# Guidelines for calculating the carbon footprint of food products available on the Danish market

Advisory report from DCA – Danish Centre for Food and Agriculture

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# Data sheet

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Agriculture and Fisheries. The data follow-up group has not been involved during the process. Members of the group have had the opportunity to submit their comments individually during the public consultation period. The group has been invited to an inquiry meeting after the public consultation period.

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# Contents

# Abbreviations

| | |
|---|---|
| BoM | Bill of Material |
| COP27 | the 27th Conference of the Parties to the United Nations Framework Convention on Climate Change |
| CPA | the Classification of Products by Activity |
| DNM | Data Needs Matrix |
| DQR | Data Quality Rating |
| EF | Environmental Footprint |
| EoL | End of Life |
| GeR | Geographical Representativeness |
| GHG | Greenhouse Gas |
| ILCD | International Reference Life Cycle Data System |
| ILCD-EL | International Reference Life Cycle Data System-Entry Level |
| LCA | Life cycle assessment |
| LCI | Life Cycle Inventory |
| LCIA | Life Cycle Impact Assessment |
| P | Precision |
| PEF | Product Environmental Footprint |
| R2C | Raw to Cook |
| RP | Representative product |
| TeR | Technological Representativeness |
| TiR | Time-related Representativeness |

# Terms and definitions

**Attributional LCA:** Process-based LCA modelling intended to provide a representation of average conditions.

**Aquatic products:** Animals (fish, crustaceans, molluscs and other aquatic animals), plants and microorganisms harvested through fisheries and aquaculture activities, whether marine or inland.

**Benchmark:** A standard or point of reference against which any comparison may be made.

**Biogenic carbon:** It covers (i) carbon emissions to air ($CO_2$, CO, and $CH_4$) originating from the oxidation and/or reduction of aboveground biomass using its transformation or degradation (e.g., combustion, digestion, composting, landfilling), and (ii) $CO_2$ uptake from the atmosphere through photosynthesis during biomass growth, i.e. corresponding to the carbon content of products, biofuels or above-ground plant residues such as litter and dead wood.

**Bill of Materials**: A bill of materials or product structure (sometimes bill of material, BoM, or associated list) is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts, and the quantities of each needed to manufacture the product in the scope of the PEF study.

**Carbon footprint:** Sum of GHG emissions and GHG removals in a product system, expressed as $CO_2$ equivalents and based on a life cycle assessment using the single impact category of climate change.

**Climate change:** An environmental footprint impact category considering all inputs and outputs that result in greenhouse gas emissions. The consequences include increased average global temperatures and sudden regional climatic changes.

**Company-specific data**: It refers to directly measured or collected data from one or more facilities (site-specific data) that are representative of the activities of the company ('company' is used as a synonym for organisation). It is synonymous with 'primary data'. To determine the level of representativeness a sampling procedure may be applied.

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

**Commissioner of the carbon footprint study:** Organisation (or group of organisations), such as a commercial company or non-profit organisation, that finances the carbon footprint study in accordance with the carbon footprint quantifying guideline.

**Co-product:** Any of two or more products resulting from the same unit process or product system.

**Direct land use change (dLUC)**: dLUC is a change resulting from a specific land use and occuring on the same land as the land use.

**Elementary flows:** In the life cycle inventory, elementary flows include 'material or energy entering the system being studied that has been drawn from the environment without previous human

transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation'. Elementary flows include, for example, resources taken from nature or emissions into air, water, soil that are directly linked to the characterisation factors of the EF impact categories.

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

**Food products:** In this guideline, food products refer to primary agricultural products, aquatic products, and processed food products sold in the Danish market, which are produced in or imported by Denmark. It can be generic products or specific products.

**Foreground processes:** Those processes in the product life cycle for which direct access to information is available.

**Generic carbon footprint**: The carbon footprint of a generic product.

**Generic product**: This may be a real or a virtual (non-existing) product. The virtual product should be calculated based on average Danish market sales-weighted characteristics for all existing technologies/materials covered by the product category or sub-category.

**Indirect land use change (iLUC)**: This occurs when a demand for a certain land use leads to changes, outside that specific land area, i.e. in other land use types. These indirect effects may be mainly estimated by means of economic modelling of the demand for land or by modelling the relocation of activities on a global scale.

**Life cycle assessment:** Compilation and evaluation of the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle.

**Non-elementary (or complex) flows:** In the life cycle inventory, non-elementary flows include all the inputs (e.g. electricity, materials, transport processes) and outputs (e.g. waste, by-products) in a system that need further modelling efforts to be transformed into elementary flows.

**Offsets:** Offsets are calculated relative to a baseline that represents a hypothetical scenario for what emissions would have been in the absence of the mitigation project that generates the offsets.

**Product category:** A group of products that can fulfil equivalent functions.

**Product-specific carbon footprint:** The carbon footprint of a specific product, which is calculated based on company-specific data.

**Product sub-category:** A group of products, under the product category, that can fulfil similar functions.

**Representative product (model or Generic product)**: This may be a real or a virtual (non-existing) product. The virtual product should be calculated based on average Danish market sales-weighted characteristics for all existing technologies/materials covered by the product category or sub-category.

