Product Environmental Footprint of the Representative Product for Fruits

Jeroen Weststrate, Quinta Bonekamp, Seval Cicek, Marisa Vieira, Ellie Williams, Roline Broekema, Irina Verweij-Novikova

WAGENINGEN
UNIVERSITY & RESEARCH

Product Environmental Footprint of the Representative Product for Fruits

Jeroen Weststrate,[1*] Quinta Bonekamp,[1] Seval Cicek,[1] Marisa Vieira,[2] Ellie Williams,[2] Roline Broekema,[1] Irina Verweij-Novikova[1]

1 Wageningen Economic Research
2 PRé Sustainability
*corresponding author, contact e-mail: jeroen.weststrate@wur.nl

Wageningen Social & Economic Research
Wageningen, June 2025

WAGENINGEN
UNIVERSITY & RESEARCH

Disclaimer

This is not a stand-alone document but should be read in parallel to the report 'Product Environmental Footprint Category Rules for Fresh Produce, Wageningen, Report 2025-038, Wageningen Social & Economic Research (Weststrate et al., 2025a). The purpose of this representative product study was to identify the most relevant impact categories, life cycle stages, processes and (direct) elementary flows and also to identify the data needs, all feeding into the methodology development for FreshProducePEFCR. The study is as much as possible conducted in line with Annex I and II of the Commission Recommendation (EU) 2021/2279 of 15 December 2021 on the use of the Environmental Footprint Method to measure and communicate the life cycle environmental performance of products and organisations (European Commission, 2021).

Contents

Preface

This document is offered to professionals who would like to learn more about the state of the art regarding the environmental footprint of fresh fruits. The document has been prepared by a group of international experts who also delivered similar work for the sector of floriculture - Product Environmental Footprint Category Rules for Cut Flowers and Potted Plants (FloriPEFCR). The development of PEFCR for Fresh Produce (FreshProducePEFCR) took place from January 2023 to April 2025. The work has been carried out by an international consortium of partners (the Technical Secretariat) led by Freshfel Europe. The development of the methodology followed as much as possible the most recent Guidance for developing Product Environmental Footprint Category Rules (PEFCR) published by the European Commission in 2021.

This technical document – Product Environmental Footprint Representative Product (PEF-RP) for fruits – is prepared with the following aims:
1. Identifying the most relevant impact categories;
2. Identifying the most relevant life cycle stages, processes and elementary flows;
3. Identifying data needs, data collection activities and data quality requirements.

This PEF-RP report follows the PEF-study template as provided in Part E of the Annex I and II of the Commission Recommendation (EU) 2021/2279 of 15 December 2021 on the use of the Environmental Footprint Method to measure and communicate the life cycle environmental performance of products and organisations (European Commission, 2021). and includes the characterised, normalised and weighted results. Some of the data used in this study are from primary sources and remain confidential.

Developing FreshProducePEFCR required intensive engagement of different stakeholders and substantial resources. However, collective sector efforts will see the wider sector benefit from this FreshProducePEFCR and succeed in reducing the environmental impact of fresh produce. The development and application of the PEF method is complex. The FreshProducePEFCR derives 16 important environmental indicators in total, among which are included climate change, resource use (fossils), toxicity, acidification, water use, and land use. The large number of indicators and the complex method result in heavy data demand on primary processes in the fresh fruit sector, i.e., on everything that a farmer decides upon. Some of the life cycle stages are modelled based on company-specific data because these have a large influence on the total impact on a product. Other stages are modelled using default data provided by the FreshProducePEFCR itself through rules and databases.

We would especially like to thank the organisations for providing company-specific data and for reflecting on the results of the representative product studies, which have contributed to the PEFCR methodology development. A special thanks goes to all the members of Freshfel Europe's Environmental Footprint Initiative for their valuable support and feedback during the process and studies.
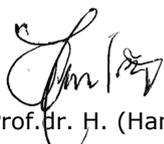
Prof.dr. H. (Hans) van Trijp
Institute Manager Wageningen Social & Economic Research
Wageningen University & Research

Acronyms

BSI	British Standards Institution
CF	characterisation factor
CFF	Circular Footprint Formula
CPA	Classification of Products by Activity
DC	distribution centre
dLUC	Direct Land Use Change
DQR	Data Quality Rating
EC	European Commission
EF	environmental footprint
EoL	end of life
FU	functional unit
GHG	greenhouse gas
GWP	global warming potential
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
JRC	Joint Research Centre
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact assessment
LU	Land Use
PEF	product environmental footprint
PEFCR	product environmental footprint category rules
PEF-RP	PEF study of the representative product
PY	person-year
RP	representative product
TS	Technical Secretariat

Definitions

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

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

Synonym of 'non-elementary flow'.

Acidification – Environmental Footprint (EF) impact category that addresses impacts due to acidifying substances in the environment. Emissions of NO_x, NH_3 and SO_x lead to releases of hydrogen ions (H^+) when the gases are mineralised. The protons contribute to the acidification of soils and water when they are released in areas where the buffering capacity is low, resulting in forest decline and lake acidification.

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

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

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

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

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.

Characterisation – calculation of the magnitude of the contribution of each classified input/output to their respective EF impact categories, and aggregation of contributions within each category.

This requires a linear multiplication of the inventory data with characterisation factors for each substance and EF impact category of concern. For example, with respect to the EF impact category 'climate change', the reference substance is CO_2 and the reference unit is kg CO_2 equivalents.

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

---

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

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.

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.

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

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

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

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.

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

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

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 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.

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.

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

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

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.

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.

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

Land use (LU) – 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).

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

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.

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.

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.

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).

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).

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.

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 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.

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).

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.

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 are not directly collected, measured or estimated by the company, but rather sourced from a third party LCI database or other sources.

Secondary data include 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.

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

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.

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.

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

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.

Summary

This representative product study was done in the context of the development of a methodology for calculating the environmental footprint of fresh fruits and vegetables; the Product Environmental Footprint Category Rules for Fresh Produce (FreshProducePEFCR, see Weststrate et al., 2025a). The results of this study feed into the method development for the FreshProducePEFCR, by identifying the most relevant impact categories, life cycle stages, processes and direct elementary flows for the sub-category fruits, as well as by identifying data needs, data collection activities and data quality requirements for the sub-category fruits.

The representative product in this report is a virtual (i.e., non-existing) product that reflects the average consumption of fruits at the European market. The representative product consists of apples cultivated in Poland (21%), apples cultivated in Italy (15%), oranges cultivated in Spain (19%), oranges cultivated in South-Africa (2%), bananas cultivated in Ecuador (19%), watermelons cultivated in Spain (11%), fresh grapes cultivated in Italy (7%), and strawberries cultivated in Spain (7%).

It should be noted that the virtual representative product does carry the risk that products and technologies with a relative low market share are overlooked, therefore the results of this study cannot be used to make statements about the environmental impact of the product-category fruits as such. No data quality rating has been applied in this study. This study is also not intended to be used in context of comparisons or for comparative assertions to be disclosed to the public.

The impact of 1 kilogram consumable fruits is calculated; this excludes the inedible parts of the fruits (e.g., peel). The study has a cradle-to-grave approach, meaning all stages of a fruit's life cycle are covered. A further split is applied: raw materials, pre-processing and starting materials; cultivation; post-harvest treatment, storage and handling; distribution; consumer packaging; retail; use; end-of-life. Product dependent and independent processes are excluded from the use phase, but inedible food losses are considered to fulfil the functional unt of 1 kilogram consumable fruit.

The life cycle inventory (LCI) has been compiled from a combination of company specific data and secondary data. Where no company specific data was available, secondary data sources such as academic literature and databases have been used. The Environmental Footprint life cycle impact assessment method version 3.1 was used to translate the emissions and resource extractions compiled in the LCI into environmental impacts.

The characterised, normalised and weighted results are shown in Table 1.

Table 1 *Characterised, normalised and weighted results of 1kg of the virtual representative product for fruits*

Impact category	Unit	Characterised result (unit)	Normalised result (person/year)	Weighted result (µPt)
Acidification	mol H+ eq	6.93E-03	1.25E-04	7.73E+00
Climate change	kg CO_2 eq	1.41E+00	1.86E-04	3.92E+01
Ecotoxicity, freshwater	CTU_e	6.12E+01	1.08E-03	2.07E+01
Particulate matter	disease inc.	8.02E-08	1.35E-04	1.21E+01
Eutrophication, marine	kg N eq	3.40E-03	1.74E-04	5.15E+00
Eutrophication, freshwater	kg P eq	3.07E-04	1.91E-04	5.34E+00
Eutrophication, terrestrial	mol N eq	2.26E-02	1.28E-04	4.74E+00
Human toxicity, cancer	CTU_h	5.74E-09	3.32E-04	7.08E+00
Human toxicity, non-cancer	CTU_h	1.69E-08	1.32E-04	2.42E+00
Ionising radiation	kBq U^{235} eq	5.69E-02	1.35E-05	6.75E-01
Land use	Pt	4.54E+01	5.54E-05	4.40E+00
Ozone depletion	kg CFC11 eq	2.07E-07	3.95E-06	2.49E-01
Photochemical ozone formation	kg NMVOC eq	5.83E-03	1.43E-04	6.82E+00
Resource use, fossils	MJ	1.78E+01	2.74E-04	2.28E+01
Resource use, minerals and metals	kg Sb eq	8.88E-06	1.40E-04	1.05E+01
Water use	m^3 depriv.	6.48E+00	5.65E-04	4.81E+01

A hotspot analysis was conducted to determine what the main contributing elements are to the environmental impact of fruits. This hotspots analysis is used to determine data needs and data collection activities. The hotspot analysis results in an overview of the most relevant impact categories, life cycle stages, processes and direct elementary flows.

Impact categories that together contribute to at least 80% of the single overall score (ranked from high to low) are identified as most relevant impact categories. The most relevant impact categories identified in this study are:
- Water use
- Climate change
- Resource use, fossils
- Ecotoxicity, freshwater
- Particulate matter
- Resource use, minerals and metals and
- Acidification.

Life cycle stages that together contribute more than 80% to that impact category are identified as most relevant life cycle stage. The most relevant life cycle stages identified in this study are:
- 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 and
- Stage 7. Use stage.

Data needs and data collection activities for the product category fruits have been identified based on this study. Data needs and data collection activities can be found in Weststrate et al., 2025a.

The three main recommendations from this study are: 1) conduct a sensitivity analysis using a higher-tier level for nitrogen and phosphorus modelling; 2) investigate whether a more sophisticated emission modelling approach would be meaningful for plant protection products, and lastly 3) determine whether the results can be used as a benchmark for the product category fruits.

1   General information

This representative product (RP) study is carried out as part of the development of harmonised calculations rules to calculate the environmental footprint of fresh fruits and vegetables consumed at the European market. The study is conducted in line with the FreshProducePEFCR (Weststrate et al., 2025a) and aims to align with Annex I and II of the Recommendation on the use of the Environmental Footprint methods from the European Commission (2021) wherever possible. This RP study on fruits is one of the two RP studies that have been selected. The other study is on vegetables (Weststrate et al., 2025b). This final version of the PEF-RP study builds on the findings of the supporting study for mangoes and integrated feedback gathered from the public consultation and external review panel.

The representative product for fruits is composed of a virtual product, which reflects the average consumption (in kg/capita/year) of fruits at the European market. This approach covers all products in the sub-category fruits according to the Classification of Products by Activity (CPA) included in FreshProducePEFCR (Weststrate et al., 2025a). More general information of this study is shown in Table 2.

Table 2   *General information on representative product study of fruits*

Information	Description
Name of the product	Virtual Representative Product for Fruits
Product identification	Not applicable
Product classification:	See image 1 to 6 below

Image 1 - Apple (CPA 01.24.10)
Representative of pome fruits and stone fruits.

Image 2 - Orange (CPA 01.23.13)
Representative of citrus fruits

Image 3 - Banana (CPA 01.22.12)
Representative of tropical and sub-tropical fruits

Image 4 – Watermelon (CPA 01.13.21) *Representative of melons*

Image 5 - Fresh Grape (CPA 01.21.11) *Representative of table Grapes*

Image 6 – Strawberry (CPA 01.25.13) *Representative of other tree and bush fruits*

Date of publication of the PEF study	**April 2025**
Geographic validity of the PEF study	European Union + European Free Trade Association (EFTA) + United Kingdom (UK). Hereinafter referred to as 'European Market'.
Compliance with the PEF method	As much as possible aligned with Annex 1 & 2 of the Recommendation on the use of the Environmental Footprint Methods from the European Commission (2021)
Company presentation:	Organisations who have delivered data for this study remain confidential
Conformance to other documents (additional to the PEF method)	The work in this report is largely based upon previous work carried out in Public Private Partnership 'HoritFootprint' that launched the FloriPEFCR (Broekema et al., 2024) and HortiFootprint Category Rules (Helmes et al., 2020).

2 Goal of the study

The goal of this study of the representative product (RP study) is to perform an environmental footprint study for fruits that is the starting point for the FreshProducePEFCR development (Weststrate et al., 2025a). The RP study helps specifically to:

- Identify the most relevant impact categories for the sub-category fruits;
- Identify the most relevant life cycle stages, processes and direct elementary flows for the sub-category fruits;
- Identify data needs, data collection activities and data quality requirements for the sub-category fruits.

The target audience of this study are the members of the Technical Secretariat responsible for developing the FreshProducePEFCR, members of Freshfel Europe's Environmental Footprint Initiative (Freshfel Europe, 2023) and stakeholders in the wider fruits and vegetables sector.

The commissioner of this study is the Technical Secretariat of the FreshProducePEFCR, consisting of Freshfel Europe, Fresh Produce Centre the Netherlands, Dole, and Greenyard. The Technical Secretariat is part of the wider consortium, consisting next to the aforementioned parties of Royal FloraHolland, Glastuinbouw Nederland, ABN AMRO Bank N.V., Rabobank, Stichting MPS, and AQS Holding. The Technical Secretariat and consortium are technically supported by experts from Wageningen Social & Economic Research, PRé Sustainability, and Mérieux NutriSciences | Blonk, who all together complete the entire consortium of parties contributing to this project. The latter three parties have worked on either drafting or reviewing the LCA models and/or the report. This report was provided to the external review panel during the initial review round and prior to final publication. Additionally, it was shared as supplementary material during the first public consultation.

3 Scope of the study

The scope of the study describes the analysed system in detail and addresses the overall approach used to establish (I) the functional unit and reference flow, (II) system boundaries, (III) list of EF impact categories, (IV) additional environmental and technical information, and (V) assumptions and limitations.

3.1 Description of the product under study

The representative product for fruits is a virtual (i.e., non-existing) product that reflects the average fruit consumption (in kg/year/capita) on the European market. The virtual representative product is constructed according to the following corresponding CPA codes:
- CPA 01.24: pome fruits and stone fruits
- CPA 01.23: citrus fruits
- CPA 01.22: tropical and sub-tropical fruits
- CPA 01.13.2: melons[2]
- CPA 01.21: table grapes
- CPA 01.25: other tree and bush fruits.

These CPA codes together represent the entire product category for fruits. The full list of CPA codes relevant for this product category can be found in Section 3.2 of the FreshProducePEFCR (Weststrate et al., 2025a).

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 the period from 2017 to 2021) in each sub-category was selected. Consumption per capita is calculated based on data from FAOSTAT (production, population) and EUROSTAT (trade). The selected products were then traced back to country of origin. The countries were selected by ranking them in decreasing order of production volume (kg), starting from the top of the list, and including those that together account for 50% of the total EU consumption (kg). The resulting preliminary construction of the RP was consulted with the Technical Secretariat after which some minor adjustments were made to better reflect realistic market conditions and/or cultivation characteristics. Table 3 lists the selected products including relevant characteristics.

Table 3 *Products and producing countries selected per sub-category, including a description of the most relevant characteristics of the product*

Sub-category	Product	Country	Description
Pome fruits and stone fruits	Apples	Poland	Perennial crop, grown in open field in soil, long storage
		Italy	Perennial crop, grown in open field in soil, long storage
Citrus fruits	Oranges	Spain	Perennial crop, grown in open field in soil, post-harvest treatment
		South-Africa	Perennial crop, grown in open field in soil, post-harvest treatment, overseas
Tropical and sub-tropical fruits	Bananas	Ecuador	Perennial crop, grown in open field in soil, post-harvest treatment, overseas, ripening
Melons	Watermelon	Spain	Annual crop, grown in open field in soil
Table grapes	Fresh grapes	Italy	Perennial crop, grown in open field in soil, trellis system
Other tree and bush fruits	Strawberries	Spain	Annual crop, short cultivation cycle, grown in open field in soil, fumigation

---

[2] In the CPA structure, melons are included as sub-group within perennial crops, other fruits are not presented at this level.

The environmental impact of the virtual product is calculated based on the market shares of each product category the fruit is representing. Market shares are based on the average consumption of fruits in kilograms, per capita-year at the European market. In case more than one producing country is selected to ensure representativeness, the selected producing countries are (re)scaled based on the relative shares of the total consumption of that product (kg). Included market shares are illustrated in Figure 1.
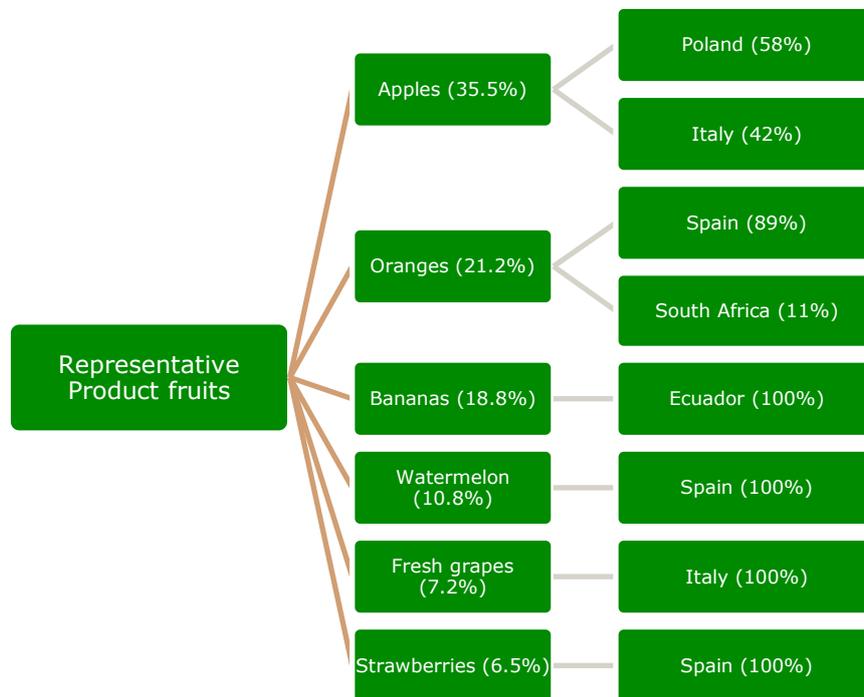

Figure 1   *Composition of the representative product, including market shares that are used to calculate the environmental impact (percentages may not add up to 100%, due to rounding). Market shares are based on the average consumption in kilograms, per capita-year on the European market*

3.2   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 describes qualitatively and quantitatively the function(s) and duration of the product in scope. The reference flow represents the amount of product needed to provide the defined function, with all other input and output flows in the analysis being quantitatively related to it.

The functional unit in this study is 1 kilogram of consumable fruits (i.e., excluding inedible parts), excluding preparation. Neither product independent processes (i.e., processes that have no relationship with the way the product is designed or used) or dependent processes (i.e., processes that are directly or indirectly determined or influenced by the product design or are related to instructions for using the product) in the use phase are included in this study. The reason for excluding these processes is that behaviour (e.g., preparation and storage) can vary across consumers and countries, and insufficient data were available to gain insights into this behaviour to design a meaningful default scenario. 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.

The nutritional content might possibly better reflect the primary functionality of fruits. However, the current state of science does not yet allow for fair comparisons that take into account the full range of nutritional properties. Since comparisons are made within the product category of fruits and it is expected that the

nutritional properties will not be at the heart of comparisons within this category, the functional unit of 1 kilogram is selected.

More characteristics of the functional unit are explained in Table 4.

Table 4   *Characteristics of the functional unit*

Aspect	Description
What?	To provide nutrition to humans
How much?	1 kilogram of consumable product, excluding preparation
How well?	According to the specification on consumer packaging or information otherwise known by the consumer related to the characteristics of the specific product.
How long?	According to the specification of the producer or the retailer and in accordance with the system boundary

Food losses at post-harvest treatment, storage, handling, distribution, consumer packaging and retail are quantified. It should be noted that the type of packaging might affect the shelf-life of fruits. The Technical Secretariat did not find sufficient data or methods to integrate this aspect into the functional unit satisfactorily.

3.3   System boundary

The following life cycle stages and processes are included in the system boundary: the entire life cycle (from cradle to grave) of fruits including the raw material production, pre-processing and starting materials, cultivation, post-harvest treatment and storage, distribution, consumer packaging and handling, retail, use, and end-of-life. A system boundary diagram is shown in Figure 2. Table 5 lists activities included in each life cycle stage.
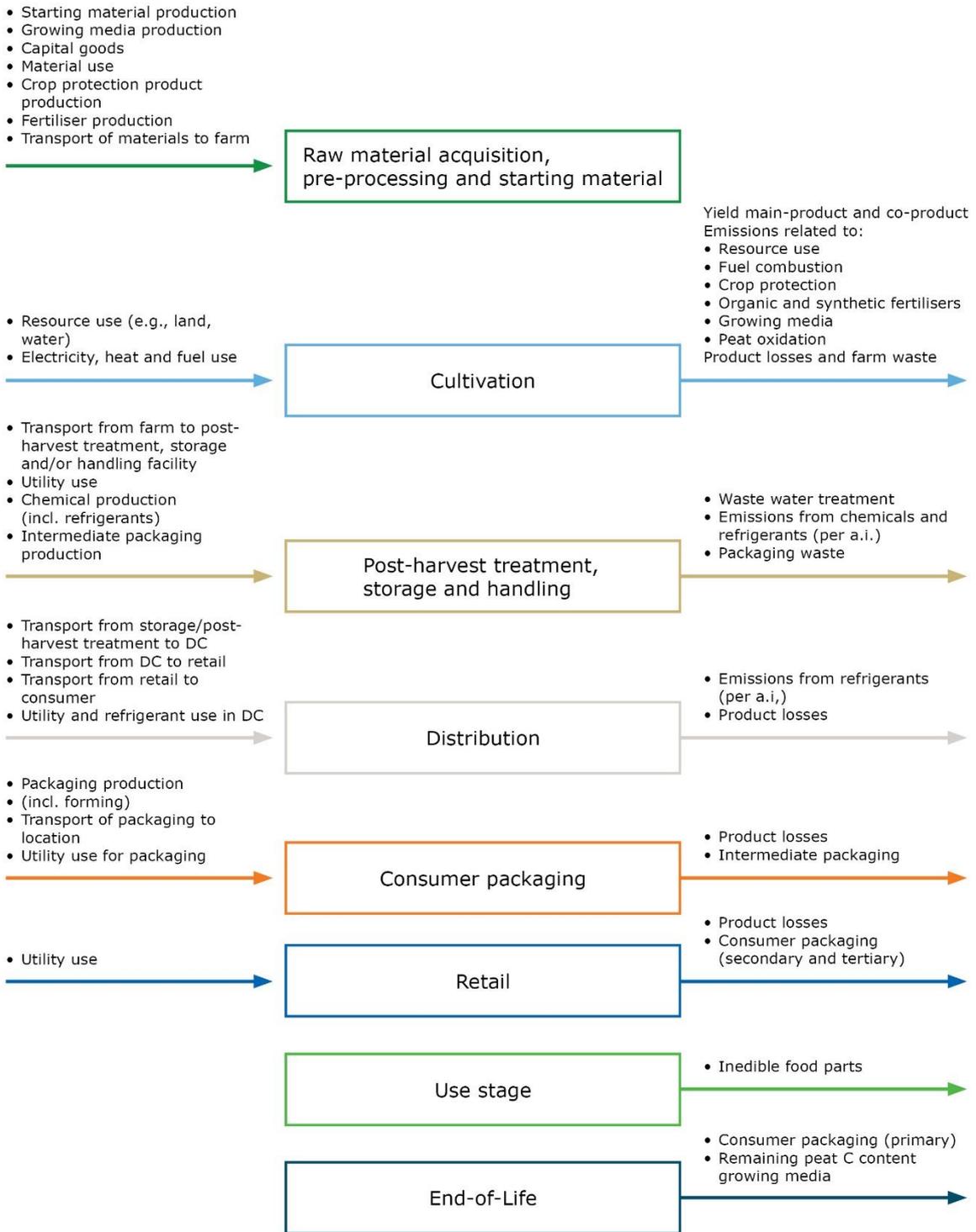
Figure 2   *Life cycle stages and processes included in the system boundaries*

Table 5 *Life cycle stages included*

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

3.4 Environmental Footprint impact categories

The Environmental Footprint (EF) impact assessment method documented in the most recent version of the PEF method is used, namely version 3.1. Table 6 lists all EF impact categories, impact category indicators, units, and their respective characterisation models included. The characterisation methods provide in characterisation factors that express how much a single unit of mass of the intervention contributes to an impact category.

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

Table 6 *List of EF impact categories with respective impact category indicators and characterisation models*

EF Impact category	Impact Category Indicator	Unit	Characterisation model	Robustness
Climate change (total) *Sub-category:[3]* • 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) and Frischknecht et al. (2000)	II
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC eq	LOTUS-EUROS model (Van Zelm et al., (2008) as applied in ReCiPe	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[4] • 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; 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
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq	CML 2002 (Guinée et al., 2002; Van Oers et al., 2002)	III
Resource use, fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)[5]	MJ	Van Oers et al. (2002) as in CML methods, v.4.8.	III

---

[3] 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 reported separately if they show a contribution of more than 5% each to the total score of climate change.

[4] This index is the result of the aggregation, performed by JRC, of the 4 indicators provided by LANCA model as indicators for LU.

[5] In the EF flow list, and for the current recommendation, Uranium is included in the list of energy carriers, and it is measured in MJ.

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 is available in Appendix 1.

Although all listed EF impact categories are included in the calculation of the weighted results, it is important to mention that 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 6. The differences in robustness have been taken into account in the weighting factors provided by the European Commission and should also be taken into account during interpreting the results of study.

3.5 Additional information

Relevant potential environmental impacts that may go beyond the EF impact categories are, whenever feasible, reported as additional environmental information.

Biodiversity
Biodiversity is considered relevant for this representative product study. However, the PEF method does not include any impact category named 'biodiversity', as currently there is no international consensus on an LCIA method capturing that impact. However, the PEF method included at least eight impact categories that have an effect on biodiversity (i.e., climate change, eutrophication (aquatic freshwater), eutrophication (aquatic marine), eutrophication (terrestrial), acidification, water use, land use, and ecotoxicity (freshwater)).

The topic is under discussion within the Agricultural Working Group of the European Commission. The FreshProducePEFCR (Weststrate et al., 2025a) is following the developments closely and intends to be updated once the issue is addressed.

3.6 Assumptions and limitations

All assumptions made during modelling are documented and reported in the LCI tables, and/or Section 5.2.

Assumptions
The assumptions made in the RP study are derived from deliberations and consensus within the TS, representing the most rigorous application of expert knowledge.
- When a transport distance was not known, the European average was used, as defined in section 6.1 or 6.4 of the FreshProducePEFCR.
- The production of capital goods, other than trellis systems, were excluded since their impact was negligible in the first version of the RP and this it falls under the 3% cut-off criteria.
- Primary, secondary, and tertiary packaging used, other than during distribution and/or consumer packaging of the product under study, e.g., the packaging of fertilisers, were excluded since their impact was negligible in the first version of the RP and this it falls under the 3% cut-off criteria.
- Transport of (food) waste to waste treatment is expected to have a negligible impact, this, it was not separately included and modelled.

Limitations

Limitations related to agricultural production:

- Characterisation factors for water extraction are provided at country-level, more granularity in the regionalisation of water flows would enable a more specific assessment of water scarcity;
- Biodiversity impacts that go beyond impacts covered in the current list of impact categories or additional environmental information are not fully covered in this FreshProducePEFCR;
- The production and application of biological pest control cannot be captured because of missing background data and characterisation factors;
- The fate of crop protection active ingredients (i.e., environmental compartment destination post-application) depends on the farm system, climate conditions, the distance to surface area, and the spraying technology. In this version of the FreshProducePEFCR, no specific emission model is recommended that differentiates fate factors based on these parameters;
- The EF 3.1 impact assessment method has country-specific characterisation factors (CFs) for ammonia and NO_x emissions to air and water for marine and terrestrial eutrophication for EU member states. This is acknowledged as a limitation in the evaluation of these impact categories for production sites outside the EU, which is frequently the case for fruits. 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;
- The system boundaries of this FreshProducePEFCR are focused on a single crop and its co-product(s). As a result, inter-crop rotation effects, such as Carbon and Nitrogen cycling, are (partly) neglected.

There are also limitations related to modelling life cycle stages further downstream in the life cycle:

- Product loss and waste may vary along the food supply chain, depending on, e.g., product type, practices (e.g., cooling), packaging, and geographical region. The PEF method prescribes a default of 10% for both distribution and retail, but does not indicate in what life cycle stage the losses should be attributed, nor does it account for different geographies, packaging, product types or practices. To solve the attribution part, retail-specific food losses are collected (see Section 4.2);
- Product volumes (excluding empty spaces and packaging) is used to allocate volume-based impacts, rather than density including packaging, due to a lack of data;
- In the context of PEF, the recycled content and end of life is modelled using the circular footprint formula (CFF). In this study, the CFF is not applied purely since the application of the CFF outside the PEF framework faces several shortcomings;
- Transport distances to market (e.g., point of sale) in background processes are not modelled in a PEF-compliant manner regarding transport distance and/or modality (see Section 4.2).

There are various limitations related to the composition of the representative product study:

- Technologies and transportation modes (e.g., airfreight) with a relatively low market share might be overlooked. The share of technologies and transportation modes in the overall consumption can be limited, whilst the environmental impact as a share of the consumption they represent is higher;
- Alternative production systems (e.g., regenerative, organic) are not included in this analysis;
- In practice, there is a large variety of products, production countries, and systems, etc. The absolute results of this RP study cannot be regarded as representative, but it is assumed that the general conclusions give a satisfactory indication of the hotspots (life cycle stages, impact categories, processes, and (direct) elementary flows).

Due to the study' composition and limitations, the results cannot be used to make statements about the sub-category fruits as such, nor are the results intended to be used in the context of comparison or for comparative assertions to be disclosed to the public.

4   Life Cycle Inventory Analysis

4.1   List and description of life cycle stages

For an overview and description of the life cycle stages, see Section 3.3. Please note that not all activities are applicable to all products part of the virtual representative product.

4.2   Modelling choices

All modelling choices are made in accordance with the FreshProducePEFCR. The following sub-paragraphs list the most relevant modelling choices.

Agricultural production:
- Wherever possible, an assessment period of three years is used to level out differences in crop yields related to fluctuations in growing conditions over the years such as climate, pests and diseases, etc. For perennial plants, a steady state situation (i.e., where all developments stages are proportionally represented in the studied time period) is constructed.
- Cutting wood (co-product in orchards), as well as co-products going to juice industry (e.g., apples and oranges) are assumed to have no monetary value.
- Emissions from pesticides are modelled per specific active ingredient using a default fraction to agricultural soil (90%), air (9%), and water (1%). Active ingredients not characterised in the EF-LCIA method are omitted. This might lead to an underestimation of the toxicity impacts related to pesticide application.
- Emissions resulting from the application of fertilisers are modelled using the default modelling approach as prescribed in the FreshProducePEFCR (Weststrate et al., 2025a). The following emissions are modelled:
  - Ammonia volatilisation (to air), based in IPCC Tier 1 (including NO_x emissions) (IPCC, 2019);
  - Direct and indirect nitrous oxide (to air), based on IPCC Tier 1 (IPCC, 2019);
  - Carbon dioxide from lime, urea and urea-compound application (to air), based on IPCC Tier 1 (IPCC, 2019);
  - Nitrate (to water), based on IPCC Tier 1 (IPCC, 2019);
  - Phosphorus (to soil), based on PEF-method (European Commission, 2021).
- The uptake of heavy metals by fruits is not considered.
- In case chemicals are used for post-harvest treatment purposes, these agents are most likely dissolved or mixed with water (e.g., via spraying). All water used is assumed to go to wastewater treatment, including any potential chemical contamination. No separate emissions are modelled.
- Production and use of refrigerant gases is being considered for storage of fruits (if applicable). Refrigerant gasses are assumed to be fully emitted to air.
- Emissions related to land occupation and land use change are modelled according to PAS 2050:2011 (BSI, 2011) and the supplementary document PAS2050-1:2012 (BSI, 2012) for horticultural products. All values are retrieved from the LUC (Land Use Change) Impact tool (Mérieux NutriSciences | Blonk, 2024).

Distribution:
- Transport distances, load factors and modalities are based on primary data wherever available. In case no primary data are available, the default scenario's as prescribed in section 6.4 of the FreshProducePEFCR are used (Weststrate et al., 2025a).
- Fust is assumed to be reused 100 times (Wehrmeijer, 2018). For other packaging materials, no reuse is assumed. The weight of packaging materials has been considered during transport, a correction for the reuse rate is applied.
- Average storage time at distribution centre is assumed to be 2 days (based on expert judgement);

- Average electricity use at distribution centre is assumed to be 30 kWh/m^3/year allocation to the product is done based on the storage volume (3 times the volume of the product) and storage time (Asselin-Balençon et al., 2022). The assumption is made that 50% of the building area stores products up to a hight of two meters;
- Average heat use at distribution centre is assumed to be 360 MJ/ m^3/year, allocation to the product is done based on the storage volume (3 times the volume of the product (Asselin-Balençon et al., 2022)) and storage time. The assumption is made that 50% of the building area stores products up to a hight of two meters;
- Food losses are assumed to be 50% trashed, 25% composted and 25% methanised. Product losses, (other than food losses) are assumed to be 100% recycled. These waste flows are modelled using a cut-off approach, thus the CFF is not applied.

Capital goods:
- The production of capital goods are not considered, as previous studies have shown they are not a relevant contributor to the overall environmental impact of horticultural products (Kan and Vieira, 2020; Broekema et al., 2024; Helmes et al., 2020). Except for trellis systems, where the materials used to construct these are taken into account;
- Energy and water use of capital goods during its use are included in the inventory data.

Retail:
- Average storage time at retail is assumed to be 1.5 days (based on expert judgement);
- Average electricity use at distribution centre is assumed to be 400 kWh/m^2/year for a general retail place dedicated to food and beverage products, and an additional amount of 1900 kWh/m^2/year for cooled products. Allocation to the product is done based on the storage volume (3 times the volume of the product (Asselin-Balençon et al., 2022)) and storage time;
- The average waste percentage for vegetables at retail is assumed to be 2.1% (Stichting Samen tegen Voedselverspilling, 2023).
- Food losses are assumed to be 50% trashed, 25% composted and 25% methanised. Product losses, (other than food losses) are assumed to be 100% recycled. These waste flows are modelled using a cut-off approach, thus the CFF is not applied.

Use stage:
- In alignment with the defined functional unit, neither product dependent and independent processes have been modelled;
- For comparability reasons, non-edible food losses considered in the reference flow to satisfy the functional unit of 1 kilogram consumable fruit. The waste of these non-edible parts are assumed to be 50% trashed, 25% composted and 25% methanised. The waste treatment of consumer packaging related to the non-edible food parts, are included in the EoL.

End-of-life modelling:
- The sensitivity analysis conducted indicates that recycling plays does not play a significant role in the fresh produce industry in most situations. In light of this, the TS evaluated the trade-offs between robustness, accuracy, comprehensiveness, and simplicity during the end-of-life (EoL) modelling process. The TS opts to integrate the CFF into the foreground modelling. However, no adjustments were made to the background modelling, as the existing approach was deemed sufficiently robust for the intended analysis.

Electricity use:
- Electricity use is modelled using the grid mix for the applicable country, because this is a representative product model and there was now information about market shared.
- For the stages after post-harvest treatment and storage. The average European grid mix is used to ensure representativeness.

Sampling procedure:
- No sampling procedure is applied.

Greenhouse gas emissions and removals:

- Three main categories of greenhouse gases emissions and removals are considered during modelling (I) fossil GHG emissions and removals, (II) biogenic carbon emissions and removals and (III) carbon emissions from land use and land use change;
- No simplified modelling approach was used to model biogenic carbon flows (not applicable);
- Credits associated with temporary and permanent carbon storage and/or delayed emissions are not being considered in the calculation of the climate change indicator. This means that all emissions and removals are considered as emitted 'now' and there is no discounting of emissions over time.

4.3 Handling multi-functional processes

In case of multifunctional processes (i.e., if a product has more than one function), all inputs and emissions linked to the process are partitioned between the product under study and the other co-products. Allocation rules applied in this study are specified in Table 7.

Table 7 *Allocation rules for activity data and elementary flows*

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, except for the mineral N fraction, which is allocated solely to the crop of application	If organic fertiliser is applied in a crop rotation scheme, the following calculation rules apply for fertilisation of N (BSI, 2012)(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 of the area (kg N/ area unit) • NcrT = nitrogen from crop residues of green manure on all of the area (kg N/ area unit) All other fertilising elements supplied using organic fertilisers, including green manure, are calculated by formula 2. Formula 2: (Calculating fertiliser application to a crop as part of a rotation scheme) Fapplied to crop A = aA/aT x (FOT) Where: • Fapplied to crop A = fertliser applied to crop A • aA = area of A (area unit) • aT = total area of rotation system (area unit) • FOT = organic fertiliser applied on all area (kg F/area unit)	

Process	Allocation rule	Modelling instructions	Allocation factor
Organic fertilisers	Manure used in conventional farming is considered as a zero-burden product unless farmers need to pay a price for the manure that exceeds transport costs. Manure is then treated as a co-product where economic allocation shall be used. If the animal farmer needs to pay a price to the party receiving the manure, it is treated as residual product. Economic allocation shall be applied for all other organic fertilisers originating from industrial processes.	For manure, as a zero-burden product, all activities needed after storage at the animal farm to application on the horticulture crop are included (thus including transport and processing if occurring). If manure has a price, then the price will be based on the revenues for the animal farmer (excluding transport costs) or the price will be based on a shadow price derived from equivalent quantities of artificial fertiliser needed.	
Energy use, cleaning and other generic operations in cultivation	Land occupation	When multiple crops are grown within the same system (plot/greenhouse), the relative land occupation of each crop shall be applied to allocate the interventions related to the inputs for which it cannot be specified. When possible, the system shall first be broken down into sub-systems, for instance into separated compartments within a greenhouse. Land occupation per crop shall be obtained by specific data for the analysed time period (this will include any changes in land occupation due to differences with planning, differences in production, etc.). When not available, the average land occupation per crop shall be used. This shall be calculated by adding together the land occupation per crop per phase using the following equation: $LO = \text{Sum over phases (p)} (GTp / PDp)$ Where: LO = land occupation ($yr*m^2$) GTp = growing time of phase p (yr) PDp = crop density of phase p (kg / m^2)	
Storage to single product	Volume and time	Only part of the emissions and resources emitted or used at storage systems shall be allocated to the product stored. This allocation shall be based on the space (in m^3) and time (in weeks) occupied by the product stored. For this the total storage capacity of the system shall be known, and the product-specific volume and storage time shall be used to calculate the allocation factor (as the ratio between product-specific volume*time and storage capacity volume*time). Further guidance on emission and resource allocation from storage can be found in European Commission (2021).	
(co-)products	Economic allocation or cut-off	If the sending party receives a price for (co-)products allocated to the processing industry that exceeds the transport costs, economic allocation shall be applied. Conversely, if the price does not exceed the transport costs, the (co-)product shall be considered a residual by-product, and a cut-off criterion shall be applied. Co-products refer to any material generated during the production of the primary product (e.g., wood produced during orange cultivation) or the primary product itself, which is considered unsuitable for direct human consumption without further processing (e.g., oranges intended for juice production). The physical separation between the main product and the co-product is likely to occur in a life cycle phase subsequent to cultivation. However, the environmental impacts shall be allocated to the cultivation phase. For example, apples are sorted into first-class apples for direct human consumption and those allocated for industrial use (e.g., juice production). If the price of apples directed to industry exceeds the transport costs, economic allocation shall be applied within the cultivation phase.	

4.4 Data collection

This section describes the data collection process and decision hierarchy applied to select data sources. Both company specific data and secondary data are used in this study. To select data sources, the decision hierarchy as illustrated in Figure 3 is used. The use of representative company-specific data prevails over any other data source. Data from academic literature prevail over other more general secondary data sources (statistics etc.).
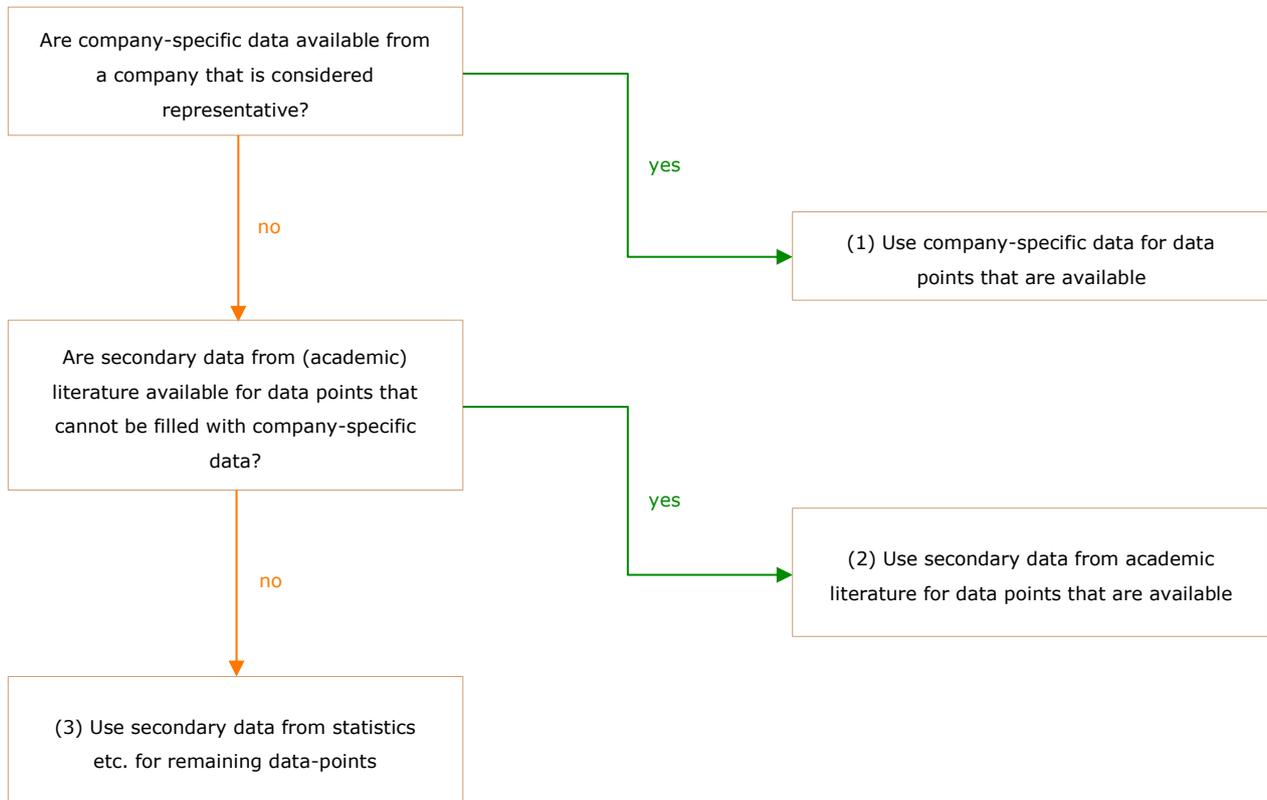

Figure 3   *Decision hierarchy for selection of data sources*

The selection of secondary data sources under point 3 is uniformly applied to similar inputs and outputs for all product under consideration. For example, if data on fertiliser use is not available for product X and Y, the same secondary data-source is used to ensure consistency.

Activity data are linked to corresponding LCI datasets. An overview of all datasets can be found in the supplementary document: 'FreshProducePEFCR_final – List of recommended datasets'.

The full life cycle inventory is available upon request to the TS coordinator that has the responsibility of distributing it with an adequate disclaimer about its limitations.

4.5 Data quality requirements and rating

No data quality rating has been applied in this PEF-RP study, since it was not modelled as a real product and therefore the Data Needs Matrix (DNM) cannot be applied.

5 Life Cycle Impact Assessment Results

5.1 Product Environmental Footprint results

This section included the EF results for the representative product of fruits. Characterised results per impact category and per life cycle stage are reported as absolute values in Table 8. Normalised results as absolute values are reported in Table 9 and weighted results as absolute values are reported in Table 10, where the total of all impact categories is the weighted results as single score. The single score results of 1 kilogram of the consumable representative product for fruits is 186.3 µPt.

The single score is obtained by first normalising the characterised results through dividing them by a normalisation factor. The applied normalisation factors are reported in Table A.1. The normalised results reflect the burdens that are attributed to a product in relation to the reference unit. Subsequently, the normalised results are multiplied by a set of weighting factors (in %) which reflects the perceived relative importance of the life-cycle impact categories considered. The applied weighting factors are reported in Table A.2.

Table 8   *Characterised results of the virtual representative product for all EF impact categories as absolute values per kg of fruits*

Impact category	Unit	Complete life cycle	Complete life cycle excl. use stage
Acidification	mol H$^+$ eq	6.93E-03	5.75E-03
Climate change	kg CO_2 eq	1.41E+00	1.20E+00
Ecotoxicity, freshwater	CTU_e	6.12E+01	5.69E+01
Particulate matter	disease inc.	8.02E-08	6.77E-08
Eutrophication, marine	kg N eq	3.40E-03	2.81E-03
Eutrophication, freshwater	kg P eq	3.07E-04	2.64E-04
Eutrophication, terrestrial	mol N eq	2.26E-02	1.86E-02
Human toxicity, cancer	CTU_h	5.74E-09	4.83E-09
Human toxicity, non-cancer	CTU_h	1.69E-08	1.46E-08
Ionising radiation	kBq U^{235} eq	5.69E-02	4.98E-02
Land use	Pt	4.54E+01	3.86E+01
Ozone depletion	kg CFC11 eq	2.07E-07	1.89E-07
Photochemical ozone formation	kg NMVOC eq	5.83E-03	4.87E-03
Resource use, fossils	MJ	1.78E+01	1.52E+01
Resource use, minerals and metals	kg Sb eq	8.88E-06	7.77E-06
Water use	m^3 depriv.	6.48E+00	5.71E+00

Table 9 *Normalised results of the virtual representative product for all EF impact categories as absolute values per kg of fruits (1 person-year reflects the contribution of 1 European citizen for 1 year to the respective impact category)*

Impact category	Unit	Complete life cycle	Complete life cycle excl. use stage
Acidification	person-year	1.25E-04	1.03E-04
Climate change	person-year	1.86E-04	1.59E-04
Ecotoxicity, freshwater	person-year	1.08E-03	1.00E-03
Particulate matter	person-year	1.35E-04	1.14E-04
Eutrophication, marine	person-year	1.74E-04	1.44E-04
Eutrophication, freshwater	person-year	1.91E-04	1.65E-04
Eutrophication, terrestrial	person-year	1.28E-04	1.05E-04
Human toxicity, cancer	person-year	3.32E-04	2.80E-04
Human toxicity, non-cancer	person-year	1.32E-04	1.13E-04
Ionising radiation	person-year	1.35E-05	1.18E-05
Land use	person-year	5.54E-05	4.72E-05
Ozone depletion	person-year	3.95E-06	3.62E-06
Photochemical ozone formation	person-year	1.43E-04	1.19E-04
Resource use, fossils	person-year	2.74E-04	2.35E-04
Resource use, minerals and metals	person-year	1.40E-04	1.22E-04
Water use	person-year	5.65E-04	4.98E-04

Table 10 *Weighted results as absolute values of the virtual representative product for all EF impact categories as absolute values per kg of fruits (microPoints (µPt) reflect the environmental impact score, as weighted with the EF weighting method)*

Impact category	Unit	Complete life cycle	Complete life cycle excl. use stage
Acidification	µPt	7.73E+00	6.41E+00
Climate change	µPt	3.92E+01	3.34E+01
Ecotoxicity, freshwater	µPt	2.07E+01	1.93E+01
Particulate matter	µPt	1.21E+01	1.02E+01
Eutrophication, marine	µPt	5.15E+00	4.26E+00
Eutrophication, freshwater	µPt	5.34E+00	4.61E+00
Eutrophication, terrestrial	µPt	4.74E+00	3.90E+00
Human toxicity, cancer	µPt	7.08E+00	5.97E+00
Human toxicity, non-cancer	µPt	2.42E+00	2.09E+00
Ionising radiation	µPt	6.75E-01	5.91E-01
Land use	µPt	4.40E+00	3.74E+00
Ozone depletion	µPt	2.49E-01	2.28E-01
Photochemical ozone formation	µPt	6.82E+00	5.70E+00
Resource use, fossils	µPt	2.28E+01	1.95E+01
Resource use, minerals and metals	µPt	1.05E+01	9.22E+00
Water use	µPt	4.81E+01	4.24E+01
Weighted result as single score	µPt	1.98E+02	1.71E+02

5.2   Additional information

No technical or environmental information is reported upon, since it is not deemed essential for achieving the goals of this study. The focus remains on the core data and analysis required to meet the study's objectives (see Section 2).

Table 11 *Most relevant impact categories and their contribution to the single score, most relevant stages and processes and their contribution to each impact category (where process that have a negative impact score are converted into positive scores)*

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

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
		Stage 7. Use stage RP Fruits	14.87	Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling	Cut-off	4.28			
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling	Cut-off	4.00			
				Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling	Cut-off	1.18			
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery	Cut-off	0.77			
				Corrugated board box {RoW}| corrugated board box production	Cut-off	0.65			
		Stage 2. Cultivation RP Fruits	7.66	Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery	Cut-off	4.23			
				Stage 2. Cultivation bananas {EC}	0.87	Dinitrogen monoxide	54.62	Air
						Carbon dioxide, fossil	45.35	Air
		Stage 3. Post-harvest handling and storage RP Fruits	7.60	Corrugated board box {RoW}| corrugated board box production	Cut-off	1.83			
				Fungicide, at plant {RER} Economic, S	1.41			
				Electricity, low voltage {PL}| market for electricity, low voltage	Cut-off	0.98			
				Corrugated board box {RER}| corrugated board box production	Cut-off	0.75			
		Stage 5. Consumer packaging and handling RP Fruits		Electricity, low voltage {PL}| market for electricity, low voltage	Cut-off	1.95			
				Corrugated board box {RER}| corrugated board box production	Cut-off	1.58			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	Cut-off	1.10			
		Stage 6. Retail RP Fruits		Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling	Cut-off	0.69			

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
Resource use, fossils	11.51	Stage 4. Distribution RP Fruits	58.27	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling	Cut-off	33.35			
				Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling	Cut-off	14.51			
				Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling	Cut-off	3.89			
				Heat, central or small-scale, natural gas {Europe without Switzerland}| market for heat, central or small-scale, natural gas	Cut-off	2.19			
				Electricity, low voltage {RER}| market group for electricity, low voltage	Cut-off	1.26			
				Transport, passenger car {RER}| transport, passenger car	Cut-off	0.89			
		Stage 7. Use stage RP Fruits	14.36	Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling	Cut-off	4.44			
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling	Cut-off	4.09			
				Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling	Cut-off	1.15			
		Stage 3. Post-harvest handling and storage RP Fruits	7.78	Fungicide, at plant {RER} Economic, S	2.10			
				Corrugated board box {RoW}| corrugated board box production	Cut-off	1.72			
				Electricity, low voltage {PL}| market for electricity, low voltage	Cut-off	0.89			
		Stage 5. Consumer packaging and handling RP Fruits		Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	Cut-off	2.12			
				Electricity, low voltage {PL}| market for electricity, low voltage	Cut-off	1.77			
				Corrugated board box {RER}| corrugated board box production	Cut-off	1.57			

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
		Stage 2. Cultivation RP Fruits		Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off	4.13			
Ecotoxicity, freshwater	10.47	Stage 2. Cultivation RP Fruits	71.87	Stage 2. Cultivation strawberries {ES}	53.00	Chloropicrin	56.55	Soil
						Chloropicrin	39.76	Water
				Stage 2a. Cultivation apples {PL}	10.78	Lambda-cyhalothrin	41.88	Water
						Tebuconazole	32.97	Soil
						Mancozeb	6.77	Water
				Stage 2. Cultivation fresh grapes {IT}	2.99	Tau-fluvalinate	46.34	Water
						Methiocarb	34.81	Water
				Stage 2a. Cultivation apples {PL}	1.44	Lambda-cyhalothrin	41.88	Water
						Tebuconazole	32.97	Soil
						Mancozeb	6.77	Water
		Stage 4. Distribution RP Fruits	10.83	Stage 2. Cultivation strawberries {ES}	4.19	Chloropicrin	56.55	Soil
						Chloropicrin	39.76	Water
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off	1.76			
		Stage 7. Use stage RP Fruits		Stage 2. Cultivation strawberries {ES}	1.75	Chloropicrin	56.55	Soil
						Chloropicrin	39.76	Water
				Stage 2a. Cultivation apples {PL}	1.36	Lambda-cyhalothrin	41.88	Water
						Tebuconazole	32.97	Soil
						Mancozeb	6.77	Water
		Stage 3. Post-harvest handling and storage RP Fruits		Stage 2a. Cultivation apples {PL}	1.49	Lambda-cyhalothrin	41.88	Water
						Tebuconazole	32.97	Soil
						Mancozeb	6.77	Water
		Stage 1. Raw materials RP Fruits		Trellis system, wooden poles, soft wood, tar impregnated {RoW}| trellis system construction, wooden poles, soft wood, tar impregnated | Cut-off	1.15			
		Stage 6. Retail RP Fruits		Stage 2. Cultivation strawberries {ES}	1.20	Chloropicrin	56.55	Soil
						Chloropicrin	39.76	Water

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
Particulate matter	6.1	Stage 4. Distribution RP Fruits	48.74	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling	Cut-off	30.50			
				Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling	Cut-off	11.74			
				Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling	Cut-off	1.91			
				Transport, passenger car {RER}| transport, passenger car	Cut-off	0.82			
		Stage 2. Cultivation RP Fruits	17.40	Stage 2a. Cultivation apples {PL}	4.00	Ammonia, PL	95.38	Air
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery	Cut-off	2.93			
				Stage 2. Cultivation bananas {EC}	2.35	Ammonia, EC	100	Air
				Stage 2a. Cultivation oranges {ES}	2.23	Ammonia, ES	100	Air
				Stage 2. Cultivation watermelons {ES}	2.21	Ammonia, ES	100	Air
				Stage 2. Cultivation strawberries {ES}	1.34	Ammonia, ES	100	Air
				Stage 2b. Cultivation apples {IT}	1.01	Ammonia, IT	100	Air
		Stage 7. Use stage RP Fruits	15.55	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling	Cut-off	3.74			
				Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling	Cut-off	3.60			
				Corrugated board box {RoW}| corrugated board box production	Cut-off	1.04			
				Stage 2. Cultivation watermelons {ES}	0.97	Ammonia, ES	100	Air
				Stage 2. Cultivation bananas {EC}	0.83	Ammonia, EC	100	Air
				Biowaste {RoW}| treatment of biowaste, industrial composting	Cut-off	0.73			

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
		Stage 3. Post-harvest handling and storage RP Fruits		Corrugated board box {RoW}| corrugated board box production	Cut-off	2.94			
				Corrugated board box {RER}| corrugated board box production	Cut-off	0.82			
				Stage 2a. Cultivation oranges {ES}	0.60	Ammonia, ES	100	Air
				Fungicide, at plant {RER} Economic, S	0.60			
		Stage 5. Consumer packaging and handling RP Fruits		Corrugated board box {RER}| corrugated board box production	Cut-off	1.73			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	Cut-off	0.79			
		Stage 6. Retail RP Fruits		Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling	Cut-off	0.64			
Resource use, minerals and metals	5.32	Stage 4. Distribution RP Fruits	36.34	Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling	Cut-off	17.19			
				Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling	Cut-off	10.17			
				Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling	Cut-off	2.03			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	Cut-off	1.80			
				Electricity, low voltage {RER}| market group for electricity, low voltage	Cut-off	1.46			
				Transport, passenger car {RER}| transport, passenger car	Cut-off	1.33			
		Stage 5. Consumer packaging and handling RP Fruits	27.02	Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	Cut-off	22.76			
				Electricity, low voltage {PL}| market for electricity, low voltage	Cut-off	1.36			
				Electricity, low voltage {IT}| market for electricity, low voltage	Cut-off	1.17			
				Corrugated board box {RER}| corrugated board box production	Cut-off	0.89			

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
		Stage 7. Use stage RP Fruits	12.54	Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling	Cut-off	3.11			
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling	Cut-off	2.11			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	Cut-off	1.53			
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery	Cut-off	0.74			
				Inorganic nitrogen fertiliser, as N {RoW}| nutrient supply from ammonium sulfate	Cut-off	0.65			
		Stage 1. Raw materials RP Fruits	9.53	Inorganic nitrogen fertiliser, as N {RoW}| nutrient supply from ammonium sulfate	Cut-off	1.83			
				Inorganic nitrogen fertiliser, as N {GLO}| nutrient supply from calcium nitrate	Cut-off	1.08			
				NPK (15-15-15) fertiliser {RER}| NPK (15-15-15) fertiliser production	Cut-off	0.90			
				Ammonium nitrate {RER}| ammonium nitrate production	Cut-off	0.65			
		Stage 3. Post-harvest handling and storage RP Fruits		Fungicide, at plant {RER} Economic, S	1.11			
				Corrugated board box {RoW}| corrugated board box production	Cut-off	0.91			
				Electricity, low voltage {PL}| market for electricity, low voltage	Cut-off	0.68			
		Stage 2. Cultivation RP Fruits		Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery	Cut-off	4.05			
				Electricity, low voltage {ES}| market for electricity, low voltage	Cut-off	0.98			

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
Acidification	3.91	Stage 4. Distribution RP Fruits	41.09	Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling | Cut-off	15.82			
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off	13.43			
				Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off	6.17			
				Electricity, low voltage {RER}| market group for electricity, low voltage | Cut-off	0.82			
				Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off	0.61			
				Transport, passenger car {RER}| transport, passenger car | Cut-off	0.59			
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off	0.57			
		Stage 2. Cultivation RP Fruits	17.91	Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off	6.47			
				Stage 2a. Cultivation apples {PL}	5.72	Ammonia, PL	88.38	Air
				Stage 2. Cultivation bananas {EC}	3.91	Ammonia, EC	100	Air
		Stage 7. Use stage RP Fruits	17.08	Transport, freight, sea, container ship with reefer, cooling {GLO}| transport, freight, sea, container ship with reefer, cooling | Cut-off	4.66			
				Transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 3.5-7.5 ton, EURO6, R134a refrigerant, cooling | Cut-off	1.89			
				Transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling {GLO}| transport, freight, lorry with refrigeration machine, 7.5-16 ton, EURO6, R134a refrigerant, cooling | Cut-off	1.65			
				Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off	1.58			
				Stage 2. Cultivation bananas {EC}	1.38	Ammonia, EC	100	Air
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery | Cut-off	1.18			
				Stage 2a. Cultivation apples {PL}	0.72	Ammonia, PL	88.38	Air
				Corrugated board box {RoW}| corrugated board box production | Cut-off	0.62			

Most relevant impact categories	[%]	Most relevant life cycle stages	[%]	Most relevant processes	[%]	Most relevant direct elementary flows	[%]	Compartment
		Stage 3. Post-harvest handling and storage RP Fruits	9.35	Corrugated board box {RoW}| corrugated board box production	Cut-off	1.77			
				Electricity, low voltage {PL}| market for electricity, low voltage	Cut-off	1.46			
				Fungicide, at plant {RER} Economic, S	1.19			
				Stage 2a. Cultivation apples {PL}	0.79	Ammonia, PL	88.38	Air
				Corrugated board box {RER}| corrugated board box production	Cut-off	0.69			
				Diesel, burned in agricultural machinery {GLO}| diesel, burned in agricultural machinery	Cut-off	0.69			
		Stage 5. Consumer packaging and handling RP Fruits		Electricity, low voltage {PL}| market for electricity, low voltage	Cut-off	2.92			
				Corrugated board box {RER}| corrugated board box production	Cut-off	1.46			
				Polyethylene terephthalate, granulate, bottle grade {RER}| polyethylene terephthalate production, granulate, bottle grade	Cut-off	0.92			
		Stage 1. Raw materials RP Fruits		NPK (15-15-15) fertiliser {RER}| NPK (15-15-15) fertiliser production	Cut-off	0.58			

6   Interpretation of EF results

6.1   Assessment of the robustness of the EF study

This version of the PEF-RP study contains a few aspects that influence the robustness of the study:
- The overall data quality rating (DQR) of this RP study is not assessed (see Section 4.5). This introduces uncertainty and limits the comparability and transparency of this study.
- The CFF has not been applied purely in the study. Although some waste treatment processes are identified as 'most relevant' their overall influence on the final results is considered minor.
- Company specific data is collected across Europe. Furthermore, the selection of secondary data sources is uniformly applied to similar inputs and outputs for all product under consideration. This is considered satisfactory to ensure a fair representation that aligns with the study's objective.

6.2   Hotspot analysis

The most relevant impact categories, life cycle stages, processes and elementary flows are identified according to the criteria in Table 12.

There is an important operational difference between most-relevant impact categories and life cycles stages on one hand and most relevant processes, and elementary flows on the other. In particular, most-relevant impact categories and life-cycle stages may be mainly relevant in the contact of communicating the results of a PEF study. They might serve to highlight environmental areas where the organisation should focus their attention. Identifying the most-relevant processes and elementary flows is more important for companies to identify actions for improving the overall footprint. This is particularly relevant for internal studies, to look deeper into how to improve the product's environmental performance.

The hotspot analysis is conducted using aggregated datasets.

Table 12   *Requirements to define most-relevant contributions*

Item	At what level does relevance need to be identified?	Threshold
Most-relevant impact categories	Single overall score	Impact categories that together contribute to at least 80% of the single overall score
Most-relevant life cycle stages	For each most-relevant impact category	All life cycle stages that together contribute more than 80% to that impact category.
Most-relevant processes	For each most-relevant impact category	All processes that together contribute (along the entire life cycle) more than 80% to that impact category, considering absolute values
Most-relevant (direct) elementary flows	For each most-relevant process, considering the most-relevant impact categories	All elementary flows that together contribute to at least 80% of the total impact of a most-relevant impact category for each most-relevant process. If disaggregated data are available: for each most relevant process, all direct elementary flows that together at least 80% to that impact category (caused by the direct elementary flow).

The most relevant impact categories in this study are (Figure 4):
- Water use;
- Climate change;
- Resource use, fossils;
- Ecotoxicity, freshwater;
- Particulate matter;
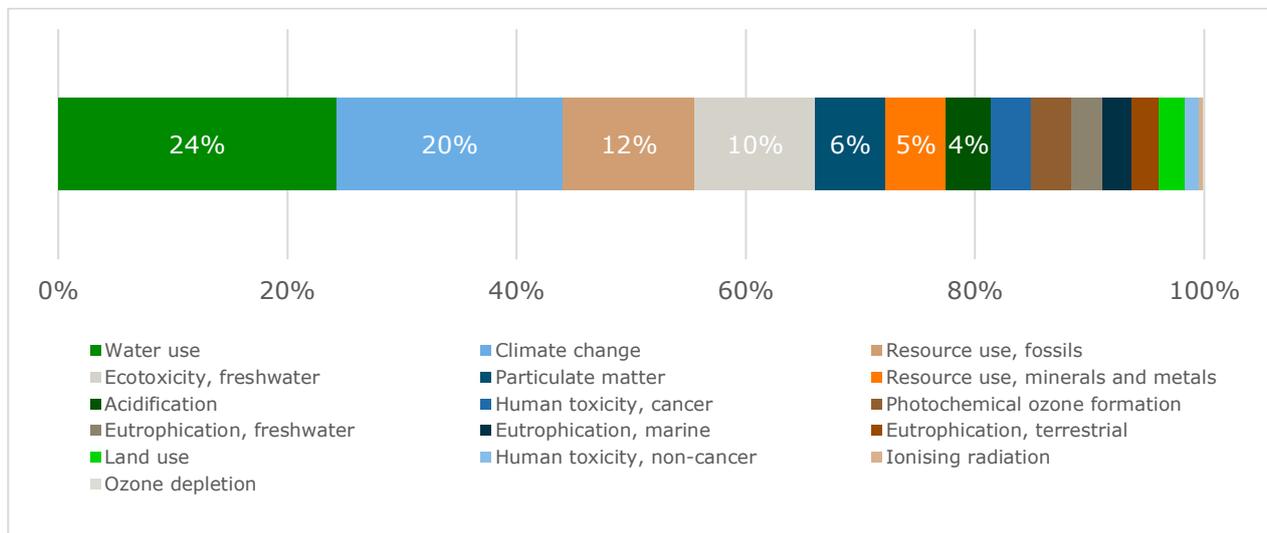- Resource use, minerals and metals; and
- Acidification.

Figure 4 *Normalised and weighted impact results of 1 kilogram of the representative product for fruits sorted from high to low contribution per impact category*

The most relevant life cycle stages in this study are (Figure 5):
- Stage 1. Raw material, pre-processing and starting materials;
- Stage 2. Cultivation;
- Stage 3. Post-harvest treatment, storage and handling;
- Stage 4. Distribution;
- Stage 5. Consumer packaging; and
- Stage 7. Use stage.

The complete list of most relevant impact categories, life cycle stages, processes and elementary flows can be found in Table 11.

6.3 Limitations and relationship of the PEF results relative to the defined goal and scope of the PEF study

The limitations and relationship of the PEF results relative to the defined goal and scope of the PEF study are the following:
- Data quality is not assessed for the overall RP, neither for the individual products the RP is composed of. Therefore, there is no insight in whether the underlying models are equally robust and the overall data quality of the study is sufficient. This introduces uncertainty and limits the comparability and transparency of this study.
- A large variation of data-sources has been consulted and used in the LCA models underlying this report. Due to the lack of sufficient data and/or methods, interlinkages between product characteristics and/or management practices (e.g., type of packaging material, food losses, transport modality) might not always be reflected accurately.

- The virtual RP does carry the risk that products and technologies with a relative low market share are overlooked, that might have a high environmental impact (e.g., airfreight). This might lead to an underestimation of the total environmental impact of fruits.
- Plant protection products are modelled as much as possible per active ingredient. Not all active ingredients are characterised by the EF impact assessment method. This might lead to an underestimation of the impacts for impact categories sensitive to the application of plant protection products (e.g., ecotoxicity).
- The Circular Footprint Formula (CFF) has not been applied purely. This is a significant deviation from the PEF method, although its implications in context of fresh produce are estimated small.

6.4   Conclusions and recommendations

The following is concluded:
- The most relevant impact categories identified in this study are Water use; Climate change; Resource use, fossils; Ecotoxicity, freshwater; Particulate matter; Resource use, minerals and metals and Acidification. These might serve to highlight environmental areas where actors along the fruit supply chain should focus their attention.
- The most relevant life cycle stages identified in this study are: Stage 1. Raw materials, Stage 2. Cultivation, Stage 3. Post-harvest treatment, storage, and handling, Stage 4. Distribution, Stage 5. Consumer packaging and Stage 7. Use stage. These might serve to highlight environmental areas where actors along the fruit supply chain should focus their attention.
- Primary and secondary data needs for this product category have been identified based on this study. Data needs can be found in the FreshProducePEFCR (Weststrate et al., 2025a).
- The Circular Footprint Formula is not fully interoperable with the background databases used in this study.

The following is recommended:
- Nitrogen and phosphorus emissions were calculated using the default approach from the FreshProducePEFCR (Weststrate et al., 2025a). These emissions contribute to at least tree impact categories identified as most relevant, i.e., climate change, particulate matter and acidification. It is recommended to conduct a sensitivity analysis using the preferred modelling approach as prescribed in FreshProducePEFCR.
- Ecotoxicity, freshwater is identified as one of the most relevant impact categories. Direct elementary flows causing this impact are related to pesticide application. It is recommended to test whether alternative emission modelling approaches (e.g., Pest-LCI) would substantially change the results.
- Explore alternative modelling approaches for emission modelling in post-harvest treatment.
- Conduct PEF studies on products and or technologies that are not well presented in the constructed in the RP, but might influence the conclusions drawn in this study (e.g., airfreight).
- Investigate the usability of the results to be used as a benchmark for the product category fruits.

Sources and literature

Asselin-Balençon, A., R. Broekema, H. Teulon, G. Gastaldi, J. Houssier, A. Moutia, V. Rousseau, A. Wermeille, V. Colomb, M. Cornelus, M. Ceccaldi, M. Doucet and H. Vasselon (2022). AGRIBALYSE 3: la base de données française d'ICV sur l'Agriculture et l'Alimentation. Methodology for the food products. Initial publication Agribalyse 3.0 - 2020, update 3.1 - 2022 Ed. ADEME 2022.

Beck, T., U. Bos, B. Wittstock, M. Baitz, M. Fischer and K. Sedlbauer (2010). 'LANCA Land Use Indicator Value Calculation in Life Cycle Assessment – Method Report', Fraunhofer Institute for Building Physics.

Blonk, H., A. Kool, B. Luske, T. Ponsioen and J. Scholten (2009). Berekening van broeikasgasemissies door de productie van tuinbouwproducten. Blonk Milieu Advies, Gouda, 2009.

Bos, U., R. Horn, T. Beck, J.P. Lindner and M. Fischer (2016). LANCA® - Characterisation Factors for Life Cycle Impact Assessment, Version 2.0, 978-3- 8396-0953-8Fraunhofer Verlag, Stuttgart.

Broekema, R., R. Helmes, M. Vieira, P. Gual Rojas, T. Ponsioen, J. Weststrate and I. Verweij-Novikova (2024). *Product Environmental Footprint Category Rules for Cut flowers and Potted plants.* Wageningen, Wageningen Economic Research, Report 2024-023.

BSI (2011). PAS 2050:2011: Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. ICS code: 13.020.40. BSI – British Standards Institution. Retrieved from: https://biolatina.com/wp-content/uploads/2018/08/PAS2050.pdf.

BSI (2012). PAS 2050-1: 2012 Assessment of Life Cycle Greenhouse Gas Emissions from Horticultural Products.' BSI - British Standards Institution.

European Commission (2021). Commission Recommendation (EU) 2021/2279 of 15 December 2021 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations. Official Journal of the European Union L 471 of 30 December 2021, pp 1-396. http://data.europa.eu/eli/reco/2021/2279/oj.

Fantke, P., J. Evans, N. Hodas, J. Apte, M. Jantunen, O. Jolliet and T.E. McKone (2016). Health impacts of fine particulate matter. In: Frischknecht, R. and O. Jolliet (Eds.), Global Guidance for Life Cycle Impact Assessment Indicators: Volume 1. UNEP/SETAC Life Cycle Initiative, Paris, pp. 76-99. Retrieved Jan 2017 from www.lifecycleinitiative.org/applying-lca/lcia-cf/.

Freshfel (2023). Freshfel Environmental Footprint Initiative. Freshfel. Accessed from: https://freshfel.org/projects/freshfel-environmental-footprint-initiative/.

Frischknecht, R., R. Steiner and N. Jungbluth (2008). The Ecological Scarcity method – Eco-Factors 2006. A method for impact assessment in LCA. Environmental studies no. 0906. Federal Office for the Environment (FOEN), Bern. 188 pp.

Guinée, J.B., M. Gorrée, R. Heijungs, G. Huppes, R. Kleijn, A. de Koning, L. van Oers, A. Wegener Sleeswijk, S. Suh, H.A. Udo de Haes, H. de Bruijn, R. van Duin and M.A.J. Huijbregts (2002). Handbook on Life Cycle Assessment. Operational Guide to the ISO Standards. Kluwer Academic Publishers. Dordrecht.

Helmes, R., T. Ponsioen, H. Blonk, M. Vieira, P. Goglio, R. van den Linden, P. Gual Rojas, D. Kan and I. Verweij-Novikova (2020). Hortifootprint Category Rules; Towards Product Environmental Footprint Category Rules for horticultural products. Wageningen, Wageningen Economic Research, Report 2020-041.

IPCC. (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (E. Calvo Buendia, K. Tanabe, A. Kranjc, J. Baasansuren, M. Fukuda, Ngarize S., A. Osako, Y. Pyrozhenko, P. Shermanau, & S. Federici, Eds.; Vol. 4). IPCC. https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol4.html.

IPCC (2021). Climate Change 2021: The Physical Science Basis. Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate ChangeIPCC Sixth Assessment Report. Accessed from: https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf.

Mérieux NutriSciences | Blonk. (2024). *LUC impact Tool*. https://blonksustainability.nl/tools-and-databases/LUC-impact.

Posch, M., J. Seppälä, J.-P. Hettelingh, M. Johansson, M. Margni and O. Jolliet (2008). The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA. Int. J. Life Cycle Assess., 13 (2008), p. 477.

Saouter, E., F. Biganzoli, L. Ceriani, R, Pant, D. Versteeg, E. Crenna and L. Zampori (2018). Using REACH and EFSA database to derive input data for the USEtox model. EUR 29495 EN, Publications Office of the European Union, Luxemburg, ISBN 978-92-79-98183-8, doi: 10.2760/611799, JRC 114227.

Seppälä, J., M. Posch, M. Johansson and J.P. Hettelingh (2006). Country- dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated Exceedance as an Impact Category Indicator. International Journal of Life Cycle Assessment 11(6): 403-416.

Stichting Samen tegen Voedselverspilling (2023). Voedselverspilling supermarkten daalt met 17,4% t.o.v. 2018 (in Dutch, Food waste in supermarkets has decreased by 17.4% compared to 2018). Accessed from: https://samentegenvoedselverspilling.nl/kennisbank/voedselverspilling-supermarkten-daalt-met-17-4-t-o-v-2018.

Struijs, J., A. Beusen, H. van Jaarsveld and M.A.J. Huijbregts (2009). Aquatic Eutrophication. Chapter 6 in: Goedkoop, M., R. Heijungs, M.A.J. Huijbregts, A. De Schryver, J. Struijs and R. van Zelm (2009). ReCiPe 2008 - A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition.

UNEP (2016) Global guidance for life cycle impact assessment indicators. Volume 1. ISBN: 978-92-807-3630-4. Available at: http://www.lifecycleinitiative.org/life-cycle-impact-assessment-indicators-and- characterization-factors/.

Van Oers, L., A. de Koning, J.B. Guinee and G. Huppes (2002). Abiotic Resource Depletion in LCA. Road and Hydraulic Engineering Institute, Ministry of Transport and Water, Amsterdam.

van Rossum, C., Sanderman-Nawijn, E., Brants, H., Dinnissen, C., Jansen-van der Vliet, M., Beukers, M., & Ockë, M. (2023). *Publication The diet of the Dutch. Results of the Dutch National Food Consumption Survey 2019- 2021 on food consumption and evaluation with dietary guidelines*. https://doi.org/https://doi.org/10.21945/RIVM-2022-0190.

Van Zelm, R., M.A.J. Huijbregts, H.A. den Hollander, H.A. van Jaarsveld, F.J. Sauter, J. Struijs, H.J. van Wijnen and D. van de Meent (2008). European characterisation factors for human health damage of PM10 and ozone in life cycle impact assessment. Atmospheric Environment 42, 441-453.

Wehrmeijer, M. (2018). *Reusable plastic boxes generate less environmental impact than disposable cardboard boxes in the distribution of fruit and vegetables in Spain*. https://www.europoolsystem.com/blog/news/reusable-plastic-boxes-generate-less-environmental-impact-than-disposable-cardboard-boxes-in-the-distribution-of-fruit-and-vegetables-in-spain-2/.

Weststrate, J., R. Broekema, M. Vieira, E. Williams, L. Schumacher, M. Hopman, D. Lucherini, Q. Bonekamp and I. Verweij-Novikova (2025a). Product Environmental Footprint Category Rules for Fresh Produce. Wageningen, Wageningen Social & Economic Research, Report 2025-038.

Weststrate, J., M. Vieira, E. Williams, M. Hopman, C. ten Pas, R. Broekema and I. Verweij-Novikova (2025b). Product Environmental Footprint of the Representative Product for Vegetables. Wageningen, Wageningen Social & Economic Research, Report 2025-040.

WMO (2014). World Metereological Organisation. Scientific Assessment of Ozone Depletion: 2014, Global Ozone Research and Monitoring Project Report No. 55, Geneva, Switzerland.

Appendix 1 List of EF normalisation and weighting factors

Table A.1 *Normalisation factors 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 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

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

To explore
the potential
of nature to
improve the
quality of life

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