Guidance document Open Access European Environmental Footprint of Food database (EFF database)

Reference: OC/EFSA/DATA/2021/03, Lot 2

Better Food. Better Health. Better World.

Mérieux NutriSciences | Blonk

National Institute for Public Health and the Environment
Ministry of Health, Welfare and Sport

About us

Mérieux NutriSciences | Blonk is a leading international expert in food system sustainability, inspiring and enabling the agri-food sector to give shape to sustainability. Our purpose is to create a sustainable and healthy planet for current and future generations. We support organizations in understanding their environmental impact in the agri-food value chain by offering advice and developing tailored software tools based on the latest scientific developments and data.

RIVM, the Dutch National Institute for Public Health and the Environment, works towards a healthy population living in a sustainable, safe and healthy environment. RIVM pursues those goals based on independent scientific research. Working with our commissioning clients, we identify the research that is needed and conduct studies accordingly. We provide advice to the government, to professionals and to members of the public, and share our knowledge. This is how RIVM supports society in staying healthy and keeping our environment healthy.

The data and methodology for the Open Access European Footprint of Food database has been developed by Blonk and reviewed by RIVM. Blonk and RIVM are co-author in the reports and publications delivered from this project.

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1. Introduction

Our food system today accounts for nearly one-third of global greenhouse gas (GHG) emissions, consumes large amounts of natural resources, causes biodiversity loss and negative health impacts due to both under- and over-nutrition and does not allow fair economic returns and livelihoods for all actors[1]. In view of this and in anticipation of the need in society for more information on nutritional and sustainability aspects of food and diets, the European Food Safety Authority (EFSA) is developing open access, high quality and harmonized databases on 1) food composition and 2) the environmental footprint of food, respectively lot 1 and lot 2 of the tender with Reference OC/EFSA/DATA/2021/03. These two databases will be linked via the FoodEx2[2] classification and description system for food items, a system developed and maintained by EFSA.

The Environmental Footprint of Food (EFF) database consists of a collection of Life Cycle Inventories (LCIs[3]) of food products, from cradle-to-grave. The goal of the Environmental Footprint of Food (EFF) database, more specifically the environmental impact results[4], is to inform users (consumers, scientists, government etc.) about the environmental impact of the products that are consumed. This guidance document describes the methodological approach, scope, data sources, data model and limitations of the EFF database and the environmental footprint results. The purpose is to provide as much transparency as possible with respect to the disclosed environmental footprints to facilitate future updates and to enable end users to apply the information in a robust way.

This guidance document includes the following topics:

- Scope of the database (Chapter 2)
    - Functional unit and system boundaries as starting point for the environmental footprint calculations
    - Environmental impact categories included in the environmental footprint calculations
    - Criteria used to select food products
    - Selected food products and coverage of FoodEx2 codes
- Creation of Life Cycle Inventories (LCIs) (Chapter 3)
- Approach to solving data gaps (Chapter 4)
- Modelling approach to develop the database including application of the PEF method (Chapter 5). See also note below.
- Data quality and representativeness (Chapter 6)
- Deviations from the PEF method (Chapter 7)
- Limitations of the EFF database (Chapter 8)
- Communication of the environmental footprint results (data model) (Chapter 9)
- Suggestions for additional FoodEx2 facets to further facilitate generation of environmental footprints of food products (Chapter 10)
- Review statement RIVM (Chapter 11)
- References (Chapter 12)

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[1] Source: Farm to fork strategy (link)

[2] See Chapter 3 and https://www.efsa.europa.eu/en/data/data-standardisation

[3] A life-cycle inventory is a quantification of energy and raw material requirements, atmospheric emissions, waterborne emissions, solid wastes, and other releases for the entire life cycle (from cradle-to-grave) of a product, process, or activity.

[4] The environmental impact results are generated by multiplying the life cycle inventory results with environmental impact or footprint (characterization) factors, see also Chapter 2.3.

This guidance is deliverable D1.2 of the first phase of the tender with Reference OC/EFSA/DATA/2021/03, Lot 2: The development of a European Environmental Footprint of Food database (EFF database).

Deliverable D1.2: Deliver a guidance for creation and maintenance of an Environmental Footprint of Food Database (EFF Database) based on the EF LCA models (in this document referred to as 'PEF method') in view of its use for assessment of the environmental impact of the EU dietary patterns, as reported in the EFSA Comprehensive European Food Consumption Database (Comprehensive Database).

Note: the environmental footprints of food products as disclosed in the EFF database are calculated via the so-called Life Cycle Assessment (LCA) framework. The European Commission has issued an EU harmonized method for LCA which is called the **Product Environmental Footprint (PEF) method**. The EFF database is developed as much as possible in accordance with this method and this guidance document often makes reference to it. When we refer to the **PEF method** we mean the Commission recommendation on the use of Environmental Footprint Methods as published on 16 December 2021[5]. This publication includes two annexes. Annex I explains the methodology and Annex II provides guidance on the methodology. In some cases, when referring to the PEF method, also the specific Annex or part of the Annex is mentioned.

[5] DG Environment, Commission recommendation on the use of Environmental Footprint Methods, Annex 1 and 2, 16 December 2021 (referred to as 'PEF method' throughout this document)

1.1 Disclaimer

In order to permit a license free distribution of the database results, Blonk has made use of background data that has a permissive license. This means that the EFF LCI database has been built using older, publicly available background datasets from ELCD6.

For the future development of the database, we recommend using EF-compliant background datasets related to energy production, packaging, and various other processes. These datasets are expected to become publicly available in the course of 2027 (EF4 core datasets).

Unfortunately, the currently used datasets are of lower quality compared to other, licensed, databases (such as Ecoinvent). As a result, the impact scores in certain categories are considered to be of a lower representativeness; particularly due to a lower time related representativeness in the ELCD background processes. The used background data has a proportionately high contribution to some specific impact categories.

When comparing impacts of the EFF database using ELCD background data to the impacts when modelled with other background data the following observations can be made:

1. The following impact categories are considered to be robust as they show a low sensitivity with regards to the background data used:
   - Climate change
   - Ozone depletion

2. There is a lower confidence on the accuracy of the following impact categories as specific datapoints turn out to be sensitive to the choice of background database:
   - Land use
   - Particulate matter
   - Acidification
   - Eutrophication, freshwater, marine and terrestrial
   - Resource use, fossils
   - Resource use, minerals and metals
   - Photochemical ozone formation

3. There is a low confidence on the accuracy of the following impact categories as they turn out to be very sensitive to the choice of background database:
   - Ionizing radiation
   - Human toxicity, non-cancer
   - Human toxicity, non-cancer – organics, inorganics and metals
   - Human toxicity, cancer
   - Human toxicity, cancer – inorganics, inorganics and metals
   - Ecotoxicity, freshwater
   - Ecotoxicity, freshwater - organics, inorganics and metals
   - Climate change – fossil, biogenic, land use and LU change
   - Water use

2. Scope of database

Chapter 2 describes what is included in the database with respect to the life cycle stages of food (Section 2.1), the reference basis for calculating the environmental impact of food (Section 2.2), the environmental impact categories that underly the environmental footprint calculations (Section 2.3), the applicable geographies of food production and consumption (Section 2.4) and the type of food products (section 2.5).

2.1 System boundaries

Key aspect: The life cycle inventories and the environmental footprint results will be provided for two system boundaries: cradle to supermarket and cradle to grave including all life cycle stages of food products

The system boundaries define which life cycle stages are analyzed. For life cycle inventories to be PEF compliant, all life cycle stages from raw materials up until the end-of-life treatment of a product are to be included.

A cradle to grave system boundary enables fair comparison between different products (e.g., pre-cooked vs raw food products). A drawback of choosing a cradle to grave system boundary, is that the life cycle stages 'consumption' and 'end of life' are very much influenced by individual consumer behavior and as such require particular modelling assumptions. For this reason, the environmental footprint figures are provided for both the cradle to supermarket (retail) system and the cradle to grave system as explained further in section 2.2.

The main life cycle stages of food products are schematically shown in Figure 1 and are further explained in Table 1. The consumption life cycle stage includes for example water, oil and energy needed to prepare the food (e.g. boiling water to cook pasta and oil to fry eggs) and also takes into account unavoidable food losses. Non-food related goods and materials (e.g. cup, pan, fridge, coffee filter) used during preparation and consumption, as well as cleaning activities (e.g. dishwashing) and waste treatment of frying oil have been excluded. This is further explained in Chapter 5.3.9.

Note that the life cycle stages within the cradle to grave system boundary can be different for the different product groups. For example, for plant-based food items (such as fruits, vegetables, and meat-replacers), the feed production and animal production stages are not applicable. More details on the activities per life cycle stage that are included in the environmental footprint calculations can be found in Table 1.

Figure 1. Cradle to supermarket and cradle to grave system boundaries

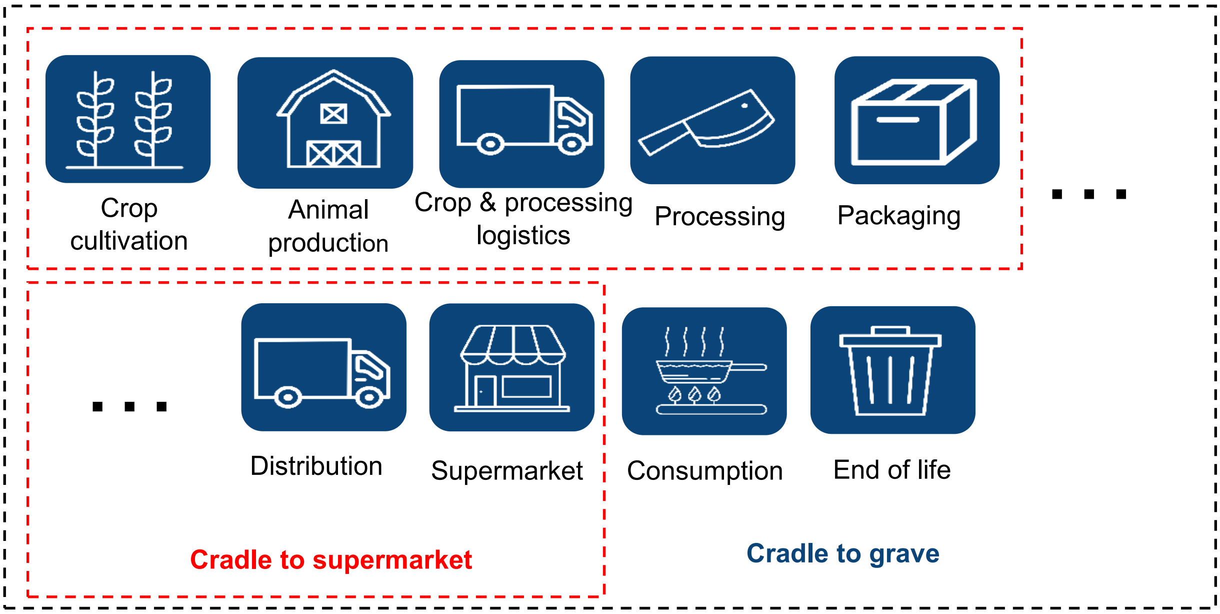


Table 1 Overview of life cycle stages and activities included in the environmental footprint calculations

Life cycle stages	Activities included	Activities excluded
Crop production	Production and transport of inputs (e.g. fertilizer, lime, pesticides, start material, etc.) Emissions during crop production Post harvesting of cereals, oilseeds and pulses (energy use for storage)	Carbon sequestration
Animal production	Animal husbandry (incl. also manure management and slaughtering), aquaculture and wild caught fishery Production and transport of inputs (incl. animal compound feed)	Capital goods (buildings)
(Crop and processing) Logistics	Transport of crops to processing facilities Transport of processed products to further processing facilities	
Processing	Processing crops into animal feed and food ingredients Pelleting of compound feeds Additional processing of processed food items Production of final food products	Capital goods (buildings)
Packaging	Production and transport of **packaging materials**	Tertiary packaging materials
Distribution	Transport from processing/packaging facilities to distribution centre Energy use for at distribution centre	
Supermarket	Transport from distribution centre to supermarkets (retail) Energy for storage at retail (supermarket) and end of life of food (due to food losses)	
Consumption	Transport from supermarket to consumer ('last mile') Energy needed to store (refrigerate/freeze) food Preparation of food (use of water, oil, gas/electricity) End of life of food due to inedible parts (unavoidable food losses) "Credits" for recycling packaging materials and energy recovery	Non-food related goods and materials (e.g. cup, pan, fridge, coffee filter) used during preparation and consumption, cleaning activities (e.g. dishwashing), waste treatment of frying oil. See explanation in Ch. 5.3.9
End-of-life	End of life of food due to avoidable food losses and primary packaging waste	

2.2 Functional unit and declared unit

Declared unit: all life cycle inventories and environmental footprint results are provided for 2 declared units: 1kg of raw (unprepared) food at supermarket and 1kg consumed food at consumer.

The functional unit (FU) is defined by specifying what function should be provided by the product, how much, how well and how long. It serves as the reference basis for all environmental footprint calculations. All input and output flows in the environmental impact analysis are related to the specified functional unit.

In some cases, products or product groups can fulfil multiple functions and it can be difficult to define one functional unit. The functions of food intake range from basic energy supply to even social or cultural functions, since due to overconsumption in parts of the world, the function of food intake is no longer restricted to the intake of required nutritional values. Because of this wide range of functions, it is not straightforward to state one functional unit. In this situation the PEF recommends applying a declared unit, such as mass or volume.

As mentioned in section 2.1, the life cycle stages ‘consumption’ and ‘end of life’ are very much influenced by individual consumer behavior. It may be useful to some users of the EFF database, to also gain insight in the environmental impact of food products as available in the supermarket (in this guidance called ‘raw, unprepared food’). For this reason, the environmental footprint figures will be provided for two declared units (reference flows):

- ***1kg of raw (unprepared)*** *food at supermarket (from cradle (crop cultivation) to supermarket) and*
- ***1kg of consumed food at consumer*** *(from cradle (crop cultivation) to grave (end-of-of life)*

Note: the environmental footprint of 1 kg consumed food at consumer cannot be compared with the environmental footprint of 1kg of the associated ‘raw’ food at supermarket. The reason for this is that you need either more or less of the amount of raw food for 1 kg of consumed food when you consider the removal of inedible parts (e.g. kiwi peeling), food wastage at home (e.g. due to the expiry date), or weight gain through cooking (e.g. 100 gram dry pasta becomes 250 gram after cooking).

2.3 Environmental footprint categories and impact assessment method

Key aspect: All 16 environmental impact categories of the EF 3.1 Method are used to determine the impact of all products in scope.

Table 2 below provides the overview of Environmental Footprint (EF) impact categories that are used for the calculation of the environmental footprint of the food products. There are 16 impact categories in the PEF method. The environmental impact assessment method used to calculate the environmental footprints is the Simapro adapted EF3.1method. The associated characterization factors can be downloaded at the website from the European Commission[6]. The LCI database has been created with Simapro version 9.6.

[6] EF3.1 reference package: https://eplca.jrc.ec.europa.eu/LCDN/developerEF.html

Table 2. Environmental Footprint Impact categories

Impact category	Indicator	Unit
Climate change, total	Radiative forcing as Global Warming Potential (GWP100)	kg CO_2 eq
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11eq
Ionising radiation, Human Health	Human exposure efficiency relative to U235	kBq U^{235} eq
Photochemical ozone formation, Human Health	Tropospheric ozone concentration increase	kg NMVOC eq
Particulate matter	Human health effects associated with exposure to small particulate matter (PM2.5)	Disease incidences
Human toxicity, cancer	Comparative Toxic Unit for humans (CTUh)	CTUh
Human toxicity, non-cancer	Comparative Toxic Unit for humans (CTUh)	CTUh
Acidification (terrestrial and freshwater)	Accumulated Exceedance (AE)	mol H+ eq
Eutrophication freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P eq
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N eq
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTUe)	CTUe
Land use	Soil quality index (Biotic production, Erosion resistance, Mechanical filtration, Groundwater replenishment)	Dimensionless (pt)
Water use	User deprivation potential (deprivation-weighted water consumption)	m^3 world eq.

Resource use, fossils	Abiotic resource depletion (ADP fossil)	MJ
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq

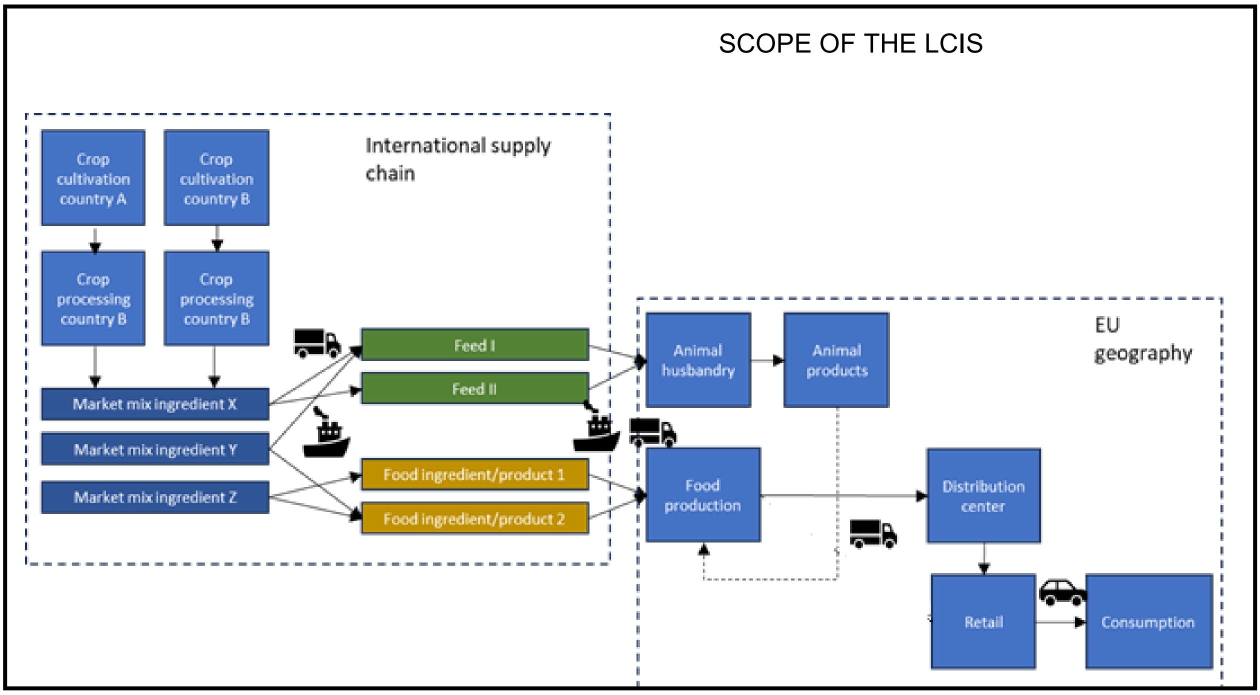
2.4 Geographical scope

Key aspects: The geographical scope of the LCIs and environmental footprint results is food consumed in the European Union, hereby taking into account the global supply chain of the food and feed ingredients.

The geographical scope of the database concerns food products that are consumed in the 27 member states of the European Union: Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden.

It should be noted that especially the cultivation of crops and the processing of feed and food ingredients take place on a global scale. This geographical spread is taken into account in the calculation of the environmental footprint of food via the market mixes. See Figure 2 below.

Figure 2 Geographical scope of food and FEED production showing for which life cycle stages only EU geography has been taken into account.



2.5 Selected food products

Key aspects: The starting point of the EFF database is food products that represent EU average food consumption patterns and that are (country) specific as much as possible.

The EFSA Comprehensive European Food Consumption Database (European Food Safety Authority (EFSA), 2022) is used to select the food products that are in scope of the EFF database. It is a source of information on food consumption and contains detailed EU-country specific data. To determine the scope of the EFF database, the results of all publicly available EFSA Comprehensive European Food Consumption Database surveys were aggregated. To ensure consistency and comparability of the surveys, we only included the surveys conducted after the publication of the EU Menu methodology in 2009[7]. This resulted in four excluded surveys as highlighted in the table 3 below. It should be noted that the surveys include countries that are not part of the EU. As described in the previous paragraph, for the environmental footprint calculations of the food products only the EU countries are taken into account.

Table 3. Included food surveys for scoping phase

Country	Start year	Include/exclude
Austria	2014	Include
Belgium	2014	Include
Bosnia and Herzegovina	2017	Include
Croatia	2011	Include
Cyprus	2014	Include
Czechia	2003	**Exclude**
Denmark	2005	**Exclude**
Estonia	2013	Include
Finland	2017	Include
France	2014	Include
Germany	2007	**Exclude**
Greece	2014	Include
Hungary	2018	Include

[7] EFSA, General principles for the collection of national food consumption data in the view of a pan-European dietary survey, 2009 https://www.efsa.europa.eu/en/efsajournal/pub/1435

Ireland	2008	**Exclude**
Italy	2018	Include
Latvia	2012	Include
Montenegro	2017	Include
Netherlands	2012	Include
Portugal	2015	Include
Romania	2019	Include
Serbia	2019	Include
Slovenian	2017	Include
Spain	2013	Include
Sweden	2016	Include

The EFSA Comprehensive European Food Consumption Database uses the food classification and description system FoodEx2. The FoodEx system (where the FoodEx2 is the second version of this system) is designed to facilitate the grouping of food items for exposure (for instance to toxins) calculations[8]. The exposure hierarchy is structured in seven levels with 21 groups at the top level. The top level (level 1) concerns very generic food groups such as **Dairy and dairy products**, **Legumes, nuts and oilseeds** and **Grains and grain-based products**. At this level the products are product categories and too generic to attribute environmental properties to, because the diversity within the category is too big. At the most detailed level (level 7), however, there are too many products to attribute environmental properties to. At the same time the differences between the products at this level can be very small in terms of composition and environmental impact. This level of detail does not have much added value for the EFF database.

For the scope of the LCI database, we chose the in-between hierarchy **level 4 of FoodEx2** as the starting point for selecting food products. Level 4 is the first level that allows to define specific food products (L3 still being too generic). In case the product at this or subsequent level(s) is not specific enough, the selection is done on a next level. "Specific enough" in this sense means that it is clear which ingredients are in the product.

Given the available resources for the first release of the database, it was decided to target food products consumed by the adult population only and which are representative of a normal diet. One exclusion with respect to the normal diet is made and concerns composite dishes such as pizzas and seafood salads. This L1 category composite dishes is mostly excluded as the variety is very large and moreover, the environmental impact can be compiled on basis of the ingredients. Only a few universal semi-composite dishes like plain cooked pasta, fried potatoes and meat balls are included.

[8] https://www.efsa.europa.eu/en/data/data-standardisation

Given this scope, prior to making the selection at L4, the following L1 categories (and the underlying L2 till L7 categories) are **excluded**:

- Food products for young population (infants and children),
- Products for non-standard diets and food supplements.[9]
- Composite dishes

When selecting the products at hierarchy level 4, **a cut-off criterium of 1%** is applied. This means that only those L4 food products are selected that account for more than 1% of the consumption in the corresponding L1 hierarchy level. In case a L4 product category is not specific enough, next level products (L5) are selected that together account for ≥80% of the consumption within the L4 category.

An example of the hierarchy structure for three different food products is shown in Figure 3. Firstly, the product on the left, **Canned sardines**, is a good example of a product where Level 4 (L4) **Canned/jarred fish** is not specific enough. In this case, three level 5 (L5) products are selected that together account for 86% of the consumption within level 4: **Canned tuna and similar**, **canned sardines and canned herring**. Secondly, for the product in the middle, **Butter**, L4 is already the most granular level and therefore sufficiently detailed. Thirdly, there are products for which even the L5 remains vague. The product on the right of the figure is a good example of this: **Flavoured milks**. In this case, we identify one representative product, e.g. in the case of Flavoured milks we select chocolate milk. In case an L4 or L5 product is a mixture, e.g.' jam, mixed fruit', the environmental footprint calculation is based on the average of the other products in the same category (e.g. average of all jams in scope).

The food products that are included in scope based on the described selection process and the associated FoodEx2 codes are listed in the Appendix (tab EFF scope), 272 products in total. Also, products that have been excluded from the selection due to overlap with other product categories and/or missing data are listed in this Appendix (tab EFF out of scope).

In the next chapter, we explain the selection of data sources that have been used to model the products.

[9] E.g. food for sporting people, dietary food for special medical purposes or vitamin and mineral supplements. Note: some meat and dairy imitates which also belong to this L1 category have been taken into account

Figure 3. FoodEx2 structure example for three different food products

Level 1	Fish, seafood, amphibians, reptiles and invertebrates	Animal and vegetable fats and oils and primary derivatives thereof	Milk and dairy products
Level 2	Fish and seafood processed	Fat emulsions and blended fats	Milk, whey and cream
Level 3	Processed or preserved fish (including processed offal)	Butter	Milk
Level 4	Canned/jarred fish	**Butter**	Flavoured milks
Level 5	**Canned tuna (69%)** **Canned sardines (10%)** **Canned herring (7%)**	Butter	Flavoured milks - e.g. **chocolate milk**

3. Creation of life cycle inventories

Key aspect: the environmental footprints are best created by calculation of environmental impact on the basis of Life Cycle Inventories (LCI). These LCIs need in turn data from other LCI databases, international statistics and LCA standards. The best data sources are dependent on the main impacting activities in the product's life cycle.

In order to calculate the environmental footprint of food products, it is best to (re-)calculate the environmental impact on the basis of Life Cycle Inventories (LCI), which are modelled in a consistent and pertinent manner. Using already available (eco) scores or carbon footprint figures is not recommendable as it is rather likely that they have been calculated on basis of different methodologies. The creation of LCI of food products require data from diverse sources, such as Life Cycle Inventory (LCI) databases, international statistics, literature and the PEF framework.

Several LCI databases exist with datasets for energy and transportation processes, packaging, crop cultivation, feed and animal production, food processing etc. In preparation of the development of the EFF database, 19 LCI databases were evaluated using the following criteria[10]:

1. Quality
2. Completeness
3. Accessibility
4. Compliancy with PEF method (DG Environment, 2021)
5. Up-to-date

The conclusion was that all 19 databases have their own strengths and weaknesses. There is no such thing as "one size fits all". Furthermore, the databases fulfilling several requirements are yet not necessarily the best option, given the context of the EFF. For instance, the LCI database Agribalyse[11] scores positive on most of the criteria but with respect to completeness (specifically geographical scope) the database scores negative as the datasets only apply to France. When developing a database for the whole of Europe, this will not be sufficient as it opposes consistency. Cherry picking of data from various databases is also not a preferred option, as this would result in incomparability. Different databases are not developed with a common methodology and use different assumptions and data sources, resulting in environmental footprint scores which cannot be compared and collected as a unified EFF. In addition, licensing constraints might limit the use of some databases.

For that reason, the selection of data sources should combine LCI and activity data and should be based on the PEF framework. Activity data are not the footprint data itself but the underlying data to calculate the environmental footprint. For example, to calculate the environmental footprint of cultivation of soybeans, farm data on yield, fertilizer application, water use for irrigation, pesticide use, and diesel use for machinery are needed, which will result in a LCI when emissions and use of input and resources are modelled. The most suitable activity data for the EFF database will be extracted from different sources within the databases in scope, depending on the footprint of products and processes that need to be calculated. For the first release of the EFF database, many LCI data from the Agrifootprint database are used as they are readily available by the EFF database generator (Blonk) and already in accordance with the PEF framework.

For LCI data not available in the Agrifootprint database, the approach to identify suitable data(base) sources is based on identifying the most relevant activity data. As an illustration, for a sample of 175 food products (representing the average European reference diet[12]), a so-called hotspot analysis was performed[8] to identify which life cycle stage has the biggest share in the contribution to the environmental footprint[13]. As a result, five groups (clusters) of foods were created, each defined by a life cycle stage that is most significant with respect to the contribution to the total carbon footprint. See figure 4.

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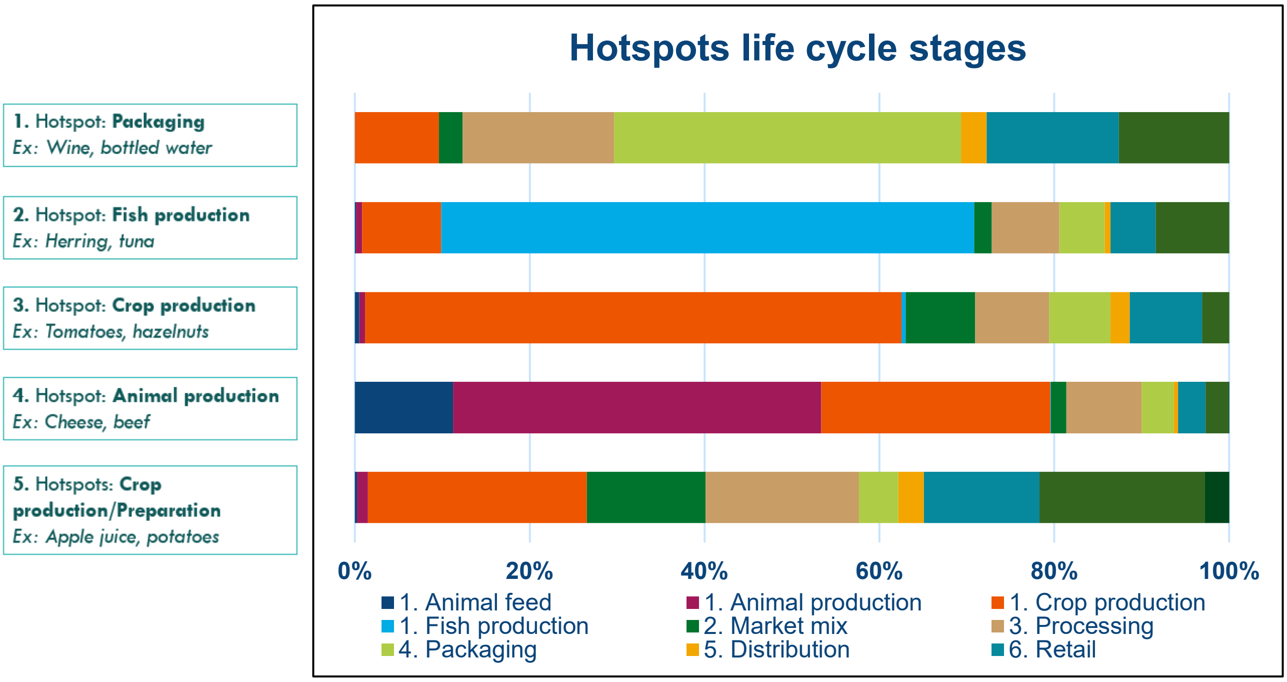
[10] Creation of open access Environmental Footprint of Food database (EFF Database), Deliverable 1.1.- Approach, 17-03-2023
[11] More information on Agribalyse can be found here: https://doc.agribalyse.fr/documentation-en/
[12] Optimeal EU data, see https://blonksustainability.nl/tools/more-databases/food-consumption-impact-datasets
[13] It was decided to use the climate impact indicator (in kg CO_2 equivalents, including Land Use Change and peat oxidation), because it is one of the most robust indicators and contributing most to the PEF single score.

Figure 4: contribution to total impact on Global warming - incl LUC and peat ox (kg CO2 eq)



Based on the hotspot analysis, key activity data points were defined for each significant life cycle stage, see Table 4. These activity data points are the main determinants for the environmental impact in the corresponding life cycle stage.

This means that when (LCI) data on food products need to be retrieved, the key activity data points of the respective products are determined on basis of which the most suitable data (base) source is identified. For example, for bottled food products, packaging is the hotspot activity data i.e., contributing most to the total environmental impact of these products. In this case, the quality of packaging data will be decisive in identifying a suitable data source.

Table 4 shows an indication (not exhaustive) of typical data sources for key activity data per life cycle stage. An extended overview of available data sources can be found in Supplementary materials S.3 of the earlier mentioned assessment[7].

Table 4. Life cycle stages and indication of some typical data sources for key activity data

Life cycle stage	Key activity data point	Data source
Crop production *(split in commodities/fruits and vegetables)*	Yield	FAOstat[14]; Eurostat[15]
	Fertilizer application	IFASTAT, 2021[16]; Heffer et al[17]
	Diesel consumption	Blonk model[18]
	Irrigation	Mekonnen & Hoekstra (Blue water footprint)[19]; Allen et al[20]
Animal production – pig/beef/poultry[21]	Feed composition	(mostly) GLEAM[22]
	Manure management system	UNFCC National Inventory submissions[23]
Animal production - Fish wild caught	Fuel consumption	Eurostat[24]
	Capital goods	Newton et al[25]

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[14] https://www.fao.org/faostat/en/#data
[15] https://ec.europa.eu/eurostat/databrowser/explore/all/all_themes?lang=en
[16] IFASTAT, Fertilizer consumption statistics, 2019 https://www.ifastat.org/
[17] Heffer, P., Gruère, A., Roberts, T., Assessment of fertilizer use by crop at the global level 2014-2014/15. International Fertilizer Association and International Plant Nutrition Institute 0–19, 2017
[18] van Paassen, M., Kuling, L., Vellinga, T., da Motta, R. de P. S., & de Boer, J. (2018). Energy model for crop cultivation
[19] Mekonnen, M.M., Hoekstra, a. Y., 2010a/b. https://www.waterfootprint.org/resources/Report-48-WaterFootprint-AnimalProducts-Vol1.pdf; https://www.waterfootprint.org/resources/Report47-WaterFootprintCrops-Vol1.pdf
[20] Allen et al., 1998 https://www.fao.org/3/x0490e/x0490e00.htm
[21] See also Agrifootprint 6 Methodology report, Part 2 https://blonksustainability.nl/tools-and-databases/agri-footprint
[22] https://www.fao.org/gleam/resources/en/
[23] https://unfccc.int/ghg-inventories-annex-i-parties/2023
[24] https://ec.europa.eu/eurostat/web/fisheries/database
[25] Newton et al., Life Cycle Inventories of Marine Ingredients, 2023 https://doi.org/10.1016/j.aquaculture.2022.739096

Animal production - Aquaculture production	Feed composition	Aas et al.[26]; FAO AFFRIS[27] Henriksson et al.[28]; Guy and Brown (AIFFD)[29]; Newton and Little[30]; Seafoodwatch[31]
	Fuel and energy use	Gephart et al.[32]
Crop and processing logistics	Transport mode	PEFCR Feed
	Transport distance	PEFCR feed, PEF defaults
Processing	Recipe (food composition)	EFSA[33]; Dutch Food Composition database[34] Blonk Food database
	Food (ingredient) processing	Very diverse for each process (listed in the LCIs). In general low contribution to total impact
Packaging	Material type	PEFCRs; Afvalfondsverpakkingen[35]
	Quantity	PEFCRs; Afvalfondsverpakkingen[31]
	Recycled content (reuse rates)	PEF – Circular footprint formula
Distribution	Transport mode	PEF defaults
	Transport distance	PEF defaults
	Energy consumption	Received from a Dutch retailer
	Food losses	PEF defaults

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[26] Aas et al., Utilization of feed resources in the production of Atlantic salmon (Salmo salar) in Norway: An update for 2020. *Aquaculture Reports*, 2022 https://doi.org/10.1016/j.aqrep.2022.101316
[27] FAO Aquaculture Feed and Fertilizer Resources Information System (AFFRIS) https://www.fao.org/fishery/affris/affris-home/en/
[28] Henriksson et al., Final LCA case study report - FINAL LCA Case Study Report - Primary data and literature sources adopted in the SEAT LCA studies. SEAT Deliverable D3.5—Annex report. Leiden, Netherlands, 2014
[29] Guy, C. S., and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data (AIFFD). American Fisheries Society, Bethesda, Maryland, 2007 https://fisheries.org/docs/books/55049C/com.pdf
[30] Newton, R. W., & Little, D. C., Mapping the impacts of farmed Scottish salmon from a life cycle perspective. *International Journal of Life Cycle Assessment*, *23*(5), 1018–1029, 2018. https://doi.org/10.1007/s11367-017-1386-8
[31] https://www.seafoodwatch.org/
[32] Gephart et al., Environmental performance of blue foods, 2021 https://www.nature.com/articles/s41586-021-03889-2
[33] https://zenodo.org/records/2537955
[34] https://nevo-online.rivm.nl/Home/En
[35] https://www.verpact.nl/sites/default/files/2023-03/Kopie%20van%20Standaard%20gewichten%20Groenten%20Fruit%20lijst%202022%20Website.pdf

Supermarket	Energy consumption	Received from a Dutch retailer
Consumption	Energy consumption	PEF defaults
	Raw-to-cook ratios and inedible factors	Received from RIVM[36]
End-of-life	Food losses	PEF defaults
	Losses/waste in supply chain	PEF defaults; FAO[37]
	Packaging waste	PEF – Circular footprint formula

4. Approach to solving data gaps

Key aspect: in case LCI data are missing to be able to calculate the environmental footprint, proxy data are selected. In future releases of the database, a data quality rating should be used based on the EF DQR method.

When collecting data to build LCIs for the EFF, even after screening the typical available sources, specific data gaps are likely to remain. For example, resulting LCIs might not be representative for specific countries and/or the available data do not (fully) represent specific products.

Usage of proxy data is normally reflected in the quality rating of datasets. However, the Data Quality Rating as prescribed by the PEF is only applied for market mixes in the EFF database. The reason is that this method is rather complex and time-consuming to implement this for all dataset and was therefore chosen only to implement this for market mixes where different modelling strategies are applied which has important influences on the precision and representativeness of the products, more on the next paragraphs and chapter 6.

4.1 Proxy market mixes

Starting from the product composition (recipes), an assessment has been made with respect to the required crops. Subsequently, for each EU country of consumption, the market mixes of these crops have been assessed. The market mix of specific raw materials is determined by adding the total import of the raw materials from various countries (FAO, 2023a) to a specific country with the national production of the same product (FAO, 2023b). To overcome large trade and production fluctuations from year to year, 5-year averages are used (2018-2022).

There are two types of market mixes considered: 1) Market mixes of crops (e.g. maize or coconuts) and 2) Market mixes of processed foods (e.g. flour or coconut milk). The minimum required coverage for each market mix is set at 50%.

[36] Dutch specific figures based on the Globodiet methodology as developed by the IARC
[37] https://www.fao.org/4/mb060e/mb060e.pdf

Market mix of crops

The FAO statistics do not provide cultivation data for each supplying country. A minimum of 50% market mix coverage per crop has been used for each EU country to overcome these cultivation data gaps (see also Agri-footprint Methodology report, part 2, Chapter 5 (Blonk, 2022)). If this 50% coverage could not be reached, the EU-average market mix was used instead, again using a minimum market mix coverage of 50%. The reason for the 50% threshold and using the European average market mix as a proxy is to limit the amount of desk research for retrieving the missing cultivation data.

An example is illustrated in the below table 5 for the market mix of avocado in Portugal (PT), and table 6 for Europe (EU-27). For avocados in Portugal the market mix coverage is 23% which is lower than the minimum of 50%. In this case, the market mix of Europe is used as a proxy for Portugal, reaching a 68% market coverage.

If an EU market mix proxy is required and the minimum coverage of 50% is not reached, desk research has been done to retrieve the missing cultivation data. For example, for blueberries the EU average market mix coverage is 0%. Spain and Poland are by far the main supplying countries and for these countries the cultivation data have been retrieved resulting in an EU market mix coverage of >50%.

Table 5 Market mix of avocado in Portugal

Supplying countries to Portugal (countries of cultivation of avocado)	Share in market mix of Portugal	Cultivation data available	Market mix coverage of avocado in Portugal
PE	12%	Yes	23%
ZA	5%	Yes	
MX	3%	Yes	
CL	2%	Yes	
MA	1%	Yes	
PT	**64%**	No	
ES	9%	No	
CO	2%	No	
KE	1%	No	

Table 6 Market mix of avocado in Europe (EU-27)

Supplying countries to EU-27 (countries of cultivation of avocado)	Share in market mix of EU-27	Cultivation data available	Market mix coverage of avocado in EU-27
PE	**36%**	Yes	68%
ZA	7%	Yes	
MX	8%	Yes	
CL	8%	Yes	
MA	3%	Yes	
IL	6%	Yes	
ES	13%	No	
CO	8%	No	
KE	7%	No	
PT	2%	No	
DO	1%	No	

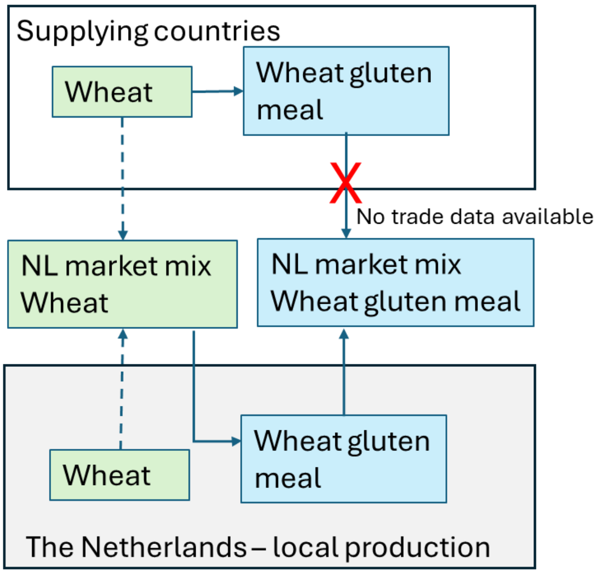
Market mixes of processed food

The FAO and Eurostat statistics do not provide trade data on all processed crops. For these processed crops we have two fallback options (proxies):

- Indirectly derive trade data based on trade data of the co-product.
  - For example: in FAOstat only the quantity of the cake of soya beans is given. By using a fixed soybean cake to soybean meal yield ratio, the amount of soybean meal production can be quantified as well.
- If not applicable (no co-product or no co-product data available), assume that they are fully locally produced (no import). An example of this fallback scenario (proxy) is illustrated in Figure 5.

This is only applied to some processed commodities. For all raw food crops the market mix is based on exact match in trade and production data, except for peppermint, beetroot and melons. For peppermint there is no trade data available, therefore a global production mix is used as proxy. Beetroot is not reported in FAOstat, instead European production data is used from Eurostat. For melons, FAO trade data of the overarching crop group 'cantaloupes and other melons' have been used.

Figure 5 Market mix of processed crop 'wheat gluten meal' in The Netherlands is based on local production only



More information on the different market mix strategies and data quality related to market mixes is explained in chapter 6.1. In the Appendix (tab market mix overview) an overview is given of the crops for which market mixes have been used, including information on the source of the used production and trade statics (FAOstat or EUROstat) and what market mix proxy strategies have been used, in addition a DQR is provided for each market mix based on the principles described in chapter 6.1.

4.2 Proxies for ingredients

Table 7 shows all proxies that have been to model food ingredients. The main approach for selecting proxies is finding a closest resemblance within the readily available LCIs or, if LCIs were not available, choosing an FAO crop that belongs to the same crop family.

Table 7 Overview of proxies used for food ingredients

Product (modelled product)	Foodex2 code	Food ingredient	Proxy used	Comment
Meat sauce (Bolognese sauce)	A16BR	Celery	Anise (fresh)	Anise is the seed of a plant in the celery family
Bologna sausage	A025R	Coriander seed	Anise	Anise belongs to the same family as coriander (Apiacea)
		Paprika powder	Pepper powder	
		Allspice	Pepper powder	
Hard candies	A034X	Flavourings or essences	Total minerals, additives, vitamins	No food specific data available. Mix derived from PEFCR Feed
Dragée, sugar coated	A035F	Nutritive sweeteners (e.g., sorbitol, manitol)	Total minerals, additives, vitamins	No food specific data available. Mix derived from PEFCR Feed
Gum drops	A035K	Flavourings or essences	Total minerals, additives, vitamins	No food specific data available. Mix derived from PEFCR Feed
Jelly candies	A035L	Flavourings or essences	Total minerals, additives, vitamins	No food specific data available. Mix derived from PEFCR Feed
Gelatine dessert	A036H	Sucralose	Sugar from sugarbeet	
Foamed sugar products (marshmallows)	A035H	Vanilla essence	Vanilla dried	
		Maple syrup	High Fructose Corn Syrup	
Pepperoni/paprika-type sausage	A025B	Cayenne pepper	Pepper powder	4
		Anise seeds	Anise fresh	
Pesto sauce	A044V	Pine nuts (Pinus pinea	Nuts mixed unsalted	

		Cheese, pecorino romano	Hard cheese	
		Cheese, grana padano	Hard cheese	
		Potato flakes	Potato starch dried	
		Basil, herb (Ocimum basilicum)	Peppermint (fresh)	Basil and mint belong to the same family (Lamiaceae)
		Fresh cheese	Cheese, Ricotta	
Pralines	A034S	Vanilla essence	Vanilla dried	
Fungi-based meat imitates	A03TG	Oregano	Peppermint (fresh)	Oregano and mint belong to the same family (Lamiaceae)
		Parmesan cheese	Hard cheese	
Mushrooms cooked sauce	A044D	Thyme	Peppermint (fresh)	Thyme and mint belong to the same family (Lamiaceae)
		Mascarpone cheese	Cream (full fat)	
Vegetables-based cooked sauce (Guacamole sauce)	A044E	Lime juice	Lemon juice	
Ale beer	A03MH	Invert sugar	Sugar from sugarbeet	
Cocktail drink (Mojito)	A03PN	Lime juice	Lemon juice	
		Sparkling water	Tap water	
Sparkling wine	A03MZ	Bentonite	Total minerals, additives, vitamins	No food specific data available. Mix derived from PEFCR Feed
Coffee beverage decaffeinated	A03KF	Carbon dioxide (liquid)	Nitrogen, via cryogenic air separation	Nitrogen process used as it has rather similar impact as liquid CO2

4.3 Dummy datasets

For a few products, there are no background datasets available in the ELCD or USLCI background libraries. This means the impact of these processes could not be determined and are therefore not included in the overall impact of the products in scope. In total, three so-called dummies are used in the whole EFSA database and are used for:

- Tetrafluoroethane production (R-134a): used in fish processing.
- Photovoltaic electricity generation: used in the electricity mixes
- Electricity generation from waste incineration: used in the electricity mixes

5. Modelling approach

Key aspect: a consistent modelling approach has been applied as much as possible building on the Agri-footprint and PEF methodology.

Paragraph 5.1 and 5.2. describe which PEF principles are applied in the methodology and the allocation rules respectively. In paragraph 5.3, emission modelling principles that are applied in the LCIs are explained for various life cycle stages and specific topics. The PEF method does not provide full details on agricultural modelling. For more details on PEF-compliant modelling of all life cycle stages we refer to the Agri-footprint methodology (Blonk, 2022). This chapter concludes with an overview of deviations with respect to the PEF method.

The PEF method (DG Environment, 2021) gives guidance on several LCA modelling issues and PEF category rules (PEFCR[38]) have been developed for several product groups. Within food, PEFCR's are developed for beer, dairy, wine, bottled water, and pasta. For other product categories, no standardized method is available.

The environmental footprint modelling for the EFF LCI database is aligned as much as possible with the current PEF method as well as existing PEFCRs.

For background processes, such as transport, energy, packaging materials, end-of-life treatment of packaging and chemicals (for fertilizers), next to AFP data, also (non-EF compliant) secondary ELCD datasets are used. See also the disclaimer in Chapter 1. Existing EF-compliant datasets (EF3.1) may only be used in the context of PEF(CR) related studies. It should be noted that open-source EF-compliant datasets for background processes (energy, transport, packaging, chemicals and end of life) are expected to become available in 2027. This means that the environmental footprint scores of the products in the EFF database will likely change if the database is updated in the future, due to an update of the PEF method and due to available EF-compliant datasets for background processes.

5.1 Life cycle stages & reference methodology

The processes and activity data which are included in the environmental footprint calculations are specified per lifecycle stage in Table 8, including the reference methodology that is used. In the following paragraphs, additional guidance is provided per life cycle stage.

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[38] A ruleset describing how to calculate the environmental footprint of a specific product group

Table 8: Processes or activity data which are included in the LCA, defined for each of the lifecycle stages based ON several sources AS listed in the last column (e.g. PEF method, AFP methodology and others).

Lifecycle stage	Activity data	Reference methodology
Crop cultivation	Cultivation of crops including emissions during cultivation (e.g. ammonia (NH_3) to air and water) Production and transport of inputs (fertilizer, pesticides and energy) Post harvesting of crops including energy needed for storage (often involving drying and/or cooling)	PEF method AFP methodology
Crop and processing logistics	Production and trade statistics to determine the market mix of each commodity. This stage also includes the transportation requirements to bring commodities to the country of consumption	PEFCR Feed & PEF method (transportation distances & mode)
Animal production	Productivity Energy consumption Manure management (type of system)	PEFCR Dairy PEF pilot Red Meat Draft PEFCR Marine Fish APS methodology
	Feed production: Processing impact per feed component Ration composition Compound feed composition	PEFCR Feed, AFP methodology
Processing	Food (ingredient) production: Transport to processing facility Energy consumption Amount and type of food ingredients and auxiliary materials Economic value of co-products Food losses and other waste	PEFCR Dairy, PEFCR dry pasta, PEFCR beer, PEFCR wine, PEFCR Bottled water, PEF method
Packaging	Production of packaging materials Amount of material per packaging type (virgin and recycled) (primary packaging only)	PEF method, representative packaging from various PEFCRs/screening studies
Logistics/ distribution	Use of electricity Transport distance and mode	PEF method
Supermarket	Use of electricity Food losses	PEF method
Consumption	Energy requirement for chilled or frozen storage Preparation method and required inputs (heat, frying oil) End of life of food (unavoidable food losses)	PEF method
End-of-life	End of life of food (avoidable food losses) End of life of food packaging	PEF method

5.2 Allocation

Whenever a process provides more than one function (e.g., delivering several goods and/or services), it is considered multifunctional. Multifunctionality implies that it can be difficult to allocate the environmental burden of the process between its different functions. According to the ISO 14044 standard[39], allocation should be avoided by, for instance, subdividing the process into multiple sub-processes to correctly share the environmental burden. When allocation cannot be avoided, multiple approaches can be applied.

In Table 9 below, the allocation approaches are listed per reporting lifecycle stage, including a justification of their choice. It shows that different allocation types are used for different products to ensure compliance with the PEF method together with relevant PEFCRs.

Table 9 Allocation approaches per life cycle stage

Life cycle stage	Allocation type	Justification
Crop cultivation	Economic, between main product and co-products	Recommended by the PEFCR Feed
	Energy, between different energy outputs (e.g., electricity and heat production) at CHP (combined heat and power) in greenhouse cultivation	Recommended by the PEFCR Horticultural products[40]
	Land occupation (yr*m2), for multiple crops in greenhouse	Recommended by the PEFCR Horticultural products
	Cut-off approach for manure production (allocate impact of manure to animal system, emissions for manure use to crop cultivation)	Recommended by PEFCR Feed
Animal production	Economic, at feed production	Recommended by the PEFCR Feed
	Biophysical, for dairy (IDF, 2015) and small ruminants farming. Economic, for other animals farming	Recommended by the PEF
	Economic, at slaughterhouse	Recommended by the PEF
	Cut-off for manure production	Recommended by the PEFCR Feed
Processing	Economic	To be consistent with most of the other allocation approaches (PEFCR Feed, draft PEFCR olive oil, PEFCR Pasta)
		Recommended by PEFCR Feed

[39] ISO14004 is a standard that provides guidelines and principles for conducting LCA (=environmental footprint) studies. With respect to allocation in general, the PEF method adheres to the ISO14044 standard with the exception of a few specific allocation requirements which are separately described in the PEF method.

[40] Wageningen Economic Research, Hortifootprint category rules. Towards a PEFCR for horticultural products, 2020

	Cut-off for waste products from food industry to feed	
Packaging incl. end-of life	Use Circular footprint formula (CFF) to deal with multifunctionality of packaging materials (recycling, energy recovery, etc.)	PEF method
Logistics Distribution Transport	Mass, for supermarket and distribution storage Mass, for transport (volume, if transport limited by volume)	PEF defaults are based on storage volume and storage time but info on storage time is lacking. See explanation in Chapter 5.3.7 and 5.3.8 Recommended by the PEF
End-of-life food	Cut-off for waste frying oil	Unknown what amount ends up in the food product
Supermarket, Consumption End-of-life food	Mass	Recommended by the PEF

Prices needed for economic allocation are used from the different PEFCRs or PEF defaults if available. For poultry, economic values for allocation are provided and extracted from the Agri-footprint Methodology (Blonk, 2022).

If not available in the PEFCRs or PEF method, average prices for the most recent 3 year-period that are representative for the region in scope are used. Taxes, transport, and insurance have not been included in the price.

5.3 Emission modelling

Emission modelling is an important component for certain stages of the life cycle, in particular for crop cultivation and animal farming. Emissions modelling refers to the accounting of emissions that originate from a process, for instance emissions as a result of combustion, oxidation, or dissolution. The modelling applied is based on PEF rules where possible. Whenever the PEF lacks guidance (e.g. in the case of animal farming), other approaches based on the PEFCRs and best available standards are used.

In paragraphs 5.3.10, 5.3.11 and 5.3.12, next to the various life cycle stages, the specific modelling approach that is applied for emissions related to peatland, land use change, and carbon sequestration is described. More information on the sources, calculations and modelling choices can be found in the Agri-footprint Methodology report (Blonk, 2022)

5.3.1 Crop cultivation

The cultivation stage includes all processes related to the production of crops. Input parameters include for instance the use of fertilizers, manure, water for irrigation, starting material (seeds), pesticides, transportation of these materials, capital goods, energy, and electricity. In crop cultivation, the same approach as in the PEF is followed for the modelling of the direct and indirect emissions. The following emissions are included in the modelling (PEF method, Annex I, paragraphs 4.4.1.4 and 4.4.1.5):

- From pesticides application:
    - Emissions to air (PEF recommendation 9%)
    - Emissions to soil (PEF recommendation 90%)
    - Emissions to water (PEF recommendation 1%)
- From fertilizers application:
    - NH_3, to air (from N-fertiliser application)
    - N_2O, to air (direct and indirect) (from N-fertiliser application)
    - CO_2, to air (from lime, urea, and urea-compounds application)
    - NO_3^-, to water unspecified (leaching from N-fertiliser application)
    - PO_4, to water unspecified or freshwater (leaching and run-off of soluble phosphate from P-fertiliser 2110 application)
    - P, to water unspecified or freshwater (soil particles containing phosphorous, from P-fertiliser 2112 application)
    - Heavy metals
- From rice cultivation (methane)
- From other activities including seed material, peat to soil, lime, machine use, N from crop residues

Emissions from fertilizers application are modelled following the Tier 1 approach as proposed in the 2019 refinement to the 2006 IPCC guidelines[41].

[41] The PEF method (Annex I, table 3) refers still to the old IPPC 2006

5.3.1.1 Greenhouse cultivations

Modelling of crops cultivated in greenhouses follows the Hortifootprint Category Rules guidance (Wageningen Economic Research, 2020). It is likely that the formal PEFCR that is being developed will be based on this guidance. For tunnel and greenhouse cultivations specific data for yield, synthetic fertilizer and energy use are used (if available).

5.3.2 Crop cultivation – post-harvesting

The post-harvesting stage is applied to crop products that are processed directly at the farm or orchard, such as the drying of grains or cooling of roots. See below table 10. Eurostat data are used on the humidity of crop at harvest and the energy requirements for safe storage using crop/country specific data for all European countries. For crops harvested in countries outside Europe, EU average values are used as a proxy. For fruit and vegetables no data is available on post-harvesting (e.g. cooling) so this is excluded.

Table 10 Overview of post-harvest activities applied

Product group	Crops	Post-harvest activity
Cereal grains	Barley, maize, oats, rice, rye, sorghum, triticale, wheat	Drying
Roots and tubers	Cassava, potatoes, onions	Cooling
Sugar crops		No activity considered
Pulses	Beans, field peas, broad beans, chickpeas, lupins, pigeon peas	Drying
Oil bearing crops	Groundnuts, linseed, mustard seed, rapeseed, sesame, soybeans, sunflower	Drying

5.3.3 Crop and processing logistics

Raw materials derived from cultivation and post-harvesting end up in import and export flows. The associated transport impact is calculated via the so-called market mixes (see also Figure 2 and chapter 4.1).

The PEF method provides default values for logistics (Annex 1, section 4.4.3.5) but these also include the international trade related transportation. Applying these values would result in double counting as the trade related transport impact is already covered in the modelled market mixes. Only in case transport distances are unknown, the PEF defaults are used as shown in Table 11.

Table 11 Default transport scenario's

From EU supplier to factory	From **non-EU** supplier to factory
130 km by truck (>32 t, EURO 4)	1000 km by truck (>32 t, EURO 4)
240 km by train (average freight train)	18 000 km by ship (transoceanic container) or 10 000 km by plane (cargo)
270 km by ship (barge)	

Market mixes of specific raw materials are determined by adding the total import of the raw materials from various countries (FAO, 2023a) to a specific country with the national production of the same product (FAO, 2023b). To overcome large trade and production fluctuations from year to year, 5-year averages are used (2018-2022). For information on what proxies have been used in the market mixes, see Chapter 4.1.

5.3.4 Processing

This life cycle stage encompasses all activities related to the processing of crops into food and feed ingredients (e.g. processing of olives into olive oil or crushing oilseeds) and processing of food ingredients into final food products (e.g. assembling a pizza from wheat flour, water, tomato sauce and cheese).

The modelling approach for processing of crops into food and feed ingredients is described in the AFP methodology document (Part 2 – Chapter 6). It is assumed that production of the final food products as sold via supermarkets takes place in the country of consumption.

For processing of food ingredients into final food products, data from literature is used with respect to type and number of utilities and waste amounts. The sources are listed in the respective LCI's. For composite food products, the type and amount of food ingredients, when available, are derived from the following sources, in hierarchical order:

1. EFSA Raw Primary Commodity Model[42]
2. Dutch Food Composition Database (NEVO)[43]
3. Other (Other databases, PEFCRs, internet etc..)

In the Appendix (Tab EFF scope) an overview is given per product which sources have been used including a reference to the recipe.

All waste that is generated during food processing is either treated as waste and/or biowaste.

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[42] EFSA, Annex A to the technical report on the raw primary commodity (RPC) model - Input data, 2019

[43] https://www.rivm.nl/en/dutch-food-composition-database

5.3.5 Animal production

Emissions modelling for animal farming systems includes emissions from enteric fermentation, from manure handling in the stable, during on-farm manure storage and during pasture.

The emission models used are extracted from the:

- APS footprint tool methodology documents[44]
- Agri-footprint Methodology report, Part 2, Chapter 7 (Blonk, 2022)
- Dairy PEFCR (Technical Secretariat Dairy PEF, 2018)
- FAO LEAP guidelines (FAO, 2016) (FAO, 2018))
- PEF pilot Red Meat (UECBV, 2019)
- Global Roundtable for Sustainable Beef Carbon Footprint Guideline (GRSB, 2022)
- Draft Marine fish PEFCR[45]

5.3.6 Packaging

For the packaging stage the following data are inventoried:

1. Type and mass of packaging materials
2. Impact of production of packaging materials using the Circular Footprint Formula
3. Impact of transporting packaging materials

It is assumed that the packaging stage takes place in the country of consumption. Additionally, no food losses are assumed for the packaging stage.

In the Appendix (tab packaging data) an overview is given of the type and mass of the packaging materials (mass rescaled to 1 kg of product packed in gram/kg) that are used for the products in scope, including the data source. Whenever possible, packaging types as described in various PEFCR (screening) reports are used. As there is no PEF standard yet for fruit and vegetables, standard weights of packaging materials from a Dutch source[46] are used. Secondary and tertiary packaging materials are not reported in various sources and have therefore been excluded. In the Appendix (tab EFF scope) an overview is given, per product in scope, what type of packaging has been used in the modelling.

The circular footprint formula (CFF) as introduced in the PEF method (Annex II part C) is used to determine the environmental impact of packaging materials. The formula consists of various parts, see Figure 6, which are applied at the packaging stage.

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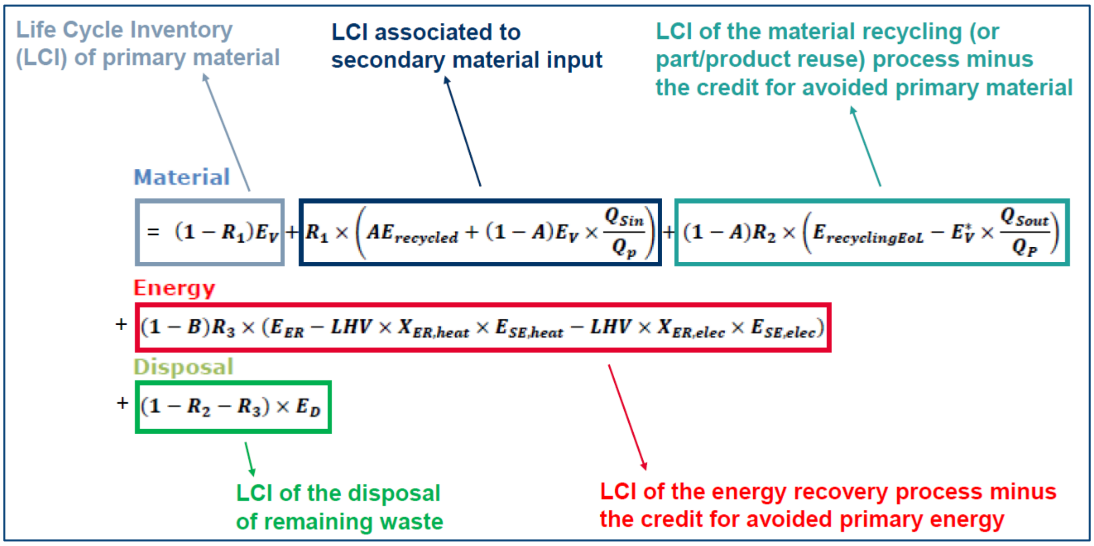
[44] https://blonksustainability.nl/tools-and-databases/aps-footprint
[45] https://www.marinefishpefcr.eu/supporting-studies
[46] https://www.afvalfondsverpakkingen.nl/sites/default/files/2023-03/Kopie%20van%20Standaard%20gewichten%20Groenten%20Fruit%20lijst%202022%20Website.pdf

Figure 6 Breakdown of the Circular Footprint Formula (see also PEF method, Annex II, part C)



The CFF can be explained as follows. **The first two "blocks" (light and dark blue) deal with the production of packaging material and are therefore included in the packaging stage**. The first block deals with primary material (E_v), the second block covers secondary material ($E_{recycled}$). The R_1 value concerns the recycled content of each specific material.

The remaining three blocks all deal with the end-of-life of packaging materials which are included in the consumption stage. Some part of the packaging material can be recycled (R_2), for which EU country specific values are used from part C of Annex II of the PEF methodology. When materials are recycled, a credit is given in the form of virgin material.

Part of the packaging material is incinerated (R_3). When packaging materials that contain energy are burned, energy recovery takes place in the form of heat and electricity. The recovered heat and electricity are credits that lead to a reduction of the overall environmental impact. The last block is the environmental impact of landfilling packaging materials.

For all parameters in the CFF formula, R_1, R_2, R_3, A and Q_{sin}/Q_p European and country specific default values as provided in part C of Annex II of the PEF method[47] are used to calculate the environmental impact of the packaging materials.

The lower heating value (LHV) of the packaging and the efficiency of the energy recovery process for both heat and electricity (XER,heat and XER,elec.) which are embedded in EF-compliant datasets have been retrieved separately as EF datasets may only be used in realm of PEF(CR) studies. The XER,heat and XER,elec are derived from CEWEP[48]. Energy recovery is determined using country specific statistics for the total amount of waste incinerated and the amount of heat and energy recovered from incineration. For a few countries, the information is incomplete and therefore no energy recover is assumed. Country specific values used for energy recovery can be found in the appendix, as well as the LHV values of the packaging materials.

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[47] Available via: https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml
[48] https://www.cewep.eu/cewep-energy-efficiency-reports/.

5.3.6.1 Transportation of packaging materials

The PEF method (Annex I section 4.4.3.4) provides default transport scenarios for packaging materials from manufacturing plant to filler plant. These scenarios are applied for all packaging materials:

1. For transport of empty bottles:
   a) 350 km by truck
   b) 39 km by train
   c) 87 km by ship (barge)
2. For transport of all other packaging materials
   a) 230 km by truck
   b) 280 km by train
   c) 360 km by ship (barge)

5.3.7 Distribution

The distribution stage takes into account:

- Transport from food processing locations (factories) to distribution centres (DCs)
- Storage at distribution centers (DC's)
- Transport from DC's to retail

See Table 12 below for an overview of the applied default values and the sources.

Food ingredients are transported all over the world. Most of the transportation impact is covered via the market mixes which are based on country specific trade mixes. It is assumed that production of the final food products takes place in the same country in which the food is being consumed.

Where available PEF default values have been used for transportation. It should be noted that the PEF default for the distance from factory to distribution is rather high. Preferably country specific transport scenarios are developed, for example based on statistical data sources such as Eurostat and CERDI.

Storage at distribution centres consumes energy and refrigerant gases. The PEF method provides default values (see PEF method, Annex I, section 4.4.5) to calculate the storage impact. These defaults require information on the storage time which is not available. For this reason, assumptions are used derived from a Dutch source. An electricity use of 90 kWh/ton is attributed to products that are stored as frozen products and 50 kWh/ton for cooled products (Broekema et al., 2016, 2015b). Additionally, 40 kWh/ton is accounted for as electricity use for lighting (Broekema et al., 2013).

Refrigerants have not been considered as applying the PEF default requires information on the storage volume of the freezers and fridges which is unknown.

Table 12 Overview of defaults used for distribution phase

Item	Default	Comment
Distance from factory to DC (km)	1200 km	PEF default
Distance from DC to supermarket	250 km	Assumption (no PEF default available)
Distance from supermarket to consumer	62%: 5 km, by passenger car	PEF default

	5%: 5 km round trip, by van lorry, <7.5t, EURO 3, utilisation ratio 20% 33%: No impact modelled	
Cooling at distribution	50 kWh/ton	Assumption
Freezing at distribution	90 kWh/ton	Assumption
Lighting at distribution	40 kWh/ton	Assumption
Losses at distribution	0%	PEF provides consolidated default loss value for transport, storage and supermarket. This is taken into account in the supermarket stage

5.3.8 Supermarket (retail)

The supermarket stage includes storage activities that consume energy. Also, food waste that is generated during storage at supermarket is included in the modelling of this stage.

The available PEF default values for energy consumption at supermarket require information on product specific volumes and storage time (shelf life). The latter information is not available. For this reason, available data from a Dutch supermarket is used (AH, 2013). Table 13 provides an overview of the default values used for supermarket.

Table 13 Defaults used for storage

Item	Default value used	PEF default[49]
Cooling at supermarket	30 kWh/ton[50]	1900 kWh/m2*year
Freezing at supermarket	50 kWh/ton[35]	2700 kWh/m2*year
Lighting at supermarket	36 kWh/ton[35]	PEF only provides a default for total energy consumption (400 kWh/m2*year)
Heating at supermarket	284.4 MJ/ton[35]	See above comment
Losses at supermarket	See Appendix	

[49] The PEF defaults require information on product volume and storage time which is not available
[50] Albert Heijn, 2013. Personal communication

Food losses, including losses during both distribution and at supermarket, are based on PEF defaults (PEF method, Annex II, part F) and the most recent FAO food loss data (FAO, 2011). These losses are categorized per product group. The food losses are listed in the Appendix (tab Consumption and EoL defaults).

5.3.9 Consumption

The consumption stage includes transport from retail to consumer, food storage (ambient/fridge/freezer) and food preparation. Transport requirement to consumer is based on the PEF guidance default from retail to final client, in which 62% of the products are transported by passenger car, 5% by van (delivery) and 33% is assumed to have no impact due to walking and/or cycling. Unavoidable food losses generated during preparation of the food is also included in this stage. However, avoidable food waste and its primary packaging, is excluded from the consumption stage and is part of the end-of-life stage of the food product.

PEF default values (PEF method, Annex II, part D) are used for storage and preparation at home, when available. Own assumptions are used in case no PEF default values are available.

In the impact assessment, non-food related goods and materials (e.g. cup, pan, fridge, coffee filter) used during preparation and consumption as well as cleaning activities (e.g. dishwashing) are excluded to ensure consistency. In food related PEFCRs this is currently inconsistently applied. For example, for coffee, milk and beer the life-cycle of the cup/glass and its dishwashing is included. However, for meat only the dishwashing of the frying pan is included (not the life cycle of the pan) and for pasta the pan nor the dishwashing is included. Especially cleaning activities can vary significantly, by hand or in a dishwashing machine. The amount and temperature of water and cleaning agent used is difficult to estimate and for these reasons cleaning is excluded.

Water used for boiling and oils used for pan frying (5 gram/kg) and deep frying (40 gram/kg) are included. Waste processing of the oil is not included in the calculations as it is not clear how much of the oil ends up in the product. Country specific values for the fraction of electric and natural gas cooking have been used based on Energy consumption household data 2023 (Eurostat, 2025). Fractions for each country are available in the appendix.

An overview of all relevant parameter values that are applied in the environmental impact calculations per food product with respect to storage method, preparation method and time, energy source used, amount of energy and water used etc. is listed in the Appendix (tab Consumption and EoL defaults). Table 14

Table 14shows a condensed overview per food product category.

For the activity food preparation, two parameters need to be taken into account that affect the amount of the reference flow. The first relate to the inedible parts of food such as bones, banana peels and pineapple skins. The inedible parts end up as (unavoidable) food losses and are defined as ‘food waste arising from food preparation that was not at any point edible. It is assumed that all inedible parts are removed before baking/cooking the food product. The reference flow, to derive to 1 kg of consumed product, is adapted accordingly. The PEF method does not provide default parameters for the (in)edible fractions of food. The edible factors as provided by the Dutch National Institute for Public Health and the Environment (RIVM)[51] are taken as defaults, see Appendix (tab EFF scope). Note that some of the edible part data is corrected to 1. This is for example done when the Almond product is already deshelled

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[51] These factors are Dutch specific and based on the Globodiet methodology as developed by the IARC. IARC also provides country-specific factors but these are not mapped to the Foodex2 codes. Moreover, the Globodiet factors are rather outdated so it was decided to use the factors as provided by RIVM as they have been reviewed by dietist experts. It should be noted that for some food products there may be variations between EU-countries.

in the processing stage. By overwriting the specific edible value of 0.4 to 1 we avoid double counting of deshelling in the preparation stage. More information about specific adjustments can be found in the appendix.

The second parameter that affects the amount of the reference flow is the raw-to-cooked factor. During preparation some products lose a certain percentage of its mass (e.g. meat, vegetables) where other food products gain mass (e.g., pasta, rice). These raw to cooked ratios are also derived from the Dutch National Institute for Public Health and the Environment (RIVM). The applied factors are listed in the Appendix (tab EFF scope).

Table 14 Default preparation parameters (full detail in Appendix, tab Consumption and EoL defaults)

Preparation technique	Energy source	Power (kWh/h	Preparation time (min)	Comment
Deep frying	Always electric	2.3	Per product group	Power based on average frying pan[52] 40 grams of sunflower oil added per kg product (=assumption)
Pan frying	Mix electric/natural gas	1	Per product group	Power based on PEF, 5 grams sunflower oil added per kg product (PEF default for meat, fish, eggs)
Boiling	Mix electric/natural gas	3	Per product group	Power based on PEF
Water cooker	Always electric	2.2	3	Assumption, based on average water cooker[53]
Oven	Always electric	1.23	Per product group	Power based on PEF
Microwave	Always electric	1	Per product group	Assumption
Chilled at consumer	Always electric	0.0777 kWh/l		Based on PEF defaults: 0,0037 kWh/l per day (storage volume), default 7 days storage in fridge,

52 https://apparaatverbruik.nl/frituurpan/hoeveel-stroom-verbruikt-een-frituurpan/
53 https://apparaatverbruik.nl/waterkoker/hoeveel-stroom-verbruikt-een-waterkoker/

			storage volume is 3x the actual product volume
Freezing at consumer	Always electric	0.294 kWh/L	Based on PEF defaults: 0.0049 kWh/l per day (storage volume), default 30 days storage in fridge, storage volume is 2x the actual product volume
No preparation	-		No energy use included

The product density values (FAO/INFOODs, 2012) together with PEF default values, are used to calculate the energy consumption during storage at consumer (in fridge or freezer). The product densities are available per product category only and are listed in the Appendix (tab Consumption and EoL defaults). In the Appendix it is also indicated:

- per product what preparation method (e.g. frying or boiling) and storage type (chilling or freezing) has been taken into account (tab EFF scope)
- per product category what preparation time has been used (tab Consumption and Eol)
- Disposal of packaging at the consumer is included in this stage.

Unavoidable food losses at the consumer phase are based on the edible factors (provided by the Dutch National Institute for Public Health and the Environment) for various food items.

5.3.10 End of life

The final stage includes avoidable food losses. Avoidable food loss rates are based on PEF defaults (PEF method, Annex II, part F), of which some are based on FAO data (FAO, 2011). The avoidable food losses are listed in the Appendix (tab Consumption and EoL defaults).

The end-of-life destination and treatment of food losses is also based on PEF defaults: 50% is assumed to be trashed (i.e., incinerated and landfilled), 25% composted and 25% methanised. Liquid food wastes at consumer are assumed to be poured in the sink and therefore treated in the wastewater treatment plant.

The end-of-life impact of packaging waste is calculated via the Circular Footprint Formula (CFF) of the PEF method and is explained in Chapter 5.3.6.

5.3.11 Emissions from drained peat soils

When cultivation occurs on peat soil, significant GHG emissions might occur. Most importantly, CO2 emissions occur from carbon oxidation and N2O emissions occur from nitrogen mineralization. In accordance with the PEF method, peat emissions are included using defaults emissions factors as provided by the IPCC (IPCC, 2014), or country's National Inventory Report.

5.3.12 Emissions from land use change

Emissions from land use change are accounted for. These refer to the emissions of carbon as CO2 initially stored in biomass and lost due to changes in land use (e.g., from forest to cropland or from grassland to cropland).

In accordance with the PEF method, the PAS 2050 approach (BSI, 2012) is applied. This involves the implementation of a direct land use accounting approach, considering an equal amortization of the emissions over a period of 20 years.

5.3.13 Carbon sequestration

In line with the PEF method, carbon sequestration is not accounted for.

6. Data quality and data representativeness

This chapter describes the data quality ratings (DQR) that have been implemented for market mixes and provides an overview of the data representativeness of the most important data points and parameters used in the database.

6.1 Data quality ratings for market mixes

Using the Environmental Footprint (EF) Data Quality Rating rules draft[54] as a guide to evaluate data, a rating system is proposed for the market mix calculations for the EFSA database. This system helps us to understand the quality of the dataset quickly and easily. To classify the data 2 parameters are used, Precision (P) and Representativeness (R). The proposed range for DQR is from 1 till 4, with 1 representing the best quality.

6.1.1 Data Quality Criteria

Two data quality criteria (**P** and **R**) shall be evaluated for each component (Chapter 1.3.1):

Precision (P): indicates the way the data is collected and derived. The precision includes the following aspects, which should be peculiar to the technology to be described. The effect of the number of samples and their redundancy:

- Sample size is relevant to ensure that the results are statistically significant. Determining the sample size can be based on statistical formulas that consider the expected variability, the desired confidence level, and the maximum acceptable error (branded data focus). The calculation methods to elaborate data and derive the final values, as to the model uncertainty aspects of the calculation method. The choice of the method depends on the nature of the population and the study's objective;
- Data sources, as to the data uncertainty aspect they bring in, e.g. if the sample size and measurement method is not documented;
- Adopted standards, as to the inherent uncertainty of the measurement prescribed in the standard and specific procedures to minimize errors and bias.

Representativeness (R): It denotes accuracy of the data, with reference to the processes and products selected. The representativeness characterises to what degree the collected data describe the system under analysis. In this respect, it checks that data correctly cover the different process operation conditions.

[54] As of time of writing, the Data Quality Rating rules proposed by the JRC, was still in draft stage

- Included datasets shall be technologically representative (TeR) for the activity data collected (i.e. the included dataset refers to a technology that is as close as possible to the one effectively in use in the studied system).
- Included datasets are geographically representative (GeR) for the activity data collected (i.e. the geography as specified in the "Location" field of the included dataset refer to a geographical area that is equal or close to the one related to the activity data).
- Included datasets are temporally representative (TiR) for the collected activity data. The included dataset is compatible with the activity data collection referring to the time period. To this end, the field *Time representativeness description* of metadata of included datasets shall be checked.

In Figure 7, schematic targets illustrate the distinction between accuracy and precision. Using this illustration we can compare visually between strategies (Howell et al. 2011).

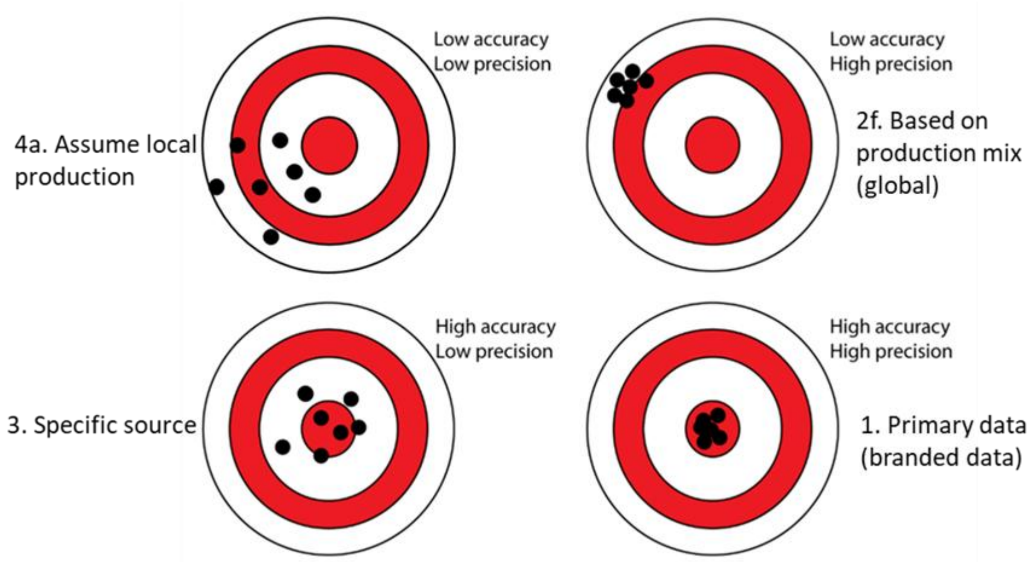

Figure 7: Dartboard of the relation between Accuracy and Precision on the results of DQR

6.1.2 Market mix strategies used in EFSA

Table 15: Overview of different market mix strategies used and related Data Quality Rating

		Precision	Representativeness			
Source	**Strategy**	**P**	**TiR**	**TeR**	**GeR**	**R (AVG)**
FAOstat	Exact match in trade and production data	1.5	1.5	1.5	2	1.66
FAOstat	Indirectly derived from specific trade and production data	2	1.5	2	2	1.83
FAOstat	Based on similar commodity or "proxy"	1.5	1.5	2.5	2	2
FAOstat	Based on commodity total or commodity group	2	1.5	3	2	2.16
Eurostat	Based on production mix (region)	2.5	1.5	1.5	2	1.66
FAOstat	Based on production mix (global)	2.5	1.5	1.5	3	2
Eurostat - fish	Based on production mix (region)	2.5	1	1.5	2	1.5
	Assume local production (based on reasonable assumption)	3				2
	Assume local production (expert estimate)	4				3

Table 15 contains an overview of all the market mix strategies used and the related data quality that is associated with it. Each strategy is briefly explained in more detail below.

- **Exact match in trade and production data**: this means that we use production and trade data for “apples” to model the market mix of “apples”. From a data point of view this represents the best possible data, and this is reflected in the Precision (1.5). Only primary or measured data can technically be better data, but because of the huge data need and the need for consistency for the EFSA database, statistical data is used. All FAOstat data used within the database is until 2022, meaning a Time representativeness of 1.5.
- **Indirectly derived from specific trade and production data**: in some cases, the data is derived from other FAOstat data. For example: FAO reports on trade data for “Soybean cakes” but there is no production data available for this commodity. Production data is derived from “Soybean oil” using the same oil and cake ratio for these commodities reported in Agri-footprint. This is slightly lower in precision and technological representativeness compared to the previous scenario.
- **Based on similar commodity or “proxy”**: in some cases, a “proxy” is used, this means the precision is as good as the first strategy, but the technological representativeness is lower.
- **Based on commodity total or commodity group**: in some cases, no specific information is available and it was chosen to fall back on information of the commodity group. This brings lower precision and lower technological representativeness
- **Based on production mix (region):** in some cases, no trade data is available and production mix of a specific region is used. For the EFSA database, no trade data for “beetroot” was available, therefore the production mix of “Beetroot” was used to model the market mix. This approach brings lower quality for precision. For most fish data, Eurostat production data for the EU-27 was chosen. Mainly because it proved to be too difficult to link detailed production and trade data from various statistics.

- **Based on production mix (global):** in some cases, no trade data is available and the global production mix of is used. For the EFSA database, no trade data for "peppermint" was available, therefore the global production mix of "peppermint" was used to model the market mix. This approach brings lower quality for precision similar as the previous approach, plus an additional lower geographical representativeness because global data was used instead of regional data.
- **Assume local production (based on reasonable assumption):** for some commodities there is no trade data available and it is assumed that it is from local origin. This is a reasonable assumption for low value co-products from cultivations (e.g. straws and stovers) or low value by-products from the processing industry (e.g. sugar beet pulp). Since it is an assumption, it automatically leads to a lower precision compared to all other strategies listed above. Since we do not use any data, a representativeness score based on expert judgment is reported.

Due to limitation in the amount of data for aquaculture systems, one system is assumed for each aquaculture system corresponding to one country. The aquaculture system used for the EFSA database are: Carp from Poland, Catfish from Vietnam, Salmon from Norway, Seabream from Great Brittain, Whiteleg shrimp from Vietnam and Trout from Denmark.

Additional DQR penalties

For each commodity, there is a specific strategy used to model market mixes and outlined in chapter 0. For each strategy the perceived data is provided in Table 15. On top of that, additional penalties are applied:

- **Penalty for coverage**: for each % of coverage not achieved an additional 0.01 penalty is applied to the precision. For example: with a market mix coverage of 60% for a specific commodity an additional 0.4 penalty is applied for precision on top of the precision related to the specific market mix strategy.
- **Penalty for proxy market mix**: for certain commodities a proxy market mix is used, as explained in chapter 4.1, in these situations a penalty is applied for the Geographical representativeness of +1 on top of the geographical representativeness related to the specific market mix strategy.

The combination of the market mix strategy and the applied penalties determines the final DQR for each market mix used in the EFSA database. The amount of market mixes, applied market mix strategy and final DQR for each market mix used for the EFSA database is listed in the Excel Appendix.

6.2 Representativeness of the data

Table 16 shows an overview of the representativeness of the main datapoints used within the different life cycle stages. DQR system is not available for these data points, in contrast to the market mix. But the table below gives at least some guidance on the representativeness of the different data points. The different datapoints from the different life cycle stages are grouped in one of the four columns, which are:

- **Commodity & country specific datapoints**: this means that the collected data is commodity and country specific information. For example: the Yield data of "Apples" in are specific for that particular country.
- **Country specific datapoints**: this means that the collected data is a country specific average. For example, the manure input data for crop production is based on a national average, since no specific data is currently available to assign manure to specific crops.
- **Commodity specific datapoints**: this means that the collected that is specific for that commodity. For example, heavy metal content of all crops is commodity specific.
- **Default values**: this means that the collected data is based on specific default values and are the same for all commodities and countries. For example: for lime input a default value of 400 kg/ha is used.

Table 15: Representativeness of the main datapoints used in the EFSA database

Life cycle stages	Commodity & country specific	Country specific	Commodity specific	Default values
Crop production	Yield data Synthetic fertilizer data Irrigation data Peat data Energy data Land use change data Pesticide data Energy use storage[55]	Manure data Peat data	Heavy metal content Fraction co-product Crop residue	Lime input Basic infrastructure Transport distances
Crop and processing logistics	Production data Trade data[56]	Transport distances between countries		Additional transport distances
Processing			Processing data Recipes products	
Animal production	Yield animal systems Feed composition animals			
Packaging	CFF parameters for packaging materials			Packaging materials Transport packaging materials
Distribution				Transport distances Energy use
Supermarket			Food losses (group)	Transport distances Energy use
Consumption		Fraction gas and electric cooking CFF EOL packaging	R2C factor Edible part	Last mile
End-of-life			Food losses (group)	
Background data				

[55] For non-European countries, EU average data is used (see AFP methodology document)
[56] Not all market mixes are based on commodity and country specific information, see chapter 6.1.2

7. Deviations from PEF method

This chapter provides a condensed explanation of all the deviations that are applied in the development of the EFF LCI database compared to the PEF or the sector PEFCRs (Table 17), in order to create a harmonized method. It should be noted in general that PEFCR prescribe the usage of primary data next to secondary data. In the development of the EFF LCI database only secondary data have been used.

Table 17: overview of the deviations from the PEF

Topic	Conflict/issue	Harmonization/ solution	Deviates from
Functional unit	Sector PEFCRs use different functional units e.g. the Pasta PEFCR is using 1 kg of dry pasta and PEFCR Dairy is using 10 g dry matter equivalent for cheese	Using both 1kg of raw (unprepared) food at retail and 1kg of consumed product as functional unit	All sector PEFCRs
System boundaries use stage	PEFCRs use different system boundaries for the use stage.	Non-food related goods and materials (e.g. cup, pan, coffee filter) used during preparation and consumption as well as cleaning activities (e.g. dishwashing) are excluded for all food products	Coffee, milk, beer, bottled water (cup/glass production and dishwashing included) Meat/fish/eggs (dishwashing frying pan included)
Secondary data (background processes)	Secondary data used for background processes are not EF-compliant. EF4.0 is not yet available, and EF 3.1 used for limited number of datasets (food/feed as available to Blonk) Other EF datasets are either not available yet and moreover, only allowed to be used in PEF/PEFCR study.	Alternative sources of secondary data are used	All sector PEFCRs
Data Quality Rating (DQR)	No DQR available in all background databases. PEF DQR method is considered very time consuming, complex to apply and difficult to interpret. Moreover, the DQR is currently being updated.	Listing of proxy data used (see Chapter 4) and DQR applied for market mixes only (Chapter 6.1)	PEF method

Allocation	Different allocation at dairy processing (e.g., whey production): economic allocation in PEFCR feed vs. mass allocation in PEFCR dairy		Dairy PEFCR
	Different allocation at crop cultivation for Grape production – allocation of co-products (grape must and grape pomace): mass allocation in PEFCR wine vs economic allocation in PEF guidance for cultivation of crops and feed PEFCR	Economic allocation (To align with allocation type in other feed & food processing steps)	Wine PEFCR
	Different allocations at food production: mass allocation in pasta PEFCR (although pasta waste is considered 0% allocation) and wine PEFCR		Pasta PEFCR and wine PEFC

8. Limitations

1. Food consumption surveys from a few countries are not considered when performing the products scope. For example, for Germany. Because of this, it could be that some very specific food products that are consumed within Germany and are not reported by other countries in scope are left out of the study.
2. Post-harvest activities such as (long term) storage or cooling was not inventoried for all fruit and vegetables but can potentially have impact.
3. Crop rotations are not integrated in the modelling of the cultivation phase. The impact of this is assumed to be minimal because the main aspect of crop rotation, which is the use of animal manure and the positive aspects for soil fertility, is included by the animal manure application method.
4. Seasonality is not taken into account in the modelling which could have a major influence on the environmental impact. An example: when the environmental impact of an import crop (winter consumption) is very high compared to domestic production (summer consumption) the overall impact will be higher. Including this season effect would require more granular data, e.g. no aggregation to market mixes.
5. Toxicity impact categories: pesticide emissions are only included on so called “super group level”. This means that the data is not specific enough to say something about toxicity impacts related to food consumption (more about the “super group” data, method and its implications see Agri-footprint methodology report 2022 – Part 2, Appendix II Pesticide model)
6. Consumption of final food products is based on domestic production. There are no figures about the country of origin related to sold food products in a certain country.
7. Trade data do not make a distinction between raw materials used for feed or food (FAO data).
8. Air transport is not completely included in the modelling of transportation due to lack of data. For modelling transport distances, we use available data from the PEFCR Feed and PEF defaults. In the PEFCR feed data on air transport are missing.[57]

[57] According to Poore & Nemecek (https://www.science.org/doi/10.1126/science.aaq0216) air transport accounts for only 0,1% of the food transportation.

9. There is no data available for minor ingredients, these are treated with a cut-off, some examples are and supplements.
10. The database is not completely PEF compliant as explained in Chapter 7.
11. Background data from ELCD was used for the EFSA database, which is relatively old, discontinued and has limited amounts of datasets available when compared to for example Ecoinvent. As an effect, the environmental impact of similar products varies significantly depending on whether ELCD or Ecoinvent is used, except for climate change and a few other categories (see disclaimer in introduction).
12. The usage of Dummy processes in the underlying LCI database: due to data gaps where no alternative processes where available in the ELCD/USLCI background libraries, 3 dummies processes with zero impact were used from these libraries during the construction of the EFF LCI database (see 4.3 - Dummy datasets).
13. The circular footprint formula for packaging end of life impacts is attributed to consumption stage due to technical limitations. It would be more appropriate to attribute this to the end-of-life stage.

These limitations should be taken into account by the user when using the environmental footprint results.

9. Communication of the environmental footprint results (data model)

Key aspect: The version of the EFF database that will be available for external communication will show the environmental impact, on each of the 16 PEF midpoint categories, of both 1 kg of raw food at supermarket and 1 kg of consumed food at consumer, for each European country in which the food is being consumed and including the contribution of each life cycle stage to the total (single score) environmental impact.

The structure and 'design' of the environmental footprint data in the EFF database is important. A good data model ensures that the data is well communicated and understood by the user. As an example, we provide the data model of 'Pasta' in Figure 8 (see below).

During the scoping phase, it was decided to represent both the impact of 1 kg of raw food at supermarket and the impact of 1 kg of consumed food at consumer. This approach yields straightforward figures, always based on 1 kg, and is PEF compliant (because the consumption and end-of-life of food is included in the impact of 1 kg of consumed food at consumer). As mentioned in Chapter 2.2, these two impact results of a particular food product cannot be compared.

The EFF database will show, for each combination of food product and EU country of consumption, two result series, one for 1kg of raw food at supermarket (retail) and one for 1kg of consumed food at consumer. Each series comprises of the results of the sixteen PEF impact categories at midpoint level. For each PEF impact category also the contribution (in %) of each life cycle stage is reported. Environmental impact scores for each product are grouped in the following life cycle stages:

- Crop production
- Crop and processing logistics
- Processing
- Animal production
- Packaging
- Distribution

- Supermarket
- Consumption
- End-of-life
- Total

Table 1 (in Chapter 2) explains what activities are included in the life cycle stages. End-of-life and consumption life cycle stages are not included in the results for the cradle-to-retail results since the stages are beyond the system boundaries.

The environmental impact of the consumption and end-of-life stage can results into negative numbers due to “credits” from packaging recycling, energy recovery from incineration and specific end-of-life background datasets.

9.1 Use of the data

The EFSA database and report has been reviewed by an independent third-party reviewer, RIVM.

Users of the data may externally communicate on the results of this study to third-parties as long as you 1) include the applicable disclaimer(s) related to the database and it is review, as provided by Blonk and/or the reviewers. If no disclaimer has been provided to you, please contact info@blonksustainability.nl to obtain the correct disclaimer, and 2) get Blonk's approval on any claims or communications related our work, please send all relevant information to your employee contact or info@blonksustainability.nl.

Conclusions and recommendations presented here are subject to the assumptions and limitations addressed in this report. Be aware that most datapoint are derived from statistics. Also, proxy data and generic data is used at multiple levels within the database. Therefore, for any comparative assessment the user should be aware of the data and choices made for this specific database. Any comparative assessment intended to be disclosed to the public should transparently refer to this report and be accompanied by the critical review statement.

The intended application of the study is twofold. Its aim is primarily to create awareness of environmental impact and hotspots throughout the products in scope. Secondly, the results of this study may be communicated externally. This external communication might include business-to-business communication, as well as communication to a broader audience, including investors and/or the general public.

Figure 8 Data model of the EFF database

Product (1 kg consumed at consumer)	**Product**	**FoodEx2 code**	**Country**	**Stages**	**Environmental impact categories: absolute and relative values**															
					Climate Change, Total	Ozone depletion	Ionising radiation, Human Health	Photochemical ozone formation, Human Health	Particulate matter	Human toxicity, cancer	Human toxicity, non-cancer	Acidification (terrestrial and freshwater)	Eutrophication, fresh water	Eutrophication, marine	Eutrophication, terrestrial	Ecotoxicity, freshwater	Land use	Water use	Resource use, fossils	Resource use, minerals and metals
					kg CO2 eq	kg CFC-11eq	kBq U235 eq	kg NMVOC eq	Disease incidences	CTUh	CTUh	mol H+ eq	kg P eq	kg N eq	mol N eq	CTUe	Dimensionless (pt)	M_3 world eq.	MJ	kg Sb eq
(A007E) Pasta, plain (not stuffed), uncooked | Ambient (long) | Pasta packaging - 1 kg | Boiling | consumed {NL} Economic	Pasta, plain (not stuffed), uncooked	A007E	NL	Animal production																
				Consumption																
				Crop and processing logistics																
				Distribution																
				End-of-life																
				Packaging																
				Processing																
				Supermarket																
				Total																

10. FoodEx2 facets

As explained in Chapter 3, certain activity data are key to accurately calculate the environmental impact of food. Some of these data could be collected through dietary surveys. EFSA has developed a guidance on the EU menu methodology which aims to standardise the information that is being collected through these surveys. Particularly relevant are the so-called **facets**. Facets are descriptors providing additional information for a particular aspect of a food. The FoodEx2 system has 28 different facets as shown in Table 18. In line with the purpose of the Comprehensive Food Consumption Database, the facets intend to provide information that could further help the assessment of potential exposure to hazards in food. However, potentially they could be complemented with information that could further facilitate environmental impact calculations.

In the development of the EFF LCI database, facets have not been used. The purpose of below is to indicate which facets could be relevant for future updates of the EFF database. If information on these facets would be available per EU country and linked to specific food products as consumed per country, it could potentially improve the accurateness of country-specific environmental impact figures of food.

Typically for environmental impact calculations, information on the type and number of inputs and outputs are required. Examples of inputs are 5 grammes of cocoa, 50 grammes of plastic polyethylene packaging or 5 litter of boiling water. Examples of outputs are: 300 grammes of fruit peel waste or 200 grammes of spoiled bread.

Next to the facets listed below, the following additional information could be relevant as well:

- **Type of frying oil used during cooking**
- **Portion size during cooking**

The environmental impact of oils can differ significantly so information on what type of frying oil is used when preparing food is relevant. The portion size of food that is being prepared is also relevant. For example, when four portions of meat are being fried in the same pan, the heating energy per portion is four times less than when one portion is being fried.

Table 18: Overview of Foodex2 facets and relevance for environmental impact calculations

Facet	Relevant for environmental impact	Comment
F01 Source	No	Could be relevant if animal or plant origin is not implicitly known from the food name but was not encountered during the scoping phase of the EFF database.
F02 Part-nature	No	Already implicitly included in the food name.
F03 Physical state	No	For impact assessment, only type of ingredients and processing technology is relevant.
F04 Ingredient	Yes	Relevant in case of composite foods and to be able to define reference recipes per country for a composite dish like sea food salad or quiche. For current scope of EFF database it is not relevant, see chapter 2.5.

F06 Surrounding medium	Yes	Often not implicit in the food name. Whether medium is water, oil, milk etc. will make difference to environmental impact.
F07 Fat-content	Yes	Fat content is related to the mass of the ingredients.
F08 Sweetening agent	No	Food additives like sugar, salt or vitamins have an insignificant contribution to the environmental impact.
F09 Fortification-agent	No	Food additives like sugar, salt or vitamins have an insignificant contribution to the environmental impact.
F10 Qualitative-info	Potentially	Currently used to provide principal claims on nutrients/ingredients like fat, salt or sugar content. Could be used to additionally provide info on parameters that significantly impact the environmental footprint.
F11 Alcohol-content	Yes	Alcohol content is related to mass of input ingredients.
F12 Dough-Mass	No	For impact assessment, only type and mass of input materials (flour, water etc.) is needed.
F17 Extent-of-cooking	Yes	Cooking requires energy and more info on the extent of cooking will give a better indication of the impact of food preparation.
F18 Packaging-format	No	For impact assessment, only type and amount of input materials is relevant.
F19 Packaging-	Yes	This provides info on type of packaging materials.
F20 Part-consumed-analysed	Yes	This provides info on whether the shell, peel, skin etc. is included during consumption. This might impact the applied edible factor and loss rate for which we currently use default values.
F21 Production-method	Yes	Production technology and practices applied, e.g. intensive, extensive or organic farming and pest management will impact the amount and type of in- and outputs.
F22 Preparation-production-place	No	Place of preparation or production refers to location where food is processed or prepared, e.g. at food industry, in restaurant, by street vendor, at home etc. For EFF database we focus on preparation at home, so this facet has no further relevance.

F23 Target-consumer	No	This facet is not providing information on the food.
F24 Intended-use	Potentially	Relevant if food is consumed differently than expected, e.g. eaten raw instead of cooked or vice versa.
F25 Risky ingredient	No	Provides information on whether raw ingredients are used (e.g. raw eggs) in composite dishes.
F26 Generic-term	No	Current purpose of the facet has no relevance but could potentially be used to provide information relevant for environmental impact calculations.
F27 Source-commodities	No	No information on exact ingredients and recipe only description of the plant, animal, other organism or other source from which a raw primary commodity has been obtained.
F28 Process	Yes	Food treatments prior to final consumption, like preservation, heat treatments, battering and breading will require energy and additional ingredients. Specific information on this could make the environmental impact calculation more accurate.
F29 Purpose-of-raising	No	Qualitative information on animal system – not relevant for environmental impact calculations.
F30 Reproductive-level	No	Qualitative information on animal system – not relevant for environmental impact calculations.
F31 Animal-age-class	Yes	Older animals have more mass and have consumed more feed. The animal age thus influences the environmental impact of meat. However, the age class of meat as generally consumed by consumers in Europe (which is basis for EFF database) is mostly related to universal industry practices.
F32 Gender	No	Qualitative information on animal system – not relevant for environmental impact calculations.
F33 Legislative-classes	No	Refers to legislations in which classes are defined for specific ingredients.

11. Review statement RIVM

RIVM carried out critical review of the EFF LCI database. This covered the Guidance Document draft version 2.3 (2025-7-18) and its Supporting Information, including the Guidance Document appendix (version 2025-7-18), as well as the accompanying Simapro file of the database, contribution analysis results, and supporting documentation on fish modelling (RIVM-EFSA fish comparison (2025-7-18).

The review took place at three stages during the development of the database:

- June 2024: Start (to assess design of the database and analysis methods).
- December 2024/January 2025: Pilot phase (to review pilot database and guidance).
- July-August 2025: Final stage (to review the complete database and documentation).

The data model was evaluated, and the Guidance Documents were reviewed for its assumptions, justifications of choices, clarity, and logical structure. The reporting of the database was found to have been conducted to a high standard with clear, detailed documentation presented in a user-friendly way. Where possible, the database itself was compliant with the PEFCR standards.

The documentation was further assessed with respect to its description in terms of quality, representativeness and completeness of the data. Based on feedback of RIVM in the pilot phase, Mérieux NutriSciences | Blonk added Data Quality Ratings to the final version on parts of the database, which significantly improved transparency regarding data choices and data quality.

The footprint outcomes were assessed for salient results and examined through cross checks and randomized detailed checks.

As stated in Disclaimer of the Guidance Document, the EFF LCI database was built on ELCD datasets due to licensing restrictions. These datasets are older and therefore of lower quality compared to alternatives, such as Ecoinvent. The use of older - lower quality - background data has a considerable impact on the (absolute and relative) results, particularly in certain impact categories. For this reason, RIVM recommends to exclude several impact categories from publication. This was the case for:

- Ionizing radiation
- Human toxicity, non-cancer
- Human toxicity, non-cancer – organics, inorganics and metals
- Human toxicity, cancer
- Human toxicity, cancer – inorganics, inorganics and metals
- Ecotoxicity, freshwater
- Ecotoxicity, freshwater - organics, inorganics and metals
- Resource use, minerals and metals
- Climate change – fossil, biogenic, land use and land use change

For most other categories, differences are still expected, but were considered to be within an acceptable margin. This was the case for:

- Climate change
- Ozone depletion
- Photochemical ozone formation
- Particulate matter
- Acidification
- Eutrophication, freshwater
- Eutrophication, marine
- Eutrophication, terrestrial
- Resource use, fossils
- Land use*
- Water use*

** It should be noted that for water use and land use, the impact of the use of ELCD background data has a larger effect than on the other impact categories mentioned, however still within an acceptable margin according to RIVM.*

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