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

**Specific product:** Food products that are produced by an existing company or farm.

**Validation:** Confirmation – by the carbon footprint verifier – that the information and data in the carbon footprint study, carbon footprint report, and communication vehicles are reliable, credible, and correct.

**Verification:** Conformity assessment process carried out by an environmental footprint verifier to demonstrate whether the carbon footprint study has been carried out in compliance with this carbon footprint quantifying guideline.

**Waste:** Substances or objects which the holder intends (or is required) to dispose of.

# 1. Introduction

There are great political and social concerns about climate change in both production and consumption of food. The 27th session of the Conference of the Parties of the United Nations Framework Convention on Climate Change (COP27) has pointed out that there should be a stronger focus on sustainable consumption. The European Union (EU) initiated the Farm-to-Fork strategy, which aims to reduce the climate and environmental impact of the food system. In the food sector, this is in agreement with the decision on climate labelling of food in Denmark to empower consumers in green transitions through making environmentally sustainable choices [1]. A guideline for calculating food carbon footprints and developing a carbon footprint database is necessary to achieve this goal.

*Generic and product-specific*

This guideline provides a methodology for calculating the carbon footprints to develop carbon footprint databases of food products. Food products refer to primary agricultural products, aquatic products, processed food products sold in the Danish market, which are produced in or imported by Denmark. It can be generic products or specific products. A generic product is a real or virtual (non-existing) product that can represent the current production and consumption of a product in general. A virtual product should be calculated based on average Danish market sales-weighted characteristics for all existing technologies/materials covered by a product sub-category. The main difference in calculating the carbon footprint between generic and specific food products lies in the data collection. Generic products are mainly based on statistical data while the specific products are mainly based on company-specific data. Therefore, the carbon footprints of generic products are not based on an average of carbon footprints of the existing specific products. This guideline indicates where specific requirements are needed for generic and specific food products. Otherwise, the requirements in this guideline apply to both types of products. The carbon footprint of a generic product can work as a benchmark of the corresponding product sub-category. Because of the potential trade-offs between climate change and other environmental impacts, there are debates about whether carbon footprint can be used as an indicator for other environmental impacts[2]. However, it is considered that the guideline may be expanded to include other environmental impact categories in the future.

This guideline allows the comparison of the carbon footprint of generic and specific products, between different product categories, and between different products, because they share the same reference flow, system boundary, impact assessment methods, data quality assessment methods, etc.

*PEF and Agribalyse*

Based on the recommendation of the Climate Label Working Group, the method will rely on the product environmental footprint (PEF) guideline[3] as well as the work of the other EU countries, e.g., Agribalyse from France[1]. PEF provides detailed and comprehensive technical guidance on how to

[1] Klimamærke_anbefalinger fra arbejdsgruppen. pptx (foedevarestyrelsen.dk)
[2] eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52023PC0166
[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021H2279

conduct a PEF study for specific products. However, PEF could not be directly used for quantifying the environmental footprints of generic products, considering the foreground and background data collection. The French life cycle inventory (LCI) database Agribalyse 3.1[4], which complies with PEF in general, also provided a methodological reference in quantifying the environmental impacts of food products, especially for generic products that are representative at the national level. However, the climate situation and production systems in France are different from those of Denmark. Therefore, neither PEF nor Agribalyse can be applied to the Danish context directly, but both provided solid references for tailoring a guideline for Denmark. The current guideline can be used to compare the carbon footprints of food products (1) between generic products and specific products, (2) among different product categories, and (3) among different products.

The present guideline for carbon footprint calculation generally complies with and follows the structure of Annex 1 of the PEF guide ((EU) 2021/2279 of 16th December 2021). The (non)-compliance between the PEF guideline and the Agribalyse guidelines have been reviewed as preparation for developing this guideline (Appendix 1). Appendix 1 also includes the comparison with the requirements in the present guideline. As in the PEF guideline and Agribalyse guidelines, this guideline follows attributional life cycle assessment (LCA). In the present guideline, item numbers from Appendix 1 are referred in brackets e.g. (Item No. 1). Furthermore, the limitations of the present guideline are reported in Appendix 2.

*Terminology*

This guideline uses precise terminology to indicate the requirements, recommendations, and options that could be chosen when a carbon footprint study is conducted.

The term 'shall' is used to indicate what is required for a carbon footprint study to be in conformance with this guideline.

The term 'should' is used to indicate a recommendation rather than a requirement. Any deviation from a 'should' requirement must be justified when conducting the carbon footprint study and made transparently.

The term 'may' is used to indicate a permissible option. Whenever options are available, the carbon footprint study shall include adequate argumentation to justify the chosen option.

[4] https://doc.agribalyse.fr/documentation-en/agribalyse-data/documentation

# 2. Goal and scope

## 2.1 Goal definition

This guideline provides methodologies to calculate the carbon footprints of generic and specific food products sold in the Danish market (Item No.8 in the Appendix 1). The intended application of this guideline is to establish a carbon footprint database for generic and specific products on the Danish market (Item No.9).

For each carbon footprint study, the following information shall be included in the goal definition phase (Item No.9):

1) Intended application(s);
2) Reasons for carrying out the study and decision context;
3) Target audience;
4) Commissