. electricity) for climate control and lighting during storage for retail and the treatment of waste which occurs.
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 (e.g. electricity) for climate control and lighting during storage for retail and the treatment of waste which occurs.
Use stage	Considers the waste of the inedible parts of the vegetable (incl. the additional quantity needed to fulfil the FU).
End of life	Considers the End-of-Life of the primary packing material and remaining Carbon emissions from growing media.

According to this PEFCR, the following processes may be excluded based on the cut-off rule:
- The production of capital goods, other than greenhouses those shall be included;
- Primary, secondary and tertiary packaging used, other than during distribution and/or consumer packaging;
- Chemical agents used for cleaning purposes and not in direct contact with the product under study.

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.

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 listed in Table 8.

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

Table 8 *List of the impact categories to be used to calculate the environmental footprint profile*

EF Impact category	Impact Category Indicator	Unit	Characterization model	Robustness
Climate change (total) *Sub-category*[7]*:* • 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 (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 (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	II
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N eq	EUTREND model (Struijs et al, 2009) as applied in ReCiPe	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	• Soil quality index[8] • Biotic production • Erosion resistance • Mechanical filtration • Groundwater replenishment	• Dimensionless (pt) • kg biotic production • kg soil • m^3 water • m^3 groundwater	Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016)	III
Water use	User deprivation potential (deprivation weighted water consumption)	m^3 world eq	Available WAter REmaining (AWARE) as recommended by UNEP 2016	III

[7] The EF impact category “Climate Change, total” is constituted of three sub-categories: Climate Change, fossil; Climate Change, biogenic; Climate Change, land use and land use change. The sub-indicators are may be reported separately.
[8] This index is the result of the aggregation, performed by JRC, of the 4 indicators provided by LANCA model as indicators for LU.

Resource use[9], minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq	CML 2002 (Guinée et al. 2002 and Van Oers et al. 2002)	III
Resource use, fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ	Van Oers et al., 2002 as in CML methods, v.4.8.	III

The EF reference package v3.1 (https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml) shall be used.

The full list of characterisation factors is available at this link http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml.

Normalisation and weighting are required steps of the Life Cycle Impact Assessment (LCIA). Those steps allow expressing LCA results aggregating the results up to 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.

The different impact categories are not equally robust. The European Commission classifies the EF impact categories into three groups, from more robust (I) to less robust (III). The robustness of the impact categories is indicated in column 5 of Table 8. The differences in robustness have been taken into account in the weighting factors provided by the European Commission and shall also be taken into account during interpreting the results of a study according to this FreshProducePEFCR.

3.6 Additional technical information

A large variety of fruits and vegetables are available on the market, which raises 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 packaging material. In case the type of packaging affects the shelf-life of the product under study, the user of the FreshProducePEFCR may indicate may indicate the potential effects of 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 type of biological pest control.

3.7 Additional environmental information

Additional environmental information shall be provided and properly documented by the user of the FreshProducePEFCR on the topic of biodiversity and the carbon and nutrient content of growing media.

Biodiversity

Biodiversity is considered as relevant for the FreshProducePEFCR. 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),

[9] The results of this impact category shall be interpreted with caution, because the results of ADP after normalization may be overestimated. The European Commission intends to develop a new method moving from deletion to dissipation model to better quantify the potential for conservation of resources.

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 discussion have led to an improved method.

The Technical Secretariat is discussing whether an intermediate solution could be applied. In the meantime the user of this FreshProducePEFCR shall only indicate whether biodiversity is relevant for the product under study or not.

Carbon and nutrient content in growing media and additives.
The user of the FreshProducePEFCR shall report on the carbon and nutrient content of growing media and additives. This information includes:
- The bulk density of the final growing media (in kg/m^3);
- The moisture content of the final growing media (in kg/m^3);
- The carbon content of the peat-based constituents in the growing media (in $kg\ C/m^3$);
- The nutrient (NPK) and limestone content of each additive (in kg/m^3).

3.8 Limitations

There are various limitations for related to agricultural modelling that need further improvement:
- Modelling of emissions of crop protection products, e.g., missing characterisation factors and LCI modelling of emissions;
- Country-specific characterisation factors for nitrogen and phosphorus emissions in eutrophication are only available for EU countries however cultivation can happen worldwide;
- Modelling of nitrogen and phosphorus emissions due to the application of fertilizers;
- More granularity in the regionalisation of water flows for a proper assessment of water scarcity;
- Quality biodiversity impacts that go beyond impacts not covered in the current list of impact categories;
- The production and application of biological pest control cannot be captured because of missing background information.

This version of the FreshProducePEFCR was drafted using the learnings of the representative product studies of fruits (Weststrate et al., 2024a) and vegetables (Weststrate et al., 2024b). The representative product studies are based on a select and representative variety of crops, cropping systems and regions. The FreshProducePEFCR will be tested for applicability during the supporting studies.

Biological pest control cannot be captured in the FreshProducePEFCR, because secondary data on biological pest control are not available.

The impact of crop protection active ingredients depends on the farm system, climate conditions, the distance to surface area, the spraying technology etc. In this version of the FreshProducePEFCR, no specific emission model is recommended that differentiates these parameters. Crop protection is also topic of the discussions of the Agricultural Working Group and the FreshProducePEFCR is intended to be updated on future learnings.

The EF 3.1 impact assessment method has country-specific characterisation factors (CFs) for ammonia and NO_x emissions to air and water to 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.

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. Furthermore, differences in environmental impact occur when allocating impacts to the product between belly freight and a dedicated freight plane. Currently allocation based on tkm is applied, whilst economic allocation might also be considered. 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 however.

The background database constitutes of LCI-datasets from several other databases that are not fully interoperable with the certain aspects of the PEF-method (e.g., Circular Footprint Formula, transport scenario's and data quality rating (DQR).

Although the in 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 actual recycling process.

Transport distances to market (e.g., point of sale) in background processes are not modelled PEF-compliant in terms of transport distance and/or modality.

3.8.1 Comparisons and comparative assertions

The results of any environmental footprint study based on the FreshProducePEFCR may be used for supply chain management, product design, optimisation, and for comparative assertions among fruits or vegetables. The FreshProducePEFCR is not designed to support comparative claims between fruits and vegetables or between these products and products that are not part of the scope if the FreshProducePEFCR.

3.8.2 Data gaps and proxies

Lifetime allocation shall be applied to estimate the environmental impact of the starting material for fruits and vegetables, in case no appropriate background dataset is available.

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 which have been identified for fruits and vegetables in the representative product studies (Weststrate et al., 2024a; Weststrate et al., 2024b).

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 in scope of the FreshProducePEFCR are the following:
- Water use (33.2%);
- Climate change (14.6%);
- Ecotoxicity, freshwater (12.8%);
- Resource use, fossils (7.8%);
- Resource use, minerals and metals (5.5%);
- Particulate matter (5.1%);
- Acidification (4.2%).

The most relevant impact categories for the sub-category vegetables in scope of the FreshProducePEFCR are the following:
- Climate Change (21.8%);
- Resource use, fossils (11.8%);
- Resource use, mineral and metals (10.9%);
- Acidification (9.2%);
- Particulate matter (9.1%);
- Water use (7.1%);
- Eutrophication, marine (6.2%);
- Eutrophication, freshwater (6.0%).

At least three impact categories shall be identified as the most relevant ones. More impact categories may be added to the list of the most relevant ones but none shall be deleted.

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.

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.

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.

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 respectively Table 9 and Table 10.

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 product category in scope of the FreshProducePEFCR are the listed in Table 9 and Table 10.

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

Table 9 *List of the most relevant impact categories, life cycle stages, processes and direct elementary flows for fruits*

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
Water use	33.2	Stage 2. Cultivation	77.8	Stage 2a. Cultivation oranges {ES}	41.9	Water, river, ES	59.2	Raw
						Water, well, ES	31.6	Raw
				Stage 2. Cultivation watermelons {ES}	15.4	Water, unspecified natural origin, ES	100.0	Raw
				Stage 2. Cultivation strawberries {ES}	12.0	Water, unspecified natural origin, ES	100.0	Raw
		Stage 7. Use stage	13.1	Stage 2. Cultivation watermelons {ES}	5.5	Water, unspecified natural origin, ES	100.0	Raw
				Stage 2a. Cultivation oranges {ES}	5.4	Water, river, ES	59.2	Raw
						Water, well, ES	31.6	Raw
Climate change	14.6	Stage 4. Distribution	23.9	Transport, truck >20t, EURO5, 100%LF, default/GLO	16.8			
				Transport, sea ship, 120000 DWT, 100%LF, long, default/GLO	1.2			
				Biowaste {RoW}| treatment of biowaste, open dump	0.5			
				Transport, truck <10t, EURO5, 20%LF, default/GLO	0.4			
				Energy, from diesel burned in machinery/RER	0.4			
		Stage 7. Use stage	18.0	Biowaste {RoW}| treatment of biowaste, open dump	4.4			
				Transport, truck >20t, EURO5, 100%LF, default/GLO	3.2			
				Energy, from diesel burned in machinery/RER	1.3			
				Electricity, low voltage {PL}| market for electricity, low voltage	0.9			
				Biowaste {RoW}| treatment of biowaste by anaerobic digestion	0.8			
				Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas	0.8			
				Corrugated board box {RoW}| corrugated board box production	0.7			
				Corrugated board box {RER}| corrugated board box production	0.6			
				Electricity, high voltage {RER}| market group for electricity, high voltage	0.5			
				Stage 2. Cultivation bananas {EC}	0.5	Dinitrogen monoxide	95.8	Air
				Fungicide, at plant/RER	0.5			
				Transport, sea ship, 120000 DWT, 100%LF, long, default/GLO	0.4			
				Electricity, low voltage {IT}| market for electricity, low voltage	0.4			

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
				Waste paperboard {RoW}| treatment of waste paperboard, sanitary landfill	0.3			
		Stage 5. Consumer packaging	16.1	Electricity, low voltage {PL}| market for electricity, low voltage	3.9			
				Corrugated board box {RER}| corrugated board box production	2.9			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	2.2			
				Corrugated board box {RoW}| corrugated board box production	1.8			
				Electricity, low voltage {IT}| market for electricity, low voltage	1.2			
				Extrusion of plastic sheets and thermoforming, inline {RoW}| processing	0.9			
				Electricity, low voltage {ES}| market for electricity, low voltage	0.4			
				Packaging film, low density polyethylene {RER}| packaging film production, low density polyethylene	0.3			
				Waste paperboard {RoW}| treatment of waste paperboard, sanitary landfill	0.3			
		Stage 2. Cultivation	15.0	Energy, from diesel burned in machinery/RER	6.3			
				Stage 2. Cultivation bananas {EC}	1.7	Dinitrogen monoxide	95.8	Air
				Stage 2. Cultivation watermelons {ES}	0.9	Dinitrogen monoxide	67.1	Air
						Carbon dioxide, land transformation	32.9	Air
				Electricity, low voltage {ES}| market for electricity, low voltage	0.8			
				Biowaste {RoW}| treatment of biowaste, open dump	0.7			
				Stage 2a. Cultivation apples {PL}	0.6	Dinitrogen monoxide	96.8	Air
				Stage 2a. Cultivation oranges {ES}	0.5	Dinitrogen monoxide	100.0	Air
				Electricity, low voltage {IT}| market for electricity, low voltage	0.4			
		Stage 3. Post-harvest treatment, storage and handling	14.2	Fungicide, at plant/RER	2.7			
				Electricity, low voltage {PL}| market for electricity, low voltage	2.0			
				Corrugated board box {RER}| corrugated board box production	1.4			
				Transport, truck 10-20t, EURO5, 80%LF, empty return/GLO	1.3			
				Transport, tractor and trailer, agricultural {RoW}| transport, tractor and trailer, agricultural	1.1			
				Stage 3a. Post-harvest handling and storage oranges {ES}	0.8	Ethane, 1,1,1-trifluoro-, HFC-143a	63.9	Air

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
						Ethane, pentafluoro-, HFC-125	34.8	Air
				Energy, from diesel burned in machinery/RER	0.7			
				Electricity, low voltage {IT}| market for electricity, low voltage	0.6			
		Other: Stage 6. Retail		Waste paperboard {RoW}| treatment of waste paperboard, sanitary landfill	1.3			
				Sulfate pulp, unbleached {RER}| sulfate pulp production, from softwood, unbleached	1.0			
				Electricity, low voltage {RER}| market group for electricity, low voltage	0.7			
				Biowaste {RoW}| treatment of biowaste, open dump	0.5			
				Transport, truck >20t, EURO5, 100%LF, default/GLO	0.4			
		Other: Stage 1. Raw materials		Inorganic nitrogen fertiliser, as N {GLO}| nutrient supply from calcium nitrate	0.9			
				Packaging film, low density polyethylene {GLO}| market for packaging film, low density polyethylene	0.6			
				Potassium nitrate {RER}| market for potassium nitrate	0.4			
				Steel, chromium steel 18/8, hot rolled {RER}| steel production, chromium steel 18/8, hot rolled	0.4			
				NPK compound (NPK 15-15-15), market mix, at regional storage/RER	0.4			
				Fruit tree seedling, for planting {GLO}| market for fruit tree seedling, for planting	0.4			
				Strawberry seedling, for planting {ES}| strawberry seedling production, in unheated greenhouse, for planting	0.4			
				Inorganic nitrogen fertiliser, as N {RoW}| nutrient supply from ammonium nitrate	0.4			
				Ammonium nitrate, as 100% $(NH_4)(NO_3)$ (NPK 35-0-0), market mix, at regional storage/RER	0.4			
		Other: Stage 8. End-of-life		Waste polypropylene {RoW}| treatment of waste polypropylene, municipal incineration	0.9			
Ecotoxicity, freshwater	12.8	Stage 2. Cultivation	74.9	Stage 2. Cultivation strawberries {ES}	57.1	Chloropicrin	56.5	Soil
						Chloropicrin	39.8	Water
				Emission from insecticides, unspecified, family Organophosphorus-compound	7.9			
				Stage 2. Cultivation fresh grapes {IT}	3.8	Tau-fluvalinate	45.9	Water
						Methiocarb	34.5	Water
		Stage 7. Use stage	9.1	Stage 2. Cultivation strawberries {ES}	3.1	Chloropicrin	56.5	Soil

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
						Chloropicrin	39.8	Water
				Emission from insecticides, unspecified, family Organophosphorus-compound	2.6			
		Other: Stage 4. Distribution		Stage 2. Cultivation strawberries {ES}	4.5	Chloropicrin	56.5	Soil
						Chloropicrin	39.8	Water
		Other: Stage 1. Raw materials		Trellis system, wooden poles, soft wood, tar impregnated {GLO}| market for trellis system, wooden poles, soft wood, tar impregnated	1.5			
Resource use, fossils	7.8	Stage 4. Distribution	27.6	Transport, truck >20t, EURO5, 100%LF, default/GLO	19.4			
				Transport, sea ship, 120000 DWT, 100%LF, long, default/GLO	1.3			
				Transport, truck <10t, EURO5, 20%LF, default/GLO	0.4			
				Energy, from diesel burned in machinery/RER	0.4			
		Stage 5. Consumer packaging	20.4	Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	4.4			
				Electricity, low voltage {PL}| market for electricity, low voltage	3.7			
				Corrugated board box {RER}| corrugated board box production	3.0			
				Corrugated board box {RoW}| corrugated board box production	1.8			
				Electricity, low voltage {IT}| market for electricity, low voltage	1.6			
				Electricity, low voltage {ES}| market for electricity, low voltage	0.9			
				Extrusion of plastic sheets and thermoforming, inline {RoW}| processing	0.9			
				Packaging film, low density polyethylene {RER}| packaging film production, low density polyethylene	0.8			
		Stage 3. Post-harvest treatment, storage and handling	15.7	Fungicide, at plant/RER	4.2			
				Electricity, low voltage {PL}| market for electricity, low voltage	1.8			
				Transport, truck 10-20t, EURO5, 80%LF, empty return/GLO	1.5			
				Corrugated board box {RER}| corrugated board box production	1.5			
				Transport, tractor and trailer, agricultural {RoW}| transport, tractor and trailer, agricultural	1.1			
				Electricity, low voltage {IT}| market for electricity, low voltage	0.8			
				Energy, from diesel burned in machinery/RER	0.8			
				Electricity, low voltage {ES}| market for electricity, low voltage	0.6			
		Stage 7. Use stage	12.4	Transport, truck >20t, EURO5, 100%LF, default/GLO	3.7			

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
				Energy, from diesel burned in machinery/RER	1.5			
				Electricity, high voltage {RER}| market group for electricity, high voltage	1.1			
				Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas	0.9			
				Electricity, low voltage {PL}| market for electricity, low voltage	0.9			
				Electricity, low voltage {ES}| market for electricity, low voltage	0.7			
				Fungicide, at plant/RER	0.7			
				Corrugated board box {RoW}| corrugated board box production	0.7			
				Corrugated board box {RER}| corrugated board box production	0.6			
				Electricity, low voltage {IT}| market for electricity, low voltage	0.5			
		Stage 1. Raw materials	11.6	Packaging film, low density polyethylene {GLO}| market for packaging film, low density polyethylene	1.5			
				Melon, seedling for open field crop, conventional, at production site {FR}	0.8			
				Inorganic nitrogen fertiliser, as N {GLO}| nutrient supply from calcium nitrate	0.6			
				Potassium nitrate {RER}| market for potassium nitrate	0.5			
				NPK compound (NPK 15-15-15), market mix, at regional storage/RER	0.5			
				Fungicide, at plant/RER	0.4			
				Steel, chromium steel 18/8, hot rolled {RER}| steel production, chromium steel 18/8, hot rolled	0.4			
				Strawberry seedling, for planting {ES}| strawberry seedling production, in unheated greenhouse, for planting	0.4			
				Ammonium nitrate, as 100% $(NH_4)(NO_3)$ (NPK 35-0-0), market mix, at regional storage/RER	0.4			
		Other: Stage 2. Cultivation		Energy, from diesel burned in machinery/RER	7.2			
				Electricity, low voltage {ES}| market for electricity, low voltage	1.8			
				Electricity, low voltage {IT}| market for electricity, low voltage	0.5			
		Other: Stage 6. Retail		Electricity, low voltage {RER}| market group for electricity, low voltage	1.3			
				Sulfate pulp, unbleached {RER}| sulfate pulp production, from softwood, unbleached	1.2			
				Electricity, high voltage {RER}| market group for electricity, high voltage	0.4			
				Transport, truck >20t, EURO5, 100%LF, default/GLO	0.4			

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
Resource use, minerals and metals	5.5	Stage 5. Consumer packaging	43.3	Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	34.7			
				Electricity, low voltage {PL}| market for electricity, low voltage	1.9			
				Electricity, low voltage {IT}| market for electricity, low voltage	1.7			
				Corrugated board box {RER}| corrugated board box production	1.2			
				Electricity, low voltage {ES}| market for electricity, low voltage	0.8			
				Corrugated board box {RoW}| corrugated board box production	0.7			
		Stage 1. Raw materials	20.4	Inorganic nitrogen fertiliser, as N {RoW}| nutrient supply from ammonium sulfate	2.9			
				NPK compound (NPK 15-15-15), market mix, at regional storage/RER	2.8			
				NPK compound (NPK 15-15-15), market mix, at regional storage {RER} Economic	1.7			
				Inorganic nitrogen fertiliser, as N {GLO}| nutrient supply from calcium nitrate	1.6			
				Steel, chromium steel 18/8, hot rolled {RER}| steel production, chromium steel 18/8, hot rolled	1.3			
				Di ammonium phosphate, as 100% $(NH_3)_2HPO_4$ (NPK 22-57-0), market mix, at regional storage/RLA	1.2			
				Phosphoric acid, merchant grade (75% H_3PO_4) (NPK 0-54-0), at plant/RER	1.0			
				Fruit tree seedling, for planting {GLO}| market for fruit tree seedling, for planting	0.8			
				Potassium nitrate {RER}| market for potassium nitrate	0.7			
				Phosphate (P2O5) synthetic fertilizer application mix, at farm {GLO} Economic	0.6			
		Stage 7. Use stage	10.1	Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	1.8			
				Energy, from diesel burned in machinery/RER	1.5			
				Inorganic nitrogen fertiliser, as N {RoW}| nutrient supply from ammonium sulfate	0.9			
				Electricity, low voltage {ES}| market for electricity, low voltage	0.6			
				NPK compound (NPK 15-15-15), market mix, at regional storage/RER	0.5			
		Stage 2. Cultivation	9.9	Energy, from diesel burned in machinery/RER	7.1			
				Electricity, low voltage {ES}| market for electricity, low voltage	1.5			
				Electricity, low voltage {IT}| market for electricity, low voltage	0.6			
				Fungicide, at plant/RER	1.6			

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
		Other: Stage 3. Post-harvest handling and storage		Transport, tractor and trailer, agricultural {RoW}| transport, tractor and trailer, agricultural	1.0			
				Electricity, low voltage {PL}| market for electricity, low voltage	1.0			
				Sulfuric acid {RoW}| market for sulfuric acid	0.9			
				Electricity, low voltage {IT}| market for electricity, low voltage	0.9			
				Energy, from diesel burned in machinery/RER	0.7			
				Corrugated board box {RER}| corrugated board box production	0.6			
		Other: Stage 4. Distribution		Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	1.5			
		Other: Stage 6. Retail		Electricity, low voltage {RER}| market group for electricity, low voltage	1.0			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	0.8			
				Sulfate pulp, unbleached {RER}| sulfate pulp production, from softwood, unbleached	0.6			
Particulate matter	5.1	Stage 2. Cultivation	39.5	Energy, from diesel burned in machinery/RER	10.6			
				Stage 2a. Cultivation apples {PL}	7.9	Ammonia, PL	95.4	Air
				Stage 2. Cultivation bananas {EC}	4.0	Ammonia, EC	100.0	Air
				Stage 2a. Cultivation oranges {ES}	3.8	Ammonia, SA	100.0	Air
				Stage 2. Cultivation watermelons {ES}	3.8	Ammonia, ES	100.0	Air
				Stage 2. Cultivation strawberries {ES}	1.9	Ammonia, ES	100.0	Air
				Stage 2b. Cultivation apples {IT}	1.7	Ammonia, IT	100.0	Air
		Stage 7. Use stage	16.0	Energy, from diesel burned in machinery/RER	2.2			
				Stage 2a. Cultivation apples {PL}	1.5	Ammonia, PL	95.4	Air
				Stage 2. Cultivation watermelons {ES}	1.4	Ammonia, ES	100.0	Air
				Stage 2. Cultivation bananas {EC}	1.3	Ammonia, EC	100.0	Air
				Transport, truck >20t, EURO5, 100%LF, default/GLO	1.2			
				Corrugated board box {RoW}| corrugated board box production	1.2			
				Transport, sea ship, 120000 DWT, 100%LF, long, default/GLO	1.1			
				Biowaste {RoW}| treatment of biowaste, industrial composting	0.6			
				Corrugated board box {RER}| corrugated board box production	0.6			

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
				Sulfate pulp, unbleached {RER}| sulfate pulp production, from softwood, unbleached	0.5			
				Stage 2a. Cultivation oranges {ES}	0.5	Ammonia, ES	100.0	Air
		Stage 4. Distribution	14.7	Transport, truck >20t, EURO5, 100%LF, default/GLO	6.5			
				Transport, sea ship, 120000 DWT, 100%LF, long, default/GLO	3.5			
				Stage 2a. Cultivation apples {PL}	0.6	Ammonia, PL	95.4	Air
				Energy, from diesel burned in machinery/RER	0.6			
		Stage 5. Consumer packaging	10.9	Corrugated board box {RoW}| corrugated board box production	3.1			
				Corrugated board box {RER}| corrugated board box production	2.8			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	1.4			
				Extrusion of plastic sheets and thermoforming, inline {RoW}| processing	0.9			
				Electricity, low voltage {PL}| market for electricity, low voltage	0.8			
				Sulfate pulp, unbleached {RER}| sulfate pulp production, from softwood, unbleached	0.5			
				Electricity, low voltage {IT}| market for electricity, low voltage	0.4			
		Other: Stage 6. Retail		Sulfate pulp, unbleached {RER}| sulfate pulp production, from softwood, unbleached	2.0			
		Other: Stage 3. Post-harvest treatment, storage and handling		Corrugated board box {RER}| corrugated board box production	1.4			
				Stage 2a. Cultivation apples {PL}	1.2	Ammonia, PL	95.4	Air
				Energy, from diesel burned in machinery/RER	1.1			
				Fungicide, at plant/RER	1.0			
				Transport, tractor and trailer, agricultural {RoW}| transport, tractor and trailer, agricultural	0.9			
				Transport, truck 10-20t, EURO5, 80%LF, empty return/GLO	0.7			
				Electricity, low voltage {PL}| market for electricity, low voltage	0.4			
				Pesticide, unspecified {GLO}| market for pesticide, unspecified	0.4			
		Other: Stage 1. Raw materials		Ammonium nitrate, as 100% $(NH_4)(NO_3)$ (NPK 35-0-0), market mix, at regional storage/RER	0.7			
				Fruit tree seedling, for planting {GLO}| market for fruit tree seedling, for planting	0.6			

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
				Steel, chromium steel 18/8, hot rolled {RER}| steel production, chromium steel 18/8, hot rolled	0.6			
				NPK compound (NPK 15-15-15), market mix, at regional storage/RER	0.5			
				Inorganic nitrogen fertiliser, as N {GLO}| nutrient supply from calcium nitrate	0.5			
				Packaging film, low density polyethylene {GLO}| market for packaging film, low density polyethylene	0.5			
				Potassium nitrate {RER}| market for potassium nitrate	0.4			
				Nitrogen (N) synthetic fertilizer application mix, at farm {RER}	0.4			
Acidification	4.2	Stage 2. Cultivation	25.5	Stage 2a. Cultivation apples {PL}	9.0	Ammonia, PL	88.4	Air
				Energy, from diesel burned in machinery/RER	6.8			
				Stage 2. Cultivation bananas {EC}	5.3	Ammonia, EC	100.0	Air
				Electricity, low voltage {ES}| market for electricity, low voltage	0.7			
				Stage 2b. Cultivation oranges {SA}	0.5	Ammonia, SA	100.0	Air
		Stage 4. Distribution	23.4	Transport, truck >20t, EURO5, 100%LF, default/GLO	14.0			
				Transport, sea ship, 120000 DWT, 100%LF, long, default/GLO	4.6			
				Stage 2a. Cultivation apples {PL}	0.7	Ammonia, PL	88.4	Air
				Energy, from diesel burned in machinery/RER	0.4			
		Stage 7. Use stage	16.1	Transport, truck >20t, EURO5, 100%LF, default/GLO	2.7			
				Stage 2a. Cultivation apples {PL}	1.7	Ammonia, PL	88.4	Air
				Stage 2. Cultivation bananas {EC}	1.7	Ammonia, EC	100.0	Air
				Transport, sea ship, 120000 DWT, 100%LF, long, default/GLO	1.4			
				Energy, from diesel burned in machinery/RER	1.4			
				Biowaste {RoW}| treatment of biowaste, industrial composting	1.1			
				Electricity, low voltage {PL}| market for electricity, low voltage	1.0			
				Corrugated board box {RoW}| corrugated board box production	0.5			
				Electricity, high voltage {RER}| market group for electricity, high voltage	0.4			
				Corrugated board box {RER}| corrugated board box production	0.4			
		Stage 3. Post-harvest handling and storage	12.9	Electricity, low voltage {PL}| market for electricity, low voltage	2.1			
				Fungicide, at plant/RER	1.6			
				Transport, truck 10-20t, EURO5, 80%LF, empty return/GLO	1.4			

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
				Stage 2a. Cultivation apples {PL}	1.4	Ammonia, PL	88.4	Air
				Transport, tractor and trailer, agricultural {RoW}| transport, tractor and trailer, agricultural	1.2			
				Corrugated board box {RER}| corrugated board box production	0.9			
				Energy, from diesel burned in machinery/RER	0.7			
				Pesticide, unspecified {GLO}| market for pesticide, unspecified	0.5			
				Electricity, low voltage {IT}| market for electricity, low voltage	0.4			
		Stage 5. Consumer packaging	12.0	Electricity, low voltage {PL}| market for electricity, low voltage	4.2			
				Corrugated board box {RER}| corrugated board box production	1.9			
				Corrugated board box {RoW}| corrugated board box production	1.3			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	1.3			
				Electricity, low voltage {IT}| market for electricity, low voltage	0.7			
				Extrusion of plastic sheets and thermoforming, inline {RoW}| processing	0.6			
		Other: Stage 6. Retail		Sulfate pulp, unbleached {RER}| sulfate pulp production, from softwood, unbleached	1.2			
				Electricity, low voltage {RER}| market group for electricity, low voltage	0.6			
		Other: Stage 1. Raw materials		Ammonium nitrate, as 100% $(NH_4)(NO_3)$ (NPK 35-0-0), market mix, at regional storage/RER	0.9			
				NPK compound (NPK 15-15-15), market mix, at regional storage/RER	0.6			
				Inorganic nitrogen fertiliser, as N {GLO}| nutrient supply from calcium nitrate	0.6			
				Nitrogen (N) synthetic fertilizer application mix, at farm {RER}	0.6			
				Ammonium nitrate, as 100% $(NH_4)(NO_3)$ (NPK 35-0-0), market mix, at regional storage {RER}	0.5			
				Packaging film, low density polyethylene {GLO}| market for packaging film, low density polyethylene	0.4			
				NPK compound (NPK 15-15-15), market mix, at regional storage {RER}	0.4			
				Potassium nitrate {RER}| market for potassium nitrate	0.4			

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

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
Climate change	21.8	Stage 4. Distribution	26.5	Transport, truck >20t, EURO5, 100%LF, default/GLO	17.7			
				Biowaste {RoW}| treatment of biowaste, open dump	2.3			
				Transport, truck <10t, EURO5, 20%LF, default/GLO	0.5			
				Energy, from diesel burned in machinery/RER	0.5			
		Stage 2. Cultivation	22.0	Energy, from diesel burned in machinery/RER	5.3			
				Stage 2. Cultivation green beans {FR}	4.4	Carbon dioxide, land transformation	85.1	Air
				Electricity, low voltage {NL}| market for	2.9			
				Stage 2. Cultivation white mushrooms {NL}	1.8	Dinitrogen monoxide	88.6	Air
				Stage 2. Cultivation cabbages {PL}	1.5	Dinitrogen monoxide	98.4	Air
				Heat from CHP, natural gas {NL}	1.2			
				Stage 2. Cultivation carrots {NL}	1.2	Dinitrogen monoxide	68.9	Air
						Carbon dioxide, land transformation	31.1	Air
				Stage 2b. Cultivation tomatoes {ES}	0.9	Dinitrogen monoxide	100.0	Air
				Stage 2a. Cultivation tomatoes {IT}	0.8	Dinitrogen monoxide	100.0	Air
		Stage 5. Consumer packaging	13.3	Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	4.9			
				Extrusion of plastic sheets and thermoforming, inline {RoW}| processing	2.2			
				Electricity, low voltage {RER}| market group for electricity, low voltage	2.2			
				Packaging film, low density polyethylene {RER}| packaging film production, low density polyethylene	1.2			
				Transport, truck >20t, EURO5, 80%LF, empty return/GLO	0.6			
				Polyethylene, high density, granulate {RER}| polyethylene production, high density, granulate	0.5			
		Stage 1. Raw materials	12.0	Greenhouse tunnel, type Rovero, at processing/GLO	2.7			
				Potassium nitrate {RER}| potassium nitrate production	1.0			
				Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/RER	1.0			
				Tomato seedling, for planting {IT}| tomato seedling production, in unheated greenhouse, for planting	0.8			
				Electricity, low voltage {NL}| market for	0.8			
				Compost, for mushroom cultivation, at processing {NL}	0.7	Dinitrogen monoxide	51.5	Air
						Methane, biogenic	48.5	Air
				Ammonium nitrate, as 100% $(NH_4)(NO_3)$ (NPK 35-0-0), market mix, at regional storage/RER	0.5			
		Stage 7. Use stage	9.8	Biowaste {RoW}| treatment of biowaste, open dump	3.0			
				Transport, truck >20t, EURO5, 100%LF, default/GLO	1.7			
				Energy, from diesel burned in machinery/RER	0.5			
				Biowaste {RoW}| treatment of biowaste by anaerobic digestion	0.5			
				Electricity, low voltage {PL}| market for electricity, low voltage	0.5			
				Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas	0.5			

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
		Other: Stage 3. Post-harvest treatment, storage and handling		Electricity, low voltage {PL}| market for electricity, low voltage	3.2			
				Transport, tractor and trailer, agricultural {RoW}| market for transport, tractor and trailer, agricultural	2.0			
				Stage 2. Cultivation green beans {FR}	0.9	Carbon dioxide, land transformation	85.1	Air
				Transport, truck >20t, EURO5, 100%LF, default/GLO	0.8			
				Electricity, low voltage {NL}| market for	0.6			
		Other: Stage 8. End-of-life		Waste polyethylene {RoW}| treatment of waste polyethylene, municipal incineration	1.9			
		Other: Stage 6. Retail		Electricity, low voltage {RER}| market group for electricity, low voltage	1.8			
				Biowaste {RoW}| treatment of biowaste, open dump	0.8			
				Electricity, low voltage {NL}| market for	0.5			
				Waste polyethylene {RoW}| treatment of waste polyethylene, municipal incineration	0.5			
				Transport, truck >20t, EURO5, 100%LF, default/GLO	0.5			
Resource use, fossils	11.8	Stage 4. Distribution	26.7	Transport, truck >20t, EURO5, 100%LF, default/GLO	20.1			
				Transport, truck <10t, EURO5, 20%LF, default/GLO	0.6			
		Stage 5. Consumer packaging	24.3	Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	9.7			
				Electricity, low voltage {RER}| market group for electricity, low voltage	4.0			
				Packaging film, low density polyethylene {RER}| packaging film production, low density polyethylene	2.8			
				Extrusion of plastic sheets and thermoforming, inline {RoW}| processing	2.2			
				Polyethylene, high density, granulate {RER}| polyethylene production, high density, granulate	1.6			
				Transport, truck >20t, EURO5, 80%LF, empty return/GLO	0.7			
		Stage 2. Cultivation	16.0	Energy, from diesel burned in machinery/RER	6.0			
				Heat from CHP, natural gas {NL}	4.9			
				Electricity, low voltage {NL}| market for	3.1			
		Stage 1. Raw materials	12.9	Greenhouse tunnel, type Rovero, at processing/GLO	2.6			
				Black peat DE (updated)	1.4	Energy, from peat	100.0	Raw
				Potassium nitrate {RER}| potassium nitrate production	1.1			
				Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/RER	1.0			
				Electricity, low voltage {NL}| market for	0.9			
				Tomato seedling, for planting {IT}| tomato seedling production, in unheated greenhouse, for planting	0.8			
		Other: Stage 6. Retail		Electricity, low voltage {RER}| market group for electricity, low voltage	3.4			
				Heat from CHP, natural gas {NL}	0.9			
				Electricity, low voltage {NL}| market for	0.6			
		Other: Stage 3. Post-harvest treatment, storage and handling		Electricity, low voltage {PL}| market for electricity, low voltage	2.9			
				Transport, tractor and trailer, agricultural {RoW}| market for transport, tractor and trailer, agricultural	2.0			
				Transport, truck >20t, EURO5, 100%LF, default/GLO - Stage 3. Post-harvest handling and storage	0.9			

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
				Electricity, low voltage {NL}| market for	0.7			
		Other: Stage 7. Use stage		Transport, truck >20t, EURO5, 100%LF, default/GLO	2.0			
				Electricity, high voltage {RER}| market group for electricity, high voltage	0.7			
				Electricity, low voltage {RER}| market group for electricity, low voltage	0.7			
				Energy, from diesel burned in machinery/RER	0.6			
				Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas	0.6			
		Other: Stage 8. End-of-life		Electricity, high voltage {RER}| market group for electricity, high voltage	0.6			
Resource use, minerals and metals	10.9	Stage 5. Consumer packaging	61.5	Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	57.0			
				Electricity, low voltage {RER}| market group for electricity, low voltage	2.3			
		Stage 1. Raw materials	13.5	Phosphoric acid, merchant grade (75% H_3PO_4) (NPK 0-54-0), at plant/RER	4.2			
				NPK compound (NPK 15-15-15), market mix, at regional storage/RER	1.5			
				Triple superphosphate, as 80% $Ca(H_2PO_4)2$ (NPK 0-48-0), at plant/RER	1.5			
		Stage 2. Cultivation	6.3	Energy, from diesel burned in machinery/RER	4.4			
				Electricity, low voltage {NL}| market for	1.7			
		Other: Stage 4. Distribution		Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	3.2			
		Other: Stage 7. Use stage		Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	2.4			
		Other: Stage 6. Retail		Electricity, low voltage {RER}| market group for electricity, low voltage	2.0			
Acidification	9.2	Stage 2. Cultivation	51.3	Stage 2. Cultivation white mushrooms {NL}	28.4	Ammonia, NL	100.0	Air
				Stage 2. Cultivation carrots {NL}	8.8	Ammonia, NL	100.0	Air
				Energy, from diesel burned in machinery/RER	3.9			
				Stage 2. Cultivation cabbages {PL}	2.9	Ammonia, PL	100.0	Air
				Heat from CHP, natural gas {NL}	2.3			
				Stage 2c. Cultivation tomatoes {NL}	1.5	Ammonia, NL	100.0	Air
				Stage 2. Cultivation green beans {FR}	1.1	Ammonia, FR	100.0	Air
		Stage 4. Distribution	16.6	Transport, truck >20t, EURO5, 100%LF, default/GLO	10.2			
				Stage 2. Cultivation white mushrooms {NL}	2.3	Ammonia, NL	100.0	Air
				Stage 2. Cultivation carrots {NL}	0.7	Ammonia, NL	100.0	Air
		Stage 7. Use stage	8.6	Stage 2. Cultivation white mushrooms {NL}	3.2	Ammonia, NL	100.0	Air
				Stage 2. Cultivation carrots {NL}	1.0	Ammonia, NL	100.0	Air
				Transport, truck >20t, EURO5, 100%LF, default/GLO	1.0			
		Stage 1. Raw materials	7.3	Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/RER	1.6			
				Greenhouse tunnel, type Rovero, at processing/GLO	1.2			
				Ammonium nitrate, as 100% $(NH_4)(NO_3)$ (NPK 35-0-0), market mix, at regional storage/RER	0.8			
		Other: Stage 3. Post-harvest treatment, storage and handling		Electricity, low voltage {PL}| market for electricity, low voltage	2.3			
				Transport, tractor and trailer, agricultural {RoW}| market for transport, tractor and trailer, agricultural	1.4			
		Other: Stage 5. Consumer packaging		Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	2.0			
				Electricity, low voltage {RER}| market group for electricity, low voltage	1.2			

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
				Extrusion of plastic sheets and thermoforming, inline {RoW}| processing	1.1			
		Other: Stage 6. Retail		Electricity, low voltage {RER}| market group for electricity, low voltage	1.0			
				Stage 2. Cultivation white mushrooms {NL}	0.7	Ammonia, NL	100.0	Air
Particulate matter	9.1	Stage 2. Cultivation	54.4	Stage 2. Cultivation white mushrooms {NL}	18.7	Ammonia, NL	100.0	Air
				Energy, from diesel burned in machinery/RER	7.8			
				Stage 2. Cultivation carrots {NL}	5.8	Ammonia, NL	100.0	Air
				Stage 2b. Cultivation tomatoes {ES}	5.1	Ammonia, ES	100.0	Air
				Stage 2a. Cultivation tomatoes {IT}	4.9	Ammonia, IT	100.0	Air
				Stage 2. Cultivation green beans {FR}	3.6	Ammonia, FR	100.0	Air
				Stage 2. Cultivation cabbages {PL}	3.5	Ammonia, PL	100.0	Air
				Heat, district or industrial, other than natural gas {RER}| heat production, wood chips from post-consumer wood, at furnace 300kW	2.0			
				Stage 2c. Cultivation tomatoes {NL}	1.0	Ammonia, NL	100.0	Air
				Heat from CHP, natural gas {NL}	0.7			
		Stage 4. Distribution	12.6	Transport, truck >20t, EURO5, 100%LF, default/GLO	5.9			
				Stage 2. Cultivation white mushrooms {NL}	1.5	Ammonia, NL	100.0	Air
				Energy, from diesel burned in machinery/RER	0.7			
		Stage 1. Raw materials	9.7	Greenhouse tunnel, type Rovero, at processing/GLO	3.1			
				Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), market mix, at regional storage/RER	1.5			
				Potassium nitrate {RER}| potassium nitrate production	0.8			
				Ammonium nitrate, as 100% $(NH_4)(NO_3)$ (NPK 35-0-0), market mix, at regional storage/RER	0.7			
		Stage 7. Use stage	7.8	Stage 2. Cultivation white mushrooms {NL}	2.1	Ammonia, NL	100.0	Air
				Energy, from diesel burned in machinery/RER	0.8			
				Stage 2. Cultivation carrots {NL}	0.7	Ammonia, NL	100.0	Air
				Stage 2. Cultivation cabbages {PL}	0.7	Ammonia, PL	100.0	Air
				Transport, truck >20t, EURO5, 100%LF, default/GLO	0.6			
		Other: Stage 5. Consumer packaging		Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	2.7			
				Extrusion of plastic sheets and thermoforming, inline {RoW}| processing	1.9			
				Packaging film, low density polyethylene {RER}| packaging film production, low density polyethylene	0.6			
				Electricity, low voltage {RER}| market group for electricity, low voltage	0.6			
		Other: Stage 3. Post-harvest treatment, storage and handling		Transport, tractor and trailer, agricultural {RoW}| market for transport, tractor and trailer, agricultural	1.4			
				Stage 2. Cultivation green beans {FR}	0.8	Ammonia, FR	100.0	Air
Water use	7.1	Stage 2. Cultivation	76.5	Stage 2b. Cultivation tomatoes {ES}	43.3	Water, river, ES	100.0	Raw
				Stage 2a. Cultivation tomatoes {IT}	28.2	Water, unspecified natural origin, IT	100.0	Raw
				Stage 2. Cultivation green beans {FR}	3.1	Water, well, FR	100.0	Raw
		Stage 4. Distribution	6.7	Stage 2b. Cultivation tomatoes {ES}	3.5	Water, river, ES	100.0	Raw
		Other: Stage 7. Use stage		Stage 2b. Cultivation tomatoes {ES}	2.5	Water, river, ES	100.0	Raw
Eutrophication, marine	6.2	Stage 2. Cultivation	60.8	Stage 2. Cultivation white mushrooms {NL}	13.6	Nitrate, NL	91.1	Water
				Stage 2. Cultivation cabbages {PL}	12.9	Nitrate, PL	98.2	Water

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
				Stage 2b. Cultivation tomatoes {ES}	7.6	Nitrate	95.7	Water
				Stage 2. Cultivation carrots {NL}	7.0	Nitrate	94.6	Water
				Stage 2a. Cultivation tomatoes {IT}	6.5	Nitrate	95.1	Water
				Stage 2. Cultivation green beans {FR}	5.7	Nitrate, FR	95.9	Water
				Energy, from diesel burned in machinery/RER	3.2			
				Heat from CHP, natural gas {NL}	2.0			
				Stage 2c. Cultivation tomatoes {NL}	1.3	Nitrate	95.1	Water
		Stage 4. Distribution	15.6	Transport, truck >20t, EURO5, 100%LF, default/GLO	8.6			
				Stage 2. Cultivation cabbages {PL}	1.1	Nitrate, PL	98.2	Water
				Stage 2. Cultivation white mushrooms {NL}	1.1	Nitrate, NL	91.1	Water
				Biowaste {RoW}| treatment of biowaste, open dump	1.0			
		Stage 7. Use stage	9.3	Stage 2. Cultivation cabbages {PL}	2.4	Nitrate, PL	98.2	Water
				Stage 2. Cultivation white mushrooms {NL}	1.5	Nitrate, NL	91.1	Water
				Biowaste {RoW}| treatment of biowaste, open dump	1.3			
		Stage 3. Post-harvest treatment, storage and handling		Stage 2. Cultivation cabbages {PL}	1.6	Nitrate, PL	98.2	Water
				Stage 2. Cultivation green beans {FR}	1.2	Nitrate, FR	95.9	Water
				Transport, tractor and trailer, agricultural {RoW}| market for transport, tractor and trailer, agricultural	1.0			
Eutrophication, freshwater	6.0	Stage 2. Cultivation	46.8	Stage 2. Cultivation white mushrooms {NL}	19.7	Phosphorus	100.0	Soil
				Stage 2. Cultivation green beans {FR}	5.1	Phosphorus	100.0	Soil
				Stage 2b. Cultivation tomatoes {ES}	4.4	Phosphorus	100.0	Soil
				Stage 2a. Cultivation tomatoes {IT}	3.5	Phosphorus	100.0	Soil
				Electricity, low voltage {NL}| market for	3.4			
				Stage 2. Cultivation carrots {NL}	3.1	Phosphorus	100.0	Soil
				Stage 2. Cultivation cabbages {PL}	2.9	Phosphorus	100.0	Soil
				Energy, from diesel burned in machinery/RER	1.1			
		Stage 3. Post-harvest treatment, storage and handling	13.3	Electricity, low voltage {PL}| market for electricity, low voltage	8.8			
				Stage 2. Cultivation green beans {FR}	1.1	Phosphorus	100.0	Soil
				Transport, tractor and trailer, agricultural {RoW}| market for transport, tractor and trailer, agricultural	1.0			
				Electricity, low voltage {NL}| market for	0.7			
		Stage 5. Consumer packaging	11.6	Electricity, low voltage {RER}| market group for electricity, low voltage	4.7			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	2.3			
				Extrusion of plastic sheets and thermoforming, inline {RoW}| processing	2.3			
		Stage 7. Use stage	8.7	Stage 2. Cultivation white mushrooms {NL}	2.2	Phosphorus	100.0	Soil
				Electricity, low voltage {PL}| market for electricity, low voltage	1.4			
				Biowaste {RoW}| treatment of biowaste, open dump	1.0			
				Electricity, high voltage {RER}| market group for electricity, high voltage	0.8			
				Electricity, low voltage {RER}| market group for electricity, low voltage	0.8			
		Other: Stage 6. Retail		Electricity, low voltage {RER}| market group for electricity, low voltage	3.9			
		Other: Stage 1. Raw materials		Greenhouse tunnel, type Rovero, at processing/GLO	2.8			
				Electricity, low voltage {NL}| market for	0.9			
				Stage 2. Cultivation white mushrooms {NL}	1.6	Phosphorus	100.0	Soil

Most relevant impact category	[%]	Most relevant life stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
		Other: Stage 4. Distribution		Biowaste {RoW}| treatment of biowaste, open dump	0.8			

5 Life cycle inventory

This chapter specifies which data need to be collected to conduct an environmental footprint study according to the FreshProducePEFCR. It specifies processes for which company-specific data shall be collected as well as rules for additional company-specific data. Company-specific data enhance the quality of the environmental footprint study. Data quality requirements (DQR) and calculation of DQR are explained. The data needs matrix, to be used to evaluate which data is needed for processes outside the list of mandatory company-specific data, is explained. This chapter also elaborates on which secondary datasets to use.

Furthermore modelling rules are elaborated for allocation in case of multifunctional processes, electricity modelling, climate change modelling and modelling of end-of-life and recycling.

In case sampling is needed, it shall be conducted as specified in the FreshProducePEFCR. However, 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 the PEF method (EC, 2021). Description of the population and of the selected sample used for the environmental footprint study shall be clearly described in the environmental footprint report.

Additionally to the requirements defined in section 4.4.6 of the PEF method the following requirements apply:

- Practitioner shall clearly report on all possible distinctive technologies/farm practices, climate zones (regions) and classes of capacity of companies when defining a sub-population and the considerations made;
- Reviewer shall verify the considerations made for defining sub-population for technologies/ farm practices and classes of capacity;
- The selection of sites shall be done from highest to lowest contributing to the production of a sub-population for at least 50%.

5.1 List of mandatory company-specific data

The following section describes the processes for which mandatory company-specific data shall be collected to comply to this PEFCR. 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. This requirement has proven to be a challenge in comparable LCA methodologies, 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 from three consecutive years. If data cannot be obtained for three consecutive years for the other mandatory company specific data, they may be based on the average of the available data or extrapolated based on expert judgement from the available data. In the LCI it shall be clearly indicated what data is collected, and what data extrapolated.

A data collection template has been developed to aid the data collection process for mandatory company specific data: FreshProducePEFCR data collection requirements overview (forthcoming). It is an Excel file connected to this document. The background processes to use for mandatory company specific data are listed in the Excel file.

Raw materials acquisition, pre-processing and starting material
Practitioner shall gather company-specific activity data for certain raw material inputs to the cultivation of fruits and vegetables. Data shall be collected in relation to the functional unit for the activities and modelling parameters described below.

The 'origin' in the points below refers to the country that the material originates from.

Starting material or young plant input: Type, amount and origin (a country e.g. Spain) of starting materials (seed, seedlings, or other) and/or young plant input shall be registered. Input losses for the required functional unit shall be considered. The production of starting material and its duration shall be considered in case no crop specific background dataset on starting materials is available. This information is needed to estimate the environmental impact of starting material, in case no crop-specific background dataset is available.

Growing media use: Amount, type and origin of growing media use shall be collected. Growing media information shall include amount of single growing medium or mix used. If mix, proportion of individual constituents in 1 m^3 of growing media mix. Also the peat C-content of the growing media and the N-, P-, and K-content and limestone, dolomite, urea content and the density and moisture content shall be collected (necessary information can be provided by the growing media producers).

Material use: Amount, type and origin of materials shall be collected. Data shall be collected for use of materials for soil covering or for guiding plants (e.g. trellis systems).

Fertilisers and manure: N, P, K input per kilogram of fruit or vegetable shall be collected and distinguished between organic and synthetic input. Mass, type and origin for both synthetic and organic fertiliser used shall be registered.

Plant protection products: Amount of active ingredient and type of plant protection product shall be collected for the cultivation of 1kg of fruit or vegetable.

CO_2 enrichment: Use and source of CO_2 shall be modelled. Practitioner shall indicate if CO_2 is produced on site or off site. Activities related to flue gas cleaning and transport shall be based on company-specific data.

Cultivation emissions and resources
The use of resources (e.g. land, water) and direct emissions for the cultivation fruits and vegetables are mandatory company-specific data. Section 6.2 provides guidance on the cultivation emissions to be calculated.

Practitioner shall also register product losses (incl. moisture losses) and related co-products at farm for cultivation of fruits and vegetables.

Combined Heat and Power (CHP) Unit
Natural gas input, unit efficiency and related emissions from heat and electricity use at farm produced in a CHP unit shall be based on company-specific data. The Excel named 'FreshProducePEFCR data collection requirements overview' (forthcoming), shows direct elementary flows to be collected for the activity related to the CHP unit.

Modelling of emissions shall follow guidance provided in chapter 6.2.4.3 of the FreshProducePEFCR.

Post-harvest treatment, storage and handling
Practitioner shall gather company-specific activity data for certain inputs related to post-harvest treatment, storage and handling of fruits and vegetables. Data shall be collected in relation to the functional unit for the activities and modelling parameters described below.

Post-harvest treatment: 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 shall be omitted.

In case any packaging (excluding consumer packaging) is added to the product, it shall be accounted for according to the modelling rules in section 6.5.

Practitioner shall register product losses (incl. moisture losses) and related co-products at all stages.

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.

Distribution
Data on all transport legs between farm and DC, shall be based on mandatory company-specific data. Practitioner shall register distance and type of transport for the different transport modes for the delivery of the fruits or vegetables. Practitioner shall also indicate first destination e.g.: if it is handling facility, DC or retailer who receives the product after cultivation. Transported weight shall account for packaging material used for transport and losses during transport based on primary activity data.

Consumer packaging
Data on consumer packaging (e.g. LDPE bags and/or cardboard trays) shall be based on mandatory company-specific data. The practitioner shall register types and amounts per packaging material related to the functional unit for at least primary packaging.

Most of the mandatory company-specific data will come from growers and access to these data is required to perform an environmental footprint study. However, performing an environmental footprint study is not limited to growers. There are horticulture service providers that have access or manage data from growers that are expected to be able to perform an environmental footprint study. Also there are owners of certification schemes which already manage a lot of the data from growers and are expected to be able to perform an environmental footprint study.

See excel file named FreshProducePEFCR data collection requirements overview - Life cycle inventory' for the list of all company-specific data to be collected (forthcoming).

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 on the company running the environmental footprint study. On this account, 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.

There are no further processes expected to be run by the company in addition to those listed as mandatory company-specific data.

5.3 Data quality requirements

Not applicable in this version of the FreshProducePEFCR (see section 5.5).

5.3.1 Company-specific datasets

Not applicable in this version of the FreshProducePEFCR (see section 5.5).

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 (see Table 11). 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.

It should be noted that DQR -requirements mentioned in the DNM are likely to change, depending on ongoing conversations in the TS (see section 5.6).

Table 11 *Data Needs Matrix (DNM)[10]. *Disaggregated datasets shall be used.*

		Most relevant process	Other process
Situation 1: process run by the company using the FreshProducePEFCR	Option 1	Provide company-specific data (as requested in the FreshProducePEFCR) and create a company-specific dataset, in aggregated form (DQR≤1.5)[11] Calculate the DQR values (for each criterion + total)	
	Option 2		Use default secondary dataset in FreshProducePEFCR, in aggregated form (DQR≤3.0) Use the default DQR values
Situation 2: process not run by the company using the FreshProducePEFCR but with access to company-specific information	Option 1	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)	
	Option 2	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	
	Option 3		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.
Situation 3: process not run by the company using the FreshProducePEFCR and without access to company-specific information	Option 1	Use default secondary data set in aggregated form (DQR≤3.0) Re-evaluate the DQR criteria within the product-specific context	
	Option 2		Use default secondary data set in aggregated form (DQR≤4.0) Use the default DQR values

[10] The options described in the DNM are not listed in order of preference.
[11] Company-specific datasets shall be made available to the EC.

5.4.1 Processes in situation 1

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

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:

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

Situation 2/Option 1
For all processes not run by the company and where the user of 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 12. The criteria GR shall be lowered by 30%[12] and the criteria P shall keep the original value.

Situation 2/Option 3
The user of the PEFCR 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.

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

Table 12 *How to assess the value of the DQR criteria when secondary datasets are used.*

	TiR	TeR	GeR
1	The EF report publication date happens 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 happens not 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 happens not 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 happens not 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 happens 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:
- It is in the list of most relevant processes (situation 3, option 1);
- 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 Which datasets to use?

Process not modelling using primary activity data shall be connected to secondary (background) data. Since this PEFCR is developed outside of the official PEF framework of the European Commission, it cannot make use of the current EF 3.1 database. In order to guarantee harmonised results, this PEFCR has developed a harmonized LCI database. This database consists of datasets from:
- Ecoinvent 3.9, with the "allocation, cut-off by classification" system model;
- Agri-footprint 6.3, economic allocation;
- Growing Media Europe LCI database;
- Processes developed by the TS (for e.g., geothermal heat, end-of-life modelling).

This database shall be used for EF studies in compliance with the FreshProducePEFCR.

The FreshProducePEFCR lists the secondary datasets to be applied by the user of the FreshProducePEFCR. Whenever a dataset needed to calculate the environmental footprint profile is not available, it shall be excluded from the environmental footprint study. This shall be clearly stated in the environmental footprint report as a data gap and validated by the environmental footprint study and verifiers. Additionally, the user of the PEFCR should inform the developers of the PEFCR about the missing dataset.

5.6 How to calculate the average DQR of the study

The LCI-database to be used in EF studies according to this FreshProducePEFCR is constituted from of datasets from different LCI-databases. The DQR in these databases differ among each other and not compatible with each other. The TS is discussing how to solve this issue.

5.7 Allocation rules

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 13.

Table 13 *Allocation rules*

Process	Allocation rule	Modelling instructions	Allocation factor
Allocating organic fertiliser use and green manure 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, expect 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, is 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)	
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.	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.	

	Economic allocation shall be applied for all other organic fertilisers originating from industrial processes.	
Energy use, cleaning and other generic operations in greenhouse cultivation	Land occupation and economic allocation depending on the situation.	When multiple crops are grown in a protected (and heated) system, 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 should first be broken down in 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 * 1 / 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 chapter 6.2.4.3)
Transport (inbound and outbound)	Physical property defining load capacity	Allocation of transport emissions to transported products shall be done on the basis of physical causality, such as mass share, unless the density of the transported product is significantly lower than average so that the volume transported is less than the maximum load. Allocation of empty transport kilometres shall be done on the basis of the average load factor of the transport that is under study. If no supporting information is available, it shall be assumed that 100% additional transport is needed for empty return, which equals the utility rate of 50% (EC, 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 m3) 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 (EC, 2021).
(co-)products	Economic allocation or cut-off	If the sending party receives a price for (co-)products going to the processing industry that exceeds the transport costs, economic allocation shall be applied. If the price does not exceed the transport costs, the (co-)product is considered as residual product and a cut-off is applied.

5.8 Electricity modelling

The following electricity mix shall be used in hierarchical order:

a. Supplier-specific electricity product shall be used if for a country there is a 100% tracking system in place, or if:
    i. available, and
    ii. the set of minimum criteria to ensure the contractual instruments are reliable is met.
b. The supplier-specific total electricity mix shall be used if:
    iii. available, and
    iv. the set of minimum criteria to ensure the contractual instruments are reliable is met.
c. The 'country-specific residual grid mix, consumption mix' shall be used. Country-specific means the country in which the life cycle stage or activity occurs. This may be an EU country or non-EU country. The residual grid mix prevents double counting with the use of supplier-specific electricity mixes in a) and b).
d. 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
Convey the energy type mix associated with the unit of electricity produced.
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.

Criterion 2 – Be a unique claim
Be the only instruments that carry the environmental attribute claim associated with that quantity of electricity generated.
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:

- Domestic production mix per production technologies;
- Import quantity and from which neighbouring countries;

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

These data may be found in the publications of the International Energy Agency (IEA (www.iea.org).
Available LCI datasets per fuel technologies. The LCI datasets available are generally specific to a country or a region in terms of:

- fuel supply (share of resources used, by import and/ or domestic supply);
- energy carrier properties (e.g. element and energy contents);
- 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:

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

- No contractual instruments have been sold to a third party: the own electricity mix (combined with LCI datasets) shall be modelled.
- 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:

- 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).
- If not possible, direct substitution shall be used. The country-specific residual consumption electricity mix shall be used as substitution[13].

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

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

5.9 Climate change modelling

The impact category 'climate change' shall 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.

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[14] shall be modelled under sub-category 3 (incl. 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.
'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.'

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[15] 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 (BSI, 2011): 'Large emissions of GHGs can result as a consequence of land use change. Removals as a direct result of land use change (and not as a result of long-term management practices) do not usually occur, although it is 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[16].

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.

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[14] 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.
[15] Following the instantaneous oxidation approach in IPCC 2013 (Chapter 2).
[16] In case of variability of production over the years, a mass allocation should be applied.

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);
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.'

Soil carbon storage shall not be modelled, calculated and reported as additional environmental information.

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

The sub-category 'Climate change-biogenic' shall not be reported separately.

The sub-category 'Climate change-land use and land transformation' shall not be reported separately.

5.10 Modelling of end of life and recycled content

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 organisation. 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.

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

Material

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

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

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

With the following parameters
A: allocation factor of burdens and credits between supplier and user of recycled materials.
B: allocation factor of energy recovery processes. It applies both to burdens and credits. It shall be set to zero for all PEF studies.

Qsin: quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.
Qsout: quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.
Qp: 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.
R3: it is the proportion of the material in the product that is used for energy recovery at EoL.
Erecycled (Erec): specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.
ErecyclingEoL (ErecEoL): specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process.
Ev: specific emissions and resources consumed (per functional unit) arising from the acquisition and 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.
EER: specific emissions and resources consumed (per functional unit) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, etc.).
ESE,heat and ESE,elec: specific emissions and resources consumed (per functional unit) that would have arisen from the specific substituted energy source, heat and electricity respectively.
ED: specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery.
XER,heat and XER,elec: the efficiency of the energy recovery process for both heat and electricity.
LHV: lower heating value of the material in the product that is used for energy recovery.

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 use of organic fertilisers like compost, use of purified CO_2, manure application and reutilisation of growing media. In these specific cases the guidance in chapter 6.1.6.3, chapter 5.7 and chapter 6.2.9 of FreshProducePEFCR should be applied respectively.

The default parameters to use in modelling the circular footprint formula are provided in Annex C Transition Phase (https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml) of the PEF method (EC, 2021) which have been summarised in Appendix 5, in Table A.3 37 (A, R_1 and R_2),

Table 38 (R_3) and Table 39 (quality ratios). In case a specific A value is not in Annex C Transition Phase the following procedure shall be followed:

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

The FreshProducePEFCR refers to chapter 4.4.8.1 of the PEF method (EC, 2021) on The Circular Footprint Formula on how to deal with alternative parameters to the once provided in Annex C.

The following part of the Circular Footprint Formula 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 1

The R_1 values applied shall be supply-chain specific or default as provided in the table above, 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

In the following subsections, the life cycle stages of products covered in the scope of the FreshProducePEFCR are documented.

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 PEFCR. This life cycle stage considers the materials acquired for the cultivation stage. Materials acquired are plant input material, growing media, greenhouse constructions, materials (e.g. trellis systems), plant protection products, biological pest control and fertilisers (synthetic and mineral, organic and CO_2).

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 may be used. In case no primary data is available, the following default scenarios shall be used:

- 30 km by truck (10-20t, EURO 5) for manure;
- 230 km by truck (>20t, EURO 5), 280 km by freight train (electricity, bulk), 360 km by barge ship (container, 2000t) for (intermediate) packaging materials;
- 150 km by truck (10-20t, EURO 5) for all other inputs.

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;
- location of supplier, (to be able to calculate distance to supplier);
- transport mode, distance and mass of plant input materials, and
- amount and type of growing media use.

For the transport of starting material secondary data may be used.

For the production of starting material secondary data may be used. In case no background process is available, lifetime allocation shall be applied to estimate the environmental impact of the starting material. For example, grower A buys starting material from grower B. The crop has grown at grower B for 40 days. Grower A growers the plant for another 50 days before reselling it. Grower A is calculation the environmental footprint of its own operation and then multiplies this impact by 1.8 (= total duration/duration at grower A = 90/50).

6.1.2 Growing media

A growing media product can be am mix of constituents or a mono-material. For growing media, the following data shall be collected:

- quantity of growing media in volume/weight;
- composition of growing media (i.e. different constituent components);
- location of supplier (to be able to calculate distance to supplier);
- transport mode, distance and mass of growing media;
- packaging material, and;
- share of carbon in the growing media that is considered as fossil shall be collected (peat constituent carbon content);

- Utility consumption in mixing, processing and packaging.

Necessary information can be provided by the growing media producers.

The use of growing media materials shall be recorded per type of growing media on an annual basis. If growing media is 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 or additives may contain nutrients. If that is the case the nutrient content shall be recorded. C, N, P, K, limestone, dolomite, urea content and density and moisture content shall be collected and shall be considered when modelling N and P emissions during cultivation (sections 6.2.7 and 6.2.9).

For the production and transport of growing media secondary data may be used.

If no applicable pre-defined growing media consumption mix is available in the background database, the growing media mix shall be modelled using company-specific data regarding the different constituent components. The constituent list shall add up to 100% of the volume composition for $1m^3$ of growing media as delivered to the user, excluding additives, and a corresponding mass balance shall be provided. All additives shall be included and reported separately, based on their used in mass per m^3 of growing media delivered to the user. Data on utility consumption in mixing, processing and packaging shall be included. If not available, the background process 'Utility use in growing media mixing, processing and packaging | FreshProducePEFCR' shall be used.

6.1.3 Capital goods

According to the PEF method (EC, 2021), 'capital goods (including infrastructures) and their end of life should be excluded, unless there is evidence from previous studies that they are relevant.' Greenhouses often have a large contribution to the environmental footprint of horticultural products (Kan & Vieira, 2020). 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.

Often primary data on greenhouses is difficult to obtain. For that reason, this FreshProducePEFCR provides default data to be used for a few greenhouse types.

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 & Vieira, 2020. In case no primary data is available, the practitioner shall use the default data provided in the background database.

Capital goods depreciation shall be taken into account in all cases. Linear depreciation shall be used. The expected service life of the capital goods 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 is established. If there is no specific information on the lifetime of the greenhouse, the default lifetime of 15 years (Montero et al., 2011) shall be assumed. For shade-net greenhouses, a default life-time of 3 years shall be assumed (based on expert judgement). 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.

$$AGH_p = (AGH_T * CT_p / CT_T) / (LTGH * YGH)$$

In which
AGHp = the area of the greenhouse per FU
AGHT = the total area of the greenhouse (h)
CTp = the cropping time (length of the cropping period) of crop p (weeks)
CTT = 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 13.

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:

6.1.4.1 Materials used for soil covering

Materials used for soil 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 included trellis systems used in fruit cultivation.

6.1.5 Plant protection products

Plant protection products are products that aim to protect crops or desirable or 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 (EC, 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 plant 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. The active ingredients can be organic or inorganic chemicals such as S and Cu compounds.

For the production of plant protection products secondary data may be used. Wherever possible, product type specific datasets shall be used. Transport of plant protection products to farm shall be omitted.

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

Secondary data on biological pest control are not available. Biological pest control does not need to be considered. If biological pest control is used, this shall be reported as additional technical information together with the type of biological pest control.

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 N, P, K, $CaCO_3$ and other Calcium compounds. Data on N fertilisers shall be split in ureum and other N compounds. For N, P, K compounds 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 14 Fertiliser use activity data collection table for default modelling

Activity data	Unit per gross area per year	Quantity	Source and method of measurement
Fertiliser brand or type name and composition	Kg /ha		
Ureum	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

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 (source (animal, compost, industry), animal type;
- Fertiliser composition: water, Total N, organic bound N, mineral N, P, K, Cd, Zn, Cu;
- location of supplier, (to be able to calculate distance to supplier); and
- transport mode, distance and mass of fertilisers.

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

6.1.6.3 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 be 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 at a third party supplier only 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 resulting CO_2 emissions shall be allocated to the original process. 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 by that industry.

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 vegetables. Emissions from (the use of) plant protection products, fertilizers, 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 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

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 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[17].
- Where the different stages in the cultivation cycle are known to be disproportional, a correction shall be made by adjusting the crop areas allocated to different development stages in proportion to the crop areas expected in a theoretical steady state. The application of such correction shall be justified and recorded. The life cycle inventory of perennial plants and crops shall not be undertaken until the production system actually yields output.
- 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 must be collected. This must be country-specific. Land use per FU is calculated from collected data on yield per hectare of land. If no data on land use is available, the following data shall be used:
- Open field, in soil: occupation, annual or permanent crop
- Open field, outside soil: occupation, annual or permanent crop
- Protected, in soil: occupation, annual crop, greenhouse
- Protected, outside soil: occupation, annual crop, greenhouse

For the farm plots where the crop(s) under study data 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 land use change for more than 20 years this means that there is no GHG impact of 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.

6.2.3 Water

Data on the following water flows shall be collected and modelled in studies compliant with this FreshProducePEFCR:
- Irrigation water
- Other blue water use
- Rain water, unless sourced via surface or groundwater resources, is not to be considered. Rain water 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.

Irrigation water is crop-specific. The flow of irrigation water can be measured/estimated with several methods. This shall be recorded as well as the source of the irrigation water and the country in which used and extracted. All water use should be calculated back to the FU.

Table 15 *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 use	Source and method of measurement
Irrigation water	m^3 per ha, kg crop or farm per year				

[17] 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).

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	

6.2.4 Electricity, heat and purified CO_2

6.2.4.1 Purchased electricity

Electricity consumed during cultivation and post-harvest operations shall be collected according to the Electricity modelling in 5.8.

Electricity from a CHP system in a farm shall be modelled as described in the sub-section below, entitled Combined heat and power (CHP) systems (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 and post-harvest operations. 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.

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.

If subdivision is not feasible, activity data shall be collected on the CHP including the flue gas cleaning system and the cultivation separately.
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.

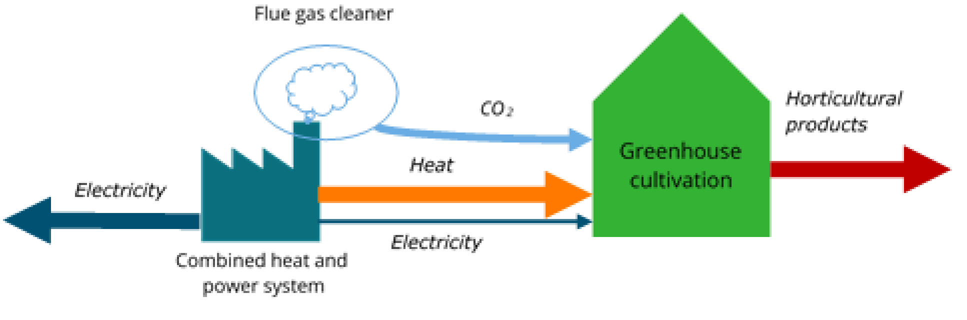

Figure 5 *Graphical representation of the heated greenhouse processes, subdivided into three unit process and the product flows*

Activity data for the CHP unit shall include:

i. 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.

ii. The environmental interventions related to the CHP unit, shall be calculated. This shall be done by applying the following provisions:
  - Carbon dioxide (CO_2) emissions to air shall be determined in the following order of preference:
    - The emission shall be collected from direct measurement or a documented prior measurement of the CHP unit considered.
    - 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.
    - If a technical specification is not available, a public source, clearly stating average emissions from CHPs in general representative for the country of cultivation shall be used.
    - If a public source is not available, secondary data from scientific papers or LCA databases are accepted.
  - 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.
  - 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 2.8% of fuel loss shall be assumed. 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.
  - Nitric oxide (NO_x) emissions to air shall be calculated using the EMEP/EEA Tier 1 approach mg emission per MJ of fuel.
  - Sulphur dioxide (SO_2) emitted to air shall be calculated using the EMEP/EEA Tier 1 approach mg emission per MJ of fuel.

iii. 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 6.1.6.

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.

6.2.5 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 HHV or LHV
- Fuel mix (for instance if biogenic fuels are mixed in) in relative shares of fuels
- Quantity of the fuel in weight and energy units

This information will be used to match the most adequate secondary datasets for production of fuels and combustion of fuels. In contradiction to other inputs, the production of fuels has to be included in the life cycle stage cultivation given the compatibility with the available background datasets.

6.2.6 Emissions from use of plant protection products

Here, only the emissions resulting from the application of plant protection products in the cultivation area is described. The input of plant protection products in the field is documented in 6.1.5.

Pesticide emissions shall be modelled as specific active ingredients. 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 (EC, 2021).

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

The impact of crop protection active ingredients depends on the farm system, climate conditions, the distance to surface area, the spraying technology etc. In this version of the PEFCR, no specific emission model is recommended that differentiates these parameters. The Technical Secretariat is aware of the Pest-LCI 2.0 (link) and Greenhouse Emission Model (link) approaches for respectively open field and protected cultivation, which are the most progressive to overcome the current limitations of the current modelling of pesticides here proposed.

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 N and P inputs shall be allocated to a specific crop in case of a rotation scheme is described in a separate chapter in this FreshProducePEFCR (chapter 5.7).

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

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

During the verification (compulsory for PEF studies) it needs to be checked whether an improved preference level could not be met.

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 freely available from a model. 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 available on a level of regular management of a farmer/grower. This means that if data is needed on the basis of very frequent measurement (for instance daily basis), information is needed on parameters that are not in scope of regular management (for instance carbon content of the soil), or a big 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 representative on a global level.

The **default modelling** must be applied if the measurement and the preferred modelling cannot be performed. So, 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.

This approach implies that comparability is more important than precision[18]. 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.

[18] 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.

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
- 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).

Please refer to Table 16 for an overview of the modelling underlying these emissions per preference level.

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 nitrogen emissions shall be calculated from nitrogen applications of the farmer 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 16. Note that for some combinations a distinction is made between soil and soilless[19] cultivation systems.

The remainder of this section is structured according to the overview in Table 16. 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 17.

[19] 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.

Table 16 *Overview of emission modelling per preference level.*

Section	Emission	Compart-ment	Measurement	Preferred modelling	Default modelling
6.2.7.1	**Ammonia (NH_3)**	Air	Direct measurement	Model based on fertiliser use compliant to Bouwman et al 2002	IPCC Tier 1
6.2.7.2	**Nitrogen oxides (NO_x)**	Air	Direct measurement	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**: direct measurement only for closed recirculation **Soil**: direct measurement not applicable	**Soilless**: not applicable **Soil**: model run-off to surface water and leaching to ground water (Miterra)	IPCC Tier 1
6.2.7.4	**Nitrous oxide (N_2O)**	Air	Direct measurement not applicable (very complex)	IPCC Tier 1 (no supra national models available)	IPCC Tier 1
6.2.7.5	**Carbon dioxide (CO_2)**	Air	Direct measurement not applicable	IPCC Tier 1 (no supra national models available)	IPCC 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**: direct measurement not applicable	No recommended model: use direct measurement or default modelling	PEFCR guide 6.3

Table 17 *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

6.2.7.1 Ammonia (NH_3) volatilisation

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 (EEA, 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., 2018). In this methodology ammonia volatilisation from N-application through synthetic and organic fertiliser is being considered.

Ammonia airborne 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. If not, the default modelling based on IPCC, Tier 1 may be used instead (see Table 18**Error! Reference source not found.**).

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

Table 18 *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)**
NH_3 rate	NH_3 fraction (0 – 1) of N application emitted as ammonia	Formula 1 (see above)
crop	Type of crop (upland/grass/flooded)	Choose 'upland' in **Table 19**
fert	Type of fertiliser (e.g., urea)	Primary data and **Table 19** or country average[1]
appl	Type of application (e.g., broadcast)	Primary data and **Table 19**
pH	pH of the soil or the growing media	Primary data and **Table 19**
CEC	Cation-Exchange-Capacity of soil or growing media	Primary data and **Table 19**
climate	Climate (temperate or tropical)	Primary data and **Table 19**
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 (as described in **Table 19**) the weighted average value for N-fertiliser use determined per country (see **Table 40 in Appendix 6**) may be used as default.

Table 19 *The values for the parameters to calculate the ammonia volatilisation rate according to (Bouwman et al., 2002)*

parameter		value
crop type	upland	-0.045
	grass	-0.158
	flooded	0
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 oxide (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 **Error! Reference source not found.**), nitrogen oxide emissions are not relevant because in the IPCC ammonia approach (IPCC, 2006) the NO_x emissions are included. Table 20 provides an overview of preferred and default nitrogen oxides modelling.

Table 20 *Preferred and default 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	$EF_{nox} = 0.04$
	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 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 (EC, 2021) may 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 N 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. We propose to 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 (For cultivation in soil: preferred or default modelling)

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 if it is protected, measurements of nitrate emissions are not applicable.

In some countries it is mandatory that for cultivation in greenhouses on growing media the annual amount of discharged water (to surface water or sewage system) and nitrate concentration is measured and reported 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 (For soilless cultivation: measurement or default modelling)
The preferred modelling of nitrate emissions is based on the Miterra-Europe model (Velthof et al., 2009)(Velthof et al., 2007). This model has a proven track record in European studies (Velthof et al., 2014), (Leip et al., 2013), (Oenema et al., 2009), (De Vries et al., 2011), data needed for calculation of nitrate emissions should be rather easily available on farm level.

Two pathways for nitrate losses can be distinguished: runoff to surface water and leaching to groundwater (which indirectly can leach to surface water). Preferred emission modelling for both pathways is described in Table 21. Note that these formulas are only applicable to cultivation in soil. For soilless cultivation, direct measurements or default modelling is applicable.

Table 21 *Preferred emission modelling for nitrate (NO_3) runoff and leaching (only applicable to 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 22
f_p, f_s, f_{rc}		Fractions based on precipitation surplus, soil type, and depth to rock	Primary data and Table 22
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 23
	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 23
$correction_{dep}$[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 $N_{fert}+N_{org} \geq N_{harv}$) 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 41 in Appendix 6
	NH_3-N	Amount of NH_3-N (kg) from synthetic and organic fertilisers	See Formula 1 or 2
	NO_x-N	Amount of NO_x-N (kg) from synthetic and organic fertilisers	See Formula 3
	N_{runoff}	Amount of N emitted as nitrate by runoff to surface water	See Formula 4
	Direct N_2O-N	Amount of N_2O-N (kg) from synthetic and organic fertilisers	See Formula 7

[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 22 *The values for the parameters to calculate the runoff to surface water (Formula 4) according to (Velthof et al., 2007, 2009)*

Parameter		value
LF_{runoff_max}	Slope 0 to 8%	10%
	Slope 8 to 15%	20%
	Slope 15 to 25%	35%

	Slope > 25%	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 23 *The values for the parameters to calculate the leaching to groundwater (Formula 5) according to (Velthof et al., 2007, 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 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 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% (25%, see Table 23**Error! Reference source not found.**). Therefore, in the default modelling the fraction leached is set to 24% for all situations. Table 24 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 24 *Default emission modelling for nitrate (NO_3) runoff and leaching (applicable to cultivation in soil and to 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}) * 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 42 in Appendix 6 Soilless: N_{cr} = 0
N_{min}	= N_{som} + N_{os}	See below
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 N) 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) to air (direct and indirect)

The relationship of direct nitrous oxide emissions from N applied is described by the 2019 Refinement to the 2006 IPCC Guidelines. 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 (N_2O) emissions are based on IPCC 2019 Tier 1 (see Table 25), 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 25 *Preferred and default emission modelling for nitrous oxide (N2O) emissions (applicable to cultivation in soil and to soilless cultivation).*

Preferred and default modelling approach for direct 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 42 in Appendix 6 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)	See Formulas 1, 2, 3
NO_3-N (kg	Amount of Nitrogen leached an runoff as nitrate (kg NO_3-N)	See Formulas 4, 5, 6
$EF_{ammonia}$	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, in section 6.2.9 on Growing 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 (CO_2) to air from lime, urea, and urea-compounds application

Liming 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. 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 as described in Table 26 below.

Table 26 *Preferred and default emission modelling for 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 in kg	Primary data
EF_{urea}	Emission factor for urea in kg C per kg urea	EF_{urea} = 0.20

6.2.7.6 Phosphate (PO4) to water

The LCI for 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 (PO4) discharged in wastewater to surface water or sewage system, the first option 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 are calculated as volume of discharged water times the measured phosphate concentration. This implies that for cultivations in the soil, regardless if it is protected, measurements of phosphate emissions are not applicable.

Table 27 describes the preferred and default emission modelling approach for Phosphorus (P) related emissions according to the PEF method (EC, 2021).

Table 27 *Preferred and default emission modelling for Phosphorus related emissions.*

P emissions: Formula 11	***P (kg) = P_{rate} * $P_{applied}$***	***PEFCR guide 6.3***
$P_{applied}$	*Amount of Phosphorus (P) 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 and Phosphorous 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 28Error! Reference source not found.**Error! Reference source not found.**.

Table 28 *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						

Refer to appendix 6 for default modelling parameters.

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 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 is only considered for the N&P balance.

6.2.8 Heavy metal emissions

Not applicable in this version of the FreshProducePEFCR. The topic is under discussion in the Technical Secretariat.

6.2.9 Growing media

Emissions from the use of growing media shall be modelled according to the guidance given in section 6.1.2. The default modelling approach shall be used.

Oxidation of peat carbon into CO_2 shall be calculated by considering a default rate of 5% per year, until growing media is transferred to the next user (reuse). 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).

6.2.10 Peat soils

The input of peat to soil (kg/ha + C/N ratio) shall be included.

Drained peat soils shall include carbon dioxide emissions on the basis of a model that relates the drainage levels to annual carbon oxidation.

Please refer to chapter 6.2.9

6.2.11 Waste

All waste resulting from the cultivation stage at farm shall be modelled in this life cycle stage.

Farm waste consists of plant and crop remains (organic) and of wasted materials. The modelling of emissions from crop residues left on the field is explained in **Error! Reference source not found.**. Other organic waste should be accounted for and modelled as composting. For materials waste the waste scenario is included in the Circular footprint formula detailed in 5.10.

Moisture losses shall be accounted for by correcting the yield outputs.

In some supply chains, part of the yield goes 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 Allocation rules are applicable.

6.2.12 Storage at farm

If any storage operation takes place at the farm no specific electricity use data needs to be collected if already captured in electricity usage compiled in section 6.2.4.

6.3 Post-harvest treatment, storage and handling

This life cycle stage encompasses 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, refrigerant use, intermediate packaging production, and waste (incl. the additional quantity needed to fulfil the FU).

Activities to be included in this life cycle stage can take place at different locations along the value chain. To ease the analysis of the results, the user of this FreshProducePEFCR may decide to further split this life cycle stage. For example into 'post-harvest treatment', 'storage' and 'handling'. The reason(s) for doing this shall be set out in the EF report.

Moisture losses, as well as physical product losses including their waste treatment shall be included. Losses shall modelled by using the default biowaste background process.

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 shall be omitted.

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

In case any packaging (excluding consumer packaging) is added to the product, it shall be accounted for according to the modelling rules in section 5.7.

6.4 Distribution

Transport from farm 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 and shall instead be included in the post-harvest treatment, storage and handling stage.

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

The waste of products during distribution shall be included in the modelling. The default loss rate for distribution is derived from the PEF method (EC, 2021) and corrected for the losses are retail (2.1%). A waste percentage of 7.9% shall be applied. If more specific data is available, this may be used.

The waste disposal at the distribution centre shall be modelled according to the default scenario for biowaste. In case more specific information is available.

Outbound transport, from location of cultivation or first handling activity, is a mandatory company-specific process. In case this 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 following default scenario shall be used:

- 1200 km, by truck (>20t EURO 5), 100% LF, from latest destination (this shall not be the farm itself) to DC;
- 250 km, by truck (>20t, EURO 5), 100% LF, from DC to retail;
- 3.1 km, by passenger car, from retail to consumer (the allocation rules described below shall be applied to this distance);
- 0.25 km, by truck (<10t, EURO 5), 20% LF, from retail to consumer.

The product volume (including packaging and empty spaces) shall be used to allocate the transport burdens between the products transported for transport from retail to final client. The allocation factor shall be calculated as the volume of the product transported divided by 0.2m^3.

For products larger than 0.2 m^3 the full car transport impact shall be considered. To simplify the modelling, all other types of consumer transport shall be modelled as above.

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).

The default storage time at the distribution centre is based on expert judgement and considered to be 2 days.

The waste disposal at the distribution centre is modelled as described in section 5.10.

6.5 Consumer packaging

This life cycle stages encompasses all 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.

Data shall be collected on material type (e.g. PET), weight, location of supplied (to be able to calculate distance to supplier) and transport mode, transport distance, mas 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.

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.

6.6 Retail

Activity data for the retail stage can be modelled using default data as provided in the PEF method (EC, 2021). If retailer-specific data is available, the data needs matrix applies (see section 5.4).

As per the PEF method (EC, 2021), storage activities consume energy and refrigerant gases. The following default data shall be used, unless site-specific storage data is available. A general energy consumption of 300 kWh/m^2·year for the entire building surface shall be considered as default. For retail specialised in non-food/ non-beverage products a 150 kWh/m^2·year for the entire building surface shall be considered. For retail specialised in food/ beverage products a 400 kWh/m^2·year for the entire building surface plus energy consumption for chilled and frozen storage of 1,900 kWh/m^2·year and 2700 kWh/m^2·year respectively is to be considered (Palandre et al., 2003)

An average retail place is assumed to store 2000 m3 of products (assuming 50% of the 2000 m^2 building is covered by shelves of 2 m high) during 52 weeks, i.e. 104,000 m^3 * weeks/year.

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

The default loss rate for retail is based on RIVM (2023) and considered to be 2.1% for both fruits and vegetables. The waste disposal at the retail place is modelled as described in section 5.10. The default waste treatment scenarios per material are displayed in Table 29.

The default storage time at retail is based on expert judgement and considered to be 1.5 days.

6.7 Use stage

Neither product independent (i.e., processes that have no relationship with the way the product is designed or used) or 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) can vary across consumers and countries, and no sufficient data is available to gain insights in this behaviour to design a meaningful default scenario.

Inedible food parts are excluded from the functional unit (see section 3.3) and shall be included in the use phase. Exclusion of inedible food parts (e.g. peel) from the functional unit means additional consumable food parts are needed to fulfil the functional unit. This approach allows comparability between products with different levels of edibility within the product category.

Product specific inedible fractions shall be used. Appendix 6 list the inedible fractions that shall be used. In case the product is not available in this table, the nearest proxy within the same sub-category shall be chosen.

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). In general, it includes the waste of the product in scope, such as the flower/plant waste, and primary packaging. Other waste (different from the product in scope) generated during the manufacturing, distribution, retail, use stage or after use shall be included in the life cycle of the product and modelled at the life cycle stage where it occurs.

The end of life of the horticultural product shall consider all activity data related to the management of the horticultural product 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 waste treatment scenarios per material are displayed in Table 29.

Table 29 *Default end-of-life waste treatment scenarios per material*

Name of the process	Unit of measurement (output)	Default (per kg)	Default dataset to be used
Waste scenario PP plastic			
Avoided virgin material	kg	*0*	Polypropylene, granulate {RER}| polypropylene production, granulate | Cut-off, S
Avoided electricity	MJ	*1.89*	Electricity, high voltage {RER}| market group for electricity, high voltage | Cut-off, S
Avoided heat	MJ	*3.67*	Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas | Cut-off, S
Lorry transport	kgkm	*30*	Transport, truck >20t, EURO4, 80%LF, default/GLO Economic
Recycling plastic	kg	*0*	dummy_wastetreatment_kg
Incinerating polypropylene	kg	*0.45*	Waste polypropylene {RoW}| treatment of waste polypropylene, municipal incineration | Cut-off, S
Landfill polypropylene	kg	*0.55*	Waste polypropylene {RoW}| treatment of waste polypropylene, sanitary landfill | Cut-off, S
Waste scenario PE plastic			
Avoided virgin material	kg	*0*	Polyethylene, high density, granulate {RER}| polyethylene production, high density, granulate | Cut-off, S
Avoided electricity	MJ	*2.50*	Electricity, high voltage {RER}| market group for electricity, high voltage | Cut-off, S
Avoided heat	MJ	*4.81*	Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas | Cut-off, S
Lorry transport	kgkm	*30*	Transport, truck >20t, EURO4, 80%LF, default/GLO Economic
Recycling plastic	kg	*0*	dummy_wastetreatment_kg
Incinerating polyethylene	kg	*0.45*	Waste polyethylene {RoW}| treatment of waste polyethylene, municipal incineration | Cut-off, S
Landfill polyethylene	kg	*0.55*	Waste polyethylene {RoW}| treatment of waste polyethylene, sanitary landfill | Cut-off, S
Waste scenario PS plastic			
Avoided virgin material	kg	*0*	Polystyrene, expandable {RER}| polystyrene production, expandable | Cut-off, S
Avoided electricity	MJ	*2.27*	Electricity, high voltage {RER}| market group for electricity, high voltage | Cut-off, S
Avoided heat	MJ	*4.37*	Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas | Cut-off, S
Lorry transport	kgkm	*30*	Transport, truck >20t, EURO4, 80%LF, default/GLO Economic
Recycling plastic	kg	*0*	dummy_wastetreatment_kg
Incinerating polystyrene	kg	*0.45*	Waste polystyrene {RoW}| treatment of waste polystyrene, municipal incineration | Cut-off, S
Landfill polystyrene	kg	*0.55*	Waste polystyrene {RoW}| treatment of waste polystyrene, sanitary landfill | Cut-off, S
Waste scenario carboard/paper			
Avoided virgin material	kg	*0.6*	Sulfate pulp, unbleached {RER}| sulfate pulp production, from softwood, unbleached | Cut-off, S
Avoided electricity	MJ	*0.224*	Electricity, high voltage {RER}| market group for electricity, high voltage | Cut-off, S
Avoided heat	MJ	*0.448*	Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas | Cut-off, S
Lorry transport	kgkm	*30*	Transport, truck >20t, EURO4, 80%LF, default/GLO Economic
Recycling paper	kg	*0.6*	Waste paperboard, sorted {RoW}| treatment of waste paperboard, unsorted, sorting | FreshProducePEFCR
Incinerating paper	kg	*0.1125*	Waste paperboard {RoW}| treatment of waste paperboard, municipal incineration | Cut-off, S

Landfill paper	kg	*0.1375*	Waste paperboard {RoW}| treatment of waste paperboard, sanitary landfill | Cut-off, S
Waste scenario steel			
Avoided virgin material	kg	*0.68*	Pig iron {RER}| market for pig iron | Cut-off, S
Avoided electricity	MJ	*0*	Electricity, high voltage {RER}| market group for electricity, high voltage | Cut-off, S
Avoided heat	MJ	*0*	Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas | Cut-off, S
Lorry transport	kgkm	*30*	Transport, truck >20t, EURO4, 80%LF, default/GLO Economic
Steel recycling	kg	*0.68*	Iron scrap, sorted, pressed {Europe without Switzerland}| treatment of metal scrap, mixed, for recycling, unsorted, sorting | FreshProducePEFCR
Incinerating steel	kg	*0.0675*	Scrap steel {RoW}| treatment of scrap steel, municipal incineration | Cut-off, S
Landfill steel	kg	*0.0825*	Scrap steel {Europe without Switzerland}| treatment of scrap steel, inert material landfill | Cut-off, S
Waste scenario concrete			
Avoided electricity	MJ	*0*	Electricity, high voltage {RER}| market group for electricity, high voltage | Cut-off, S
Avoided heat	MJ	*0*	Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas | Cut-off, S
Lorry transport	kgkm	*30*	Transport, truck >20t, EURO4, 80%LF, default/GLO Economic
Incinerating concrete	kg	*0*	dummy_wastetreatment_kg
Landfill concrete	kg	*1*	Waste concrete {Europe without Switzerland}| treatment of waste concrete, inert material landfill | Cut-off, S
Waste scenario wood			
Avoided virgin material	kg	*0.0243*	Wood chips, wet, measured as dry mass {Europe without Switzerland}| market for wood chips, wet, measured as dry mass | Cut-off, S
Avoided electricity	MJ	*0.548*	Electricity, high voltage {RER}| market group for electricity, high voltage | Cut-off, S
Avoided heat	MJ	*1.099*	Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas | Cut-off, S
Lorry transport	kgkm	*30*	Transport, truck >20t, EURO4, 80%LF, default/GLO Economic
Recycling wood	kg	*0.0286*	Waste paperboard, sorted {RoW}| treatment of waste paperboard, unsorted, sorting | FreshProducePEFCR
Incinerating wood	kg	*0.315*	Waste wood, untreated {RoW}| treatment of waste wood, untreated, municipal incineration | Cut-off, S
Landfill biowaste	kg	*0.385*	Waste wood, untreated {RoW}| treatment of waste wood, untreated, sanitary landfill | Cut-off, S
Waste scenario biowaste			
Avoided virgin material	kg	*0.125*	Compost, fresh {GLO}| avoided fertiliser nutrient supply as if poultry manure | FreshProducePEFCR
Avoided electricity	MJ	*0.195*	Electricity, high voltage {RER}| market group for electricity, high voltage | Cut-off, S
Avoided heat	MJ	*0.475*	Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas | Cut-off, S
Lorry transport	kgkm	*30*	Transport, truck >20t, EURO4, 80%LF, default/GLO Economic
Composting	kg	*0.125*	Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off, S
Incinerating biowaste	kg	*0.225*	Biowaste {GLO}| treatment of biowaste, municipal incineration | Cut-off, S
Landfill biowaste	kg	*0.275*	Biowaste {RoW}| treatment of biowaste, open dump | Cut-off, S
Methanation	kg	*0.250*	Biowaste {RoW}| treatment of biowaste by anaerobic digestion | Cut-off, S
Waste scenario rockwool			
Avoided virgin material	kg	0	DUMMY (kg)
Avoided electricity	MJ	0	Electricity, high voltage {RER}| market group for electricity, high voltage | Cut-off, S

Avoided heat	MJ	0	Heat, district or industrial, natural gas {RER}| market group for heat, district or industrial, natural gas | Cut-off, S
Lorry transport	kgkm	30	Transport, truck >20t, EURO4, 80%LF, default/GLO Economic
Recycling rockwool	kg	0	dummy_wastetreatment_kg
Incinerating rockwool	kg	0	dummy_wastetreatment_kg
Landfill rockwool	kg	1	Waste concrete {Europe without Switzerland}| treatment of waste concrete, inert material landfill | Cut-off, S

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 'End of life modelling' (see chapter 5.10) of this PEFCR and in the PEF method, together with the default parameters listed in Annex C Transition Phase (https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml) of the PEF method which have been summarised in Appendix 4.

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[20].

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 in the table below.

- 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 R2 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.

The post-consumer waste-related activities of the product studied shall be included and reported in the end-of-life life cycle stage. The waste generated in other lifecycle stages is treated per life cycle stage. All modelled EoL processes shall be connected to the appropriate secondary data for municipal waste management processes, according to Table 29.

Emissions of peat C shall be modelled based on remaining C content of peat after transferring to EoL, in which case full oxidation of remaining C from peat shall be modelled.

[20] E.g. the EPBP design guidelines (http://www.epbp.org/design-methodlines), or Recyclability by design (http://www.recoup.org/).

7 Environmental footprint results

7.1 Benchmark values

Benchmarks are provided as characterised results, normalised results and weighted results, as requested in the PEFCR method. One benchmark was calculated for each sub-category: fruits and vegetables. 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.

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 benchmark values listed below should therefore be seen as an indicative guide only.

7.1.1 Benchmark values for RP fruits

Table 30 *Characterised benchmark values for Representative Product fruits*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	mol H+ eq	4.00E-03	4.76E-03
Climate change	kg CO_2 eq	5.42E-01	6.61E-01
Ecotoxicity, freshwater	CTUe	4.32E+01	4.75E+01
Particulate matter	disease inc.	3.60E-08	4.29E-08
Eutrophication, marine	kg N eq	2.39E-03	2.95E-03
Eutrophication, freshwater	kg P eq	1.77E-04	2.09E-04
Eutrophication, terrestrial	mol N eq	1.50E-02	1.80E-02
Human toxicity, cancer	CTUh	2.94E-10	3.38E-10
Human toxicity, non-cancer	CTUh	8.30E-09	9.62E-09
Ionising radiation	kBq U-235 eq	4.47E-02	5.01E-02
Land use	Pt	2.57E+01	3.03E+01
Ozone depletion	kg CFC11 eq	2.06E-07	2.29E-07
Photochemical ozone formation	kg NMVOC eq	2.66E-03	3.14E-03
Resource use, fossils	MJ	6.69E+00	7.64E+00
Resource use, minerals and metals	kg Sb eq	5.23E-06	5.82E-06
Water use	m3 depriv.	4.91E+00	5.65E+00

Table 31 *Normalised benchmark values for Representative Product fruits*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	person-year	7.19E-05	8.57E-05
Climate change	person-year	7.18E-05	8.76E-05
Ecotoxicity, freshwater	person-year	7.61E-04	8.37E-04
Particulate matter	person-year	6.05E-05	7.20E-05
Eutrophication, marine	person-year	1.22E-04	1.51E-04
Eutrophication, freshwater	person-year	1.10E-04	1.30E-04
Eutrophication, terrestrial	person-year	8.47E-05	1.02E-04
Human toxicity, cancer	person-year	1.70E-05	1.96E-05
Human toxicity, non-cancer	person-year	6.45E-05	7.47E-05
Ionising radiation	person-year	1.06E-05	1.19E-05
Land use	person-year	3.13E-05	3.70E-05
Ozone depletion	person-year	3.94E-06	4.37E-06
Photochemical ozone formation	person-year	6.50E-05	7.69E-05
Resource use, fossils	person-year	1.03E-04	1.18E-04
Resource use, minerals and metals	person-year	8.23E-05	9.15E-05
Water use	person-year	4.28E-04	4.92E-04

Table 32 *Weighted benchmark values for Representative Product fruits*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	μPt	4.46	5.32
Climate change	μPt	15.12	18.44
Ecotoxicity, freshwater	μPt	14.61	16.07
Particulate matter	μPt	5.42	6.45
Eutrophication, marine	μPt	3.62	4.46
Eutrophication, freshwater	μPt	3.09	3.63
Eutrophication, terrestrial	μPt	3.14	3.77
Human toxicity, cancer	μPt	0.36	0.42
Human toxicity, non-cancer	μPt	1.19	1.37
Ionising radiation	μPt	0.53	0.59
Land use	μPt	2.49	2.94
Ozone depletion	μPt	0.25	0.28
Photochemical ozone formation	μPt	3.11	3.68
Resource use, fossils	μPt	8.56	9.78
Resource use, minerals and metals	μPt	6.21	6.91
Water use	μPt	36.40	41.89

7.1.2 Benchmark values for RP vegetables

Table 33 *Characterised benchmark values for Representative Product vegetables*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	mol H+ eq	5.10E-03	5.58E-03
Climate change	kg CO2 eq	4.79E-01	5.31E-01
Ecotoxicity, freshwater	CTUe	6.35E+00	7.16E+00
Particulate matter	disease inc.	3.74E-08	4.06E-08
Eutrophication, marine	kg N eq	2.52E-03	2.78E-03
Eutrophication, freshwater	kg P eq	2.12E-04	2.33E-04
Eutrophication, terrestrial	mol N eq	1.49E-02	1.62E-02
Human toxicity, cancer	CTUh	1.97E-10	2.12E-10
Human toxicity, non-cancer	CTUh	3.89E-09	4.34E-09
Ionising radiation	kBq U-235 eq	3.48E-02	3.64E-02
Land use	Pt	2.00E+01	2.11E+01
Ozone depletion	kg CFC11 eq	2.01E-07	2.10E-07
Photochemical ozone formation	kg NMVOC eq	2.03E-03	2.19E-03
Resource use, fossils	MJ	5.92E+00	6.29E+00
Resource use, minerals and metals	kg Sb eq	5.94E-06	6.22E-06
Water use	m3 depriv.	6.18E-01	6.49E-01

Table 34 *Normalised benchmark values for Representative Product vegetables*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	person-year	9.17E-05	1.00E-04
Climate change	person-year	6.34E-05	7.03E-05
Ecotoxicity, freshwater	person-year	1.12E-04	1.26E-04
Particulate matter	person-year	6.29E-05	6.81E-05
Eutrophication, marine	person-year	1.29E-04	1.42E-04
Eutrophication, freshwater	person-year	1.32E-04	1.45E-04
Eutrophication, terrestrial	person-year	8.40E-05	9.17E-05
Human toxicity, cancer	person-year	1.14E-05	1.23E-05
Human toxicity, non-cancer	person-year	3.02E-05	3.37E-05
Ionising radiation	person-year	8.26E-06	8.62E-06
Land use	person-year	2.44E-05	2.57E-05
Ozone depletion	person-year	3.83E-06	4.02E-06
Photochemical ozone formation	person-year	4.96E-05	5.37E-05
Resource use, fossils	person-year	9.10E-05	9.68E-05
Resource use, minerals and metals	person-year	9.33E-05	9.78E-05
Water use	person-year	5.39E-05	5.66E-05

Table 35 *Weighted benchmark values for Representative Product vegetables*

Impact category	Unit	Life cycle excl. use stage	Total life cycle
Acidification	µPt	5.69	6.22
Climate change	µPt	13.36	14.80
Ecotoxicity, freshwater	µPt	2.15	2.43
Particulate matter	µPt	5.63	6.11
Eutrophication, marine	µPt	3.82	4.21
Eutrophication, freshwater	µPt	3.70	4.06
Eutrophication, terrestrial	µPt	3.12	3.40
Human toxicity, cancer	µPt	0.24	0.26
Human toxicity, non-cancer	µPt	0.56	0.62
Ionising radiation	µPt	0.41	0.43
Land use	µPt	1.94	2.04
Ozone depletion	µPt	0.24	0.25
Photochemical ozone formation	µPt	2.37	2.57
Resource use, fossils	µPt	7.57	8.05
Resource use, minerals and metals	µPt	7.04	7.38
Water use	µPt	4.59	4.82

7.2 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);
- weighted result in absolute values, for all impact categories (as a table);
- the aggregated single overall score in absolute values.

7.3 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.

In the next stages of the project, this topic will be further discussed.

8 Verification

Currently, there are several actors developing and updating their tools to adopt the rules for product environmental footprinting documented in this PEFCR. 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 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 (…)."[21] 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 significant reduce the efforts and costs for verification of specific studies/assessments.
For this reason, in this section we consider 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** (see section 8.2).

The verification of a PEF study/ report carried out in compliance with this PEFCR shall be done according to all the general requirements included in section A.8 of the Annex of the PEF guidance on verification and validation of PEF studies, reports and communication vehicles, and the requirements listed below.

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 data checks shall include, but should not be limited to, the activity data used, the selection of secondary sub-processes, 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, 5 secondary datasets and 10 CFF parameters, then the verifier(s) has to check at least 4 out of 5 processes (70%) and, for each process, (s)he shall check at least 4 activity data (70% of the total amount of activity data), 4 secondary datasets (70% of the total amount of secondary datasets), and 7 CFF parameters (70% of the total amount of CFF parameters), i.e. the 70% of each of data that could be subject to a check.

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 A.8 of Annex of the PEF guidance on verification and validation of PEF studies, reports and communication vehicles, and the requirements listed below.

8.1. Verification requirements 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. 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 assessment methods was used. For each of the most relevant EF impact categories (ICs), at least 50% of the characterisation factors shall be verified, while all normalisation and weighting factors of all Ics shall be verified. In particular, the verifier(s) shall check that the characterisation factors correspond to those included in the EF impact assessment method the study declares compliance with140. This may also be done indirectly, for example:

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

a) Export the EF-compliant datasets from the LCA software used to do the PEF study and run them in Look@LCI141 to obtain LCIA results. If Look@LCI results are within a deviation of 1% from the results in the LCA software, the verifier(s) may assume that the implementation of the characterisation factors in the software used to do the PEF study was correct.

b) Compare the LCIA results of the most relevant processes calculated with the software used to do the PEF study with the ones available in the metadata of the original dataset. If the compared results are within a deviation of 1%, the verifier(s) may assume that the implementation of the characterisation factors in the software used to do the PEF study was correct.

2. Cut-off applied (if any) fulfils the requirements at section 4.6.4 of Annex I.
3. All datasets used shall be checked against the data requirements (sections 4.6.3 and 4.6.5. of Annex I).
4. For at least 80% (in number) of the most relevant processes (as defined in section 6.3.3 of Annex I), 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;
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) 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;
6. The verifier(s) shall check that the datasets are correctly implemented in the software (i.e. LCIA results of the dataset in the software are within a deviation of 1% to the ones in the metadata). At least 50% (in number) of the datasets used to model most relevant processes and 10% of those used to model other processes shall be checked.

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

The aim of the verification of a tool is to check the compliance with this PEFCR. A tool is verified based on the tool itself as well as the first PEF report and the first PEF verification report based on the tool. The tool owner shall arrange for the verification of the tool. A real product or a virtual product or the recalculated RP model in the tool, may be used for the first verification.

The tool verification shall be documented by the verifier in a tool verification report and shall be made available to tool users. Verification of the first EPD developed by a tool shall be part of the pre-verified tool verification.

The verification section of the PEFCR template of the most recent version of the PEF method[1] was taken as a starting point (text highlighted in grey is the text currently included in the PEFCR report template). These were further categorized in: "Pre-verification of the tool" vs "Additional verification requirements to be met by specific PEF studies conducted using a pre-verified tool" (see Table 36).

Table 36 *Verification requirements. Adapted from section B.8 of the PEF method*[22]

Original bullet in chapter B.8 of the PEFCR template	Pre-verification of the tool	Additional verification requirements to be met by specific PEF studies conducted using a pre-verified tool
Bullet 1	The verifier(s) shall check if the correct version of all impact assessment methods was used. For each of the most relevant EF impact categories (Ics), at least 50% of the characterisation factors shall be verified, while all normalisation and weighting factors of all Ics shall be verified. In particular, the verifier(s) shall check that the characterisation factors correspond to those included in the EF impact assessment method the study declares compliance with.[23] This may also be done indirectly, for example: a) Export the EF-compliant datasets from the LCA software used to do the PEF study and run them in Look@LCI[24] to obtain LCIA results. If Look@LCI results are within a deviation of 1% from the results in the LCA software, the verifier(s) may assume that the implementation of the characterisation factors in the software used to do the PEF study was correct.	This may also be done indirectly, for example: b) Compare the LCIA results of the most relevant processes calculated with the software used to do the PEF study with the ones available in the metadata of the original dataset. If the compared results are within a deviation of 1%, the verifier(s) may assume that the implementation of the characterisation factors in the software used to do the PEF study was correct.
Bullet 2		cut-off applied (if any) fulfils the requirements at section 4.6.4 of Annex I. The verifier shall check if a maximum of 10% of the single overall score is derived from ILCD entry-level compliant datasets.
Bullet 3	all secondary datasets included by default in the tool shall be checked against the data requirements (sections 4.6.3 and 4.6.5. of Annex I).	all other datasets i.e., secondary datasets not originally included in the tool and all newly created datasets, shall be checked against the data requirements (sections 4.6.3 and 4.6.5. of Annex I).
Bullet 4	The tool shall require the user to populate fields related to the list of mandatory-specific data required in this PEFCR. CFF parameters included in Annex C and added to the model as default values and datasets used to model them shall also be validated.	The verifiers shall validate all related activity data and datasets used to model 100% of the mandatory company-specific data required in this PEFCR (see section 5.1). For 100% of the most relevant processes (as defined in section 6.3.3 of Annex I), the verifier(s) shall validate all related activity data[25] and the datasets used to model these processes. If relevant, CFF parameters and datasets used to model them that are either not documented or different from those included in Annex C, shall also be validated in the same way.

[22] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021H2279
[23] Available at: http://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml
[24] https://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml
[25] Data validation can be done by data auditors that parties already work with.

Bullet 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) the verifier(s) shall validate all related activity data[26] and the datasets used to model these processes. If relevant, CFF parameters and datasets used to model them that are either not documented or different from those included in Annex C, shall also be validated in the same way.
Bullet 6		The verifier(s) shall check that the datasets are correctly implemented in the software (i.e. LCIA results of the dataset in the software are within a deviation of 1% to the ones in the metadata). At least 50% (in number) of the datasets used to model most relevant processes and 10% of those used to model other processes shall be checked. In particular, verifier(s) shall verify if the DQR of the process satisfies the minimum DQR as specified in the DNM for the selected processes.
	Universal model created for allowing for product-specific calculations to be verified in the tool. The LCA model used in the tool is parameterised for the bill of potential materials and/or activities in a way which allows the user of the tool, to modify a pre-defined selection of input data or choose from a pre-defined menu of activities connected to a specific product life cycle in order to produce product-specific PEF results. The output of a pre-verified PEFCR-compliant tool is a list of characterized and single score results per life cycle stage.	

[26] Data validation can be done by data auditors that parties already work with.

Some of the activity data requested – to enter by the user of the PEFCR, and to validate by the verifier – is already collected and audited by standards included in the FSI basket of standards. If the basket of standards can extend the list of data to be audited to cover for all data points required in a PEF study compliant with this PEFCR, then the verifier will not need to additionally validate the activity data entered in the tool because this is part of data already audited.

In the context of the verification requirements to be met by a PEFCR-compliant tool, only the PEF study will be subject of verification and validation. The verification and validation of the PEF report and of the technical content of the communication vehicles are not covered.

Without changes to the pre-verified tool, the verification of the tool shall be valid for a maximum of 5 years, and not exceed the validity of this PEFCR.

Any change to the tool beyond the variation of user-defined input parameters shall result in a new version of the tool (so tool versioning is required). All changes that may affect numeric results of the PEF calculation require a reverification of the tool. The reverification may be limited to the parts of the tool that were modified. Only verified versions of the tool can be applied. Older versions of the tool shall be stored and be accessible, for a minimum of 5 years after their modification.

7.3. Verifier(s)

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 and cannot include members of the Technical Secretariat or of the consultants involved in previous part of the work – PEF-RP studies, supporting studies, PEFCR review, etc.).

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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 EF study template

This is the checklist from the PEF study template as provide in Part E of the PEF method (EC, 2021), including additional chapters required.

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Appendix 3 Review reports of the FreshProducePEFCR

To be included after final external review.

Appendix 4 Parameters to the circular footprint formula

The parameters to be used by the applicant to implement the CFF are all default values from the PEF method, Annex C. We refer to the Annex C Transition Phase (https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml) for the full list of default parameters, where country specific parameters are also available for R_2. In this appendix we provide most of the parameters from Annex C, except for the country specific R_2 values and any additional information provided in Annex C.

Table A.3 37 *A, R_1 and R_2 parameters to use in the circular footprint formula.*

Category	Material	Application	Parameters			
			A	R_1	R_2	
Metals	Steel	MATERIAL	0.2	0	0.85	
		building sheet	0.2	0.18	0.95	
		building stainless steel parts in copper alloy fittings	0.2	0.63	0	
		appliances – sheet	0.2	0.18	0.90	
		packaging	0.2	0.58	0.80	including bottom ashes
		photovoltaic panel – not specified	0.2	0.37	0	
		photovoltaic panel – mounting structure; electric installation	0.2	0.37	0.95	
		steel hangers and screws	0.2	0.107	0.95	
		building – water supply pipes – stainless steel in PPSU fittings	0.2	0.63	0	
		building – water supply pipes – stainless steel in copper fittings	0.2	0.63	0	
		building – water supply pipes – galvinzed steel – clamps	0.2	0.10	0.95	
		uniterruptible power supply (UPS)	0.2	0	0.93	R_2 value is valid for all steel types used in UPS
	Aluminum	MATERIAL	0.2	0	0.85	

automotive	0.2	0	0.90	R_1 shall refer to application-specific values. Material specific values are not valid.
Building – sheet	0.2	0	0.95	R_1 shall refer to application-specific values. Material specific values are not valid.
Building – e.g. doors, windows	0.2	0	0.90	R_1 shall refer to application-specific values. Material specific values are not valid.
Appliances – sheet	0.2	0	0.90	R_1 shall refer to application-specific values. Material specific values are not valid.
Other packaging – food cans, closures, trays	0.2	0	0.60	R_1 shall refer to application-specific values. Material specific values are not valid.
Packaging – liquid beverage carton	0.2	0	0.43*	Values in the R_2 cells refer to the recycling input rate, and they refer to liquid beverage carton (including paper, plastics and aluminium). The conversion to the recycling output rate (R_2) for the three materials is included in the EF -compliant dataset for the recycling of liquid beverage carton.
Packaging – beverage can body (final product)	0.2	0.55	0.75	
packaging – beverage can end (final product)	0.2	0.03	0.75	
photovoltaic panel – not specified	0.2	0.32	0	
photovoltaic panel – mounting structure; electric installation	0.2	0.32	0.95	

	building – water supply pipes – Pol/Al/Pol pipe	0.2	0	0	R_1 shall refer to application-specific values. Material specific values are not valid.
	Building – water supply pipes – copper alloy fittings	0.2	0	0	R_1 shall refer to application-specific values. Material specific values are not valid.
	Building – water supply pipes – production waste	0.2	0	1.00	R_1 shall refer to application-specific values. Material specific values are not valid.
	Sheet – uniterruptible power supply (UPS)	0.2	0	0.90	R_2 value is valid for all steel types used in UPS
Aluminum alloys	AlMg3 – photovoltaic panel	0.2	0.77	0	
Copper	MATERIAL	0.2	0	0	
	building – sheet	0.2	0.79	0.95	R_1 is calculated using the formula $R_{1,2}$ clean + [(1-$R_{1,2}$ clean)* $R_{1,1}$ sec cathode. R_1 sec cathode =0.3; $R_{1,2}$ clean = 0.7
	building – pipes	0.2	0.79	0.95	R_1 is calculated using the formula $R_{1,2}$ clean + [(1-$R_{1,2}$ clean)* $R_{1,1}$ sec cathode. R_1 sec cathode =0.3; $R_{1,2}$ clean = 0.7
	electronic applications	0.2	0.72	0.80	R_1 is calculated using the formula $R_{1,2}$ clean + [(1-$R_{1,2}$ clean)* $R_{1,1}$ sec cathode. R1sec cathode =0.3; $R_{1,2}$ clean = 0.6
	electrical applications (cables)	0.2	0.30	0.95	R_1 is calculated using the formula $R_{1,2}$ clean + [(1-$R_{1,2}$ clean)* $R_{1,1}$ sec cathode. R_1

						sec cathode =0.3; $R_{1,2}$ clean =0
		mechanical applications	0.2	0.79	0.80	R_1 is calculated using the formula $R_{1,2}$ clean + [(1-$R_{1,2}$ clean)* $R_{1,1}$ sec cathode. R_1 sec cathode =0.3; $R_{1,2}$ clean = 0.7
		photovoltaic panel – PV modules or not specified	0.2	0.44	0	
		photovoltaic panel – mounting structure; electric installation	0.2	0.44	0.95	
		building – water supply pipes	0.2	0.79	0.95	
		tube/sheet in uniterruptible power supply (UPS)	0.2	0	0.93	R_2 value is valid for all steel types used in UPS
	Copper alloys	building – water supply pipes	0.2	0.80	0.95	
		CuZn38 cast – uniterruptible power supply (UPS)	0.2	0	0.93	R_2 value is valid for all steel types used in UPS
	Copper telluride	photovoltaic panel	0.2	0	0	
	Lead	MATERIAL	0.2	0	0	
		building – sheet	0.2	1	0.95	
		lead-acid batteries	0.2	0.80	0.99	
	Antimony	MATERIAL	0.2	0	0	
		lead-acid batteries	0.2	0.79	0.99	
	Cadmium	MATERIAL	0.2	0	0	
		photovoltaic panel	0.2	0	0	
	Ferrite	MATERIAL	0.2	0	0	
		uniterruptible power supply (UPS)	0.2	0	0	
Paper	Paper	MATERIAL	0.2	0	0.62	
		graphic paper	0.5	0.21	n.a	
		packaging – corrugated – pads/box/inserts	0.2	0.88	0.75	

		packaging – paper sack	0.2	0	0.75	
		packaging – paper bag	0.2	0	0.75	
		packaging – carton board/inserts	0.2	0.47	0.75	
		packaging – solid board box	0.2	0.47	0.75	
		packaging – solid board box – bleached	0.2	0.47	0.75	
		packaging – liquid beverage carton	0.2	0	0.43*	Values in the R_2 cells refer to the recycling input rate, and they refer to liquid beverage carton (including paper, plastics and aluminium). The conversion to the recycling output rate (R_2) for the three materials is included in the EF -compliant dataset for the recycling of liquid beverage carton.
		Tissue paper	0.5	0.25	0	
Plastics	PET	MATERIAL	0.5	0	0	
		packaging – bottle	0.5	0	0.42	
	ABS	MATERIAL	0.5	0	0	
		uniterruptible power supply (UPS)	0.5	0	0.7	
	PE	MATERIAL	0.5	0	0	
		building – water supply pipes	0.5	0	0	
		PE-LD building and construction	0.5	0	0.275	
		PE-HD building and construction	0.5	0	0.225	
		PE-LD uniterruptible power supply (UPS)	0.5	0	0.70	
		PE-HD uniterruptible power supply (UPS)	0.5	0	0.70	
	PMMA	MATERIAL	0.5	0	0	
		uniterruptible power supply (UPS)	0.5	0	0.7	

PP	MATERIAL	0.5	0	0	
	building and construction	0.5	0	0.183	
	Lead-acid batteries	0.2	0	0.000	
PS	MATERIAL	0.5	0	0	
	building and construction	0.5	0	0.067	
EPS	building and construction	0.5	0	0.067	
PVC	building and construction	0.5	0	0.321	
	uniterruptible power supply (UPS)	0.5	0	0.00	
PA polyamide	building – water supply pipes	0.5	0	0	
	uniterruptible power supply (UPS)	0.5	0	0.7	
PVDF	building – water supply pipes	0.5	0	0	
PPSU	building – water supply pipes	0.5	0	0	
Polycarbonate PC	packaging – water	0.5	0	0.29	R_2 values refer to Generic plastics "packaging-generic"
	uniterruptible power supply (UPS)	0.5	0	0.7	
Generic plastics	packaging – generic	0.5	0	0.29	
	packaging – liquid beverage carton	0.5	0	0.43*	Values in the R_2 cells refer to the recycling input rate, and they refer to liquid beverage carton (including paper, plastics and aluminium). The conversion to the recycling output rate (R_2) for the three materials is included in the EF -compliant dataset for the recycling of liquid beverage carton.

Glass	Glass	MATERIAL	0.2	0	0	
		packaging – container glass unspecified colour	0.2	0.52	0.66	
		packaging – container glass colourless (flint)	0.2	0.40	0.66	
		packaging – container glass green colour	0.2	0.80	0.66	
		packaging – container glass amber colour	0.2	0.50	0.66	
		Lead-acid batteries	0.2	0	0	
		photovoltaic panel	0.2	0	0	
Wood	Wood	packaging – pallet	0.8	0	0.3	
Batteries	unspecified	cordless power tool (CPT)	see comments box	0	0.45*	Values in the R_2 cells refer to the collection rate, and they refer to the whole product. The conversion to the recycling output rate (R_2) for the different materials is included in the EF -compliant dataset. A values of the different materials apply.
		Information and communication technology (ICT)	see comments box	0	0.45*	Values in the R_2 cells refer to the collection rate, and they refer to the whole product. The conversion to the recycling output rate (R_2) for the different materials is

						included in the EF -compliant dataset. A values of the different materials apply.
		e-mobility	see comments box	0	0.95*	Values in the R_2 cells refer to the collection rate, and they refer to the whole product. The conversion to the recycling output rate (R_2) for the different materials is included in the EF -compliant dataset. A values of the different materials apply.
Chemicals	Chromium	leather tanning	0.5	0	0.24	
	Powder coating	uniterruptible power supply (UPS)	0.5	0	0	
	sulphuric acid	Lead-acid batteries	0.5	0	0	
			Thermal insulation			
	Wood	pitched roof – rafters	0.8	0	0.38	
	Bitumen	vapour barrier flat roof	0.5	0	0	
	Bitumen	flat roof – fixing	0.5	0	0	
	Glass	vapour barrier flat roof	0.2	0	0	
	PU glue	flat roof – fixing	0.5	0	0	
	PP	pitched roof – sublayer	0.5	0	0	
	Wood	pitched roof – extensions oriented standard board (OSB)	0.8	0	0.38	
	PE	pitched roof – Vapour barrier (+ tape for fixing/closing holes)	0.5	0	0	
	Steel	pitched roof – screws	0.2	0	0.95	
	Cellulose	insulation	0.5	1	0	
	Glass wool	insulation	0.5	0.407	0	
	Stone wool	insulation	0.5	0.25	0	

	Wood fiber	insulation	0.8	0	0	
	Cellular glass	insulation	0.5	0.49	0	
	EPS	insulation	0.5	0.02	0.067	
	PU	insulation – PU insulation	0.5	0	0	
	Aluminum	insulation – Al facing in PU insulation product	0.2	0	0	
	Glass	insulation – glass facing in PU insulation product	0.5	0	0	
	XPS	insulation	0.5	0	0	
Olive oil	oilve oil	exhausted olive oil	0.5	0	0.3	
Rubbers	EPDM	building – water supply pipes; copper alloy fitting in pipes	0.5	0	0	
Textiles		t-shirts	0.8	0	0.11	R_2 is defined based on collection rate and the percentage of recycling after sorting.
Resins	Epoxy	uniterruptible power supply (UPS)	0.5	0	0	
Fibers	E-glass fiber	MATERIAL	0.5	0	0	
		uniterruptible power supply (UPS)	0.5	0	0	
	Aramid	MATERIAL	0.5	0	0	
		uniterruptible power supply (UPS)	0.5	0	0	
Fillers	Talc filler	MATERIAL	0.5	0	0	
		uniterruptible power supply (UPS)	0.5	0	0	

Table 38 *R_3 parameters to use in the circular footprint formula on municipal waste by waste operation*

	Landfill	Incineration	Landfill share	Incineration share
	Absolute values	Absolute values		
European Union (28 countries)	74561	61634	55%	45%
European Union (27 countries)	73148	61633	54%	46%
Belgium	46	2180	2%	98%
Bulgaria	2167	49	98%	2%
Czech Republic	1815	631	74%	26%
Denmark	65	2270	3%	97%
Germany	109	17559	1%	99%
Estonia	53	214	20%	80%
Ireland	1028	427	71%	29%
Greece	4507	0	100%	0%
Spain	12606	2038	86%	14%
France	9886	11845	36%	64%
Croatia	1413	1	100%	0%
Italy	10914	5970	65%	35%
Cyprus	423	0	100%	0%
Latvia	521	0	100%	0%
Lithuania	798	92	90%	10%
Luxembourg	62	123	34%	66%
Hungary	2415	336	88%	12%
Malta	196	1	99%	1%
Netherlands	131	4305	3%	97%
Austria	199	1716	10%	90%
Poland	5979	766	99%	1%
Portugal	2320	1091	68%	32%
Romania	4248	0	100%	0%
Slovenia	224	4	98%	2%
Slovakia	1152	174	87%	13%
Finland	672	1137	37%	63%
Sweden	28	2192	1%	99%
United Kingdom	10584	6514	62%	38%
Iceland	55	7	89%	11%
Norway	52	1446	3%	97%
Switzerland	0	2798	0%	100%
Montenegro	278	0	100%	0%
Former Yugoslav Republic of Macedonia, the	793		100%	
Serbia	1920	0	100%	0%
Turkey	25267		100%	
Bosnia and Herzegovina	898		100%	
Kosovo (under United Nations Security Council Resolution 1244/99)				

Values in Table 39 are applicable only to packaging materials.

Table 39 Qsin/Qp and Qsout/Qp values *to use in the circular footprint formula.*

	Default value (Qsin/Qp)	Default value (Qsout/Qp)
Glass	1	1
Steel	1	1
Aluminium	1	1
Other metals	1	1
Paper and cardboard This value shall be used when the recycling process doesn't consider fibre losses	0.85	0.85
Paper and cardboard This value shall be used when the recycling process considers fibre losses	1	1
PET – SSP recycling	1	1
PET mechanical recycling	0,9	0,9
PS	0.9	0.9
PP	0.9	0.9
HDPE	0.9	0.9
LDPE film	0.75	0.75

Appendix 5 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 this section, some parameter lists are included in this Appendix.

Table 40 *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	CÃ´te 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
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 41*. Nitrogen content in harvested products.*

Type of cultivation	Proxy	N-content harvested (kg N/tonne fresh product)	Source
Cultivation in soil	Onion	2.2	https://edepot.wur.nl/526774, Annex B, page 13
Soilless cultivation	Parameter N_{harv} is only applicable in formulas for cultivation in soil.		

Table 42*. Nitrogen in crop residues above and below ground.*

Type of cultivation	Proxy	Crop residues above and below ground (kg N/ha)	Source
Annual plants in soil	Onion	60	https://edepot.wur.nl/290558, Appendix III, page III-2 and III-3
Permanent plants in soil	Asparagus	33	https://edepot.wur.nl/526774 Annex A, page 12
Soilless cultivation	Crop residues not applicable in cultivation stage: it ends up in the use and end-of-life stage where it is judged negligible.		

Appendix 6 Inedible fractions

sub-category	product	inedible fraction	sub-category	product	inedible fraction
Leafy vegetables (except cabbage)	Lambs/Lollo Bionda/rosso, lettuce	0.10	Grain and pot vegetables	Peas	0.65
	Romaine/Batavia lettuce	0.20		Corn	0.30
	Endive	0.15		Broad beans	0.55
	Chicory	0.10	Stalk vegetables, sprouts	Onion, sweet	0.05
	Leafy vegetables	0.15		Garlic	0.15
	Water/Chinese spinach	0.10		Leek	0.20
	Purslane	0.05		Shallot	0.25
	Turnip greens	0.10		Onion, normal	0.05
	Oak lettuce	0.20		Asparagus, green/white	0.20
	Frisee lettuce	0.15		Bamboo shoots	0.20
	Iceberg lettuce	0.20		Celery	0.30
	Lettuve head/dandelion lettice/lettuce n.s./lettuce red/spinach	0.20		Vegetable, stalk, n.s.	0.20
	Rocket	0.20		Vegetable, sprout, n.s.	0.35
	Corn salad	0.05		Soy sprouts	0.35
	Chard	0.50		Fennel	0.15
	Elephant ear	0.49	Unclassified, mixed fruits	Pear, n.s.	0.80
	Cress	0.30		Prickly pear	0.40
	Watercress	0.05		Strawberry	0.05
	Chicory	0.90		Apricot	0.22
Fruiting vegetables	Zucchini	0.10		Pineapple	0.50
	Tomato	0.05		Apple	0.15
	African eggplant	0.15		Awarra fruit	0.15
	Artichoke	0.55		Banana	0.30
	Eggplant	0.20		Berry, blue/red/white	0.02
	Pickle	0.05		Berry, huckle	0.02
	Avocado	0.28		Berry, goose	0.05
	Butterbeans/green beans/green pods	0.05		Berry, n.s.	0.05
	String beans	0.05		Black currant	0.02
	Vegetables, fruit, n.s.	0.17		Startfruit	0.03
	Cucumber	0.10		Lemon (flesh)	0.48
	Garter	0.05		Cranberry	0.02
	Lady's fingers/gumbo	0.05		Grapes n.s., blue/white	0.05
	Bell pepper, yellow	0.26		Fruit, citrus, n.s.	0.30
	Bell pepper, green/orange/red	0.20		Fruit, n.s.	0.25
	Pods	0.10		Fruit, non-citrus, n.s.	0.25
	Pumpkin	0.25		Pomegranate/grapefruit	0.40
	Indian beans/bitter melon	0.10		Guava	0.10
	Spanish pepper	0.13		Persimmon	0.02

	Sugar snap pea	0.10
	Tomato, normal/vine/beef	0.05
	Tomato, cherry	0.05
Root vegetables	Turnip	0.25
	Parsnip	0.10
	Red beet	0.20
	Vegetable, tuber, root, n.s.	0.20
	Burdock root	0.10
	Celeriac	0.30
	Swede	0.20
	Kohlrabi	0.20
	Radish	0.05
	Horseradish	0.10
	Radish	0.15
	Salsify	0.35
	Carrot n.s./winter carrot	0.10
Cabbages	Brown mustard/mustard greens	0.15
	Broccoli	0.45
	Cabbage, white	0.25
	Kale	0.45
	Cabbage, Chinese	0.15
	Cabbage, green/savoy, brussels sprouts	0.20
	Cabbage, n.s./oxheart	0.15
	Cabbage, red/white	0.15
	Bok choy	0.15
	Roman cauliflower	0.25
Mushrooms	Mushrooms	0.10
	Cherry	0.05
	Kiwi, golden/green	0.17
	Kumquat	0.11
	Lime	0.01
	Lychee	0.30
	Tangerine	0.40
	Mango	0.16
	Melon, cantaloupe	0.40
	Melon, honeydew	0.35
	Melon, galia	0.40
	Melon, cantaloupe/water	0.40
	Ogen melon	0.45
	Melon (cucumis melo)	0.35
	Tangor	0.24
	Nectarine	0.17
	Papaya	0.30
	Passion fruit	0.45
	Pear, hand	0.13
	Peach	0.165
	Pomelo	0.41
	Plums	0.08
	Orange	0.30
	Melogold grapefruit	0.40
	Tamarind	0.59
	Jamaincan tangelo	0.35

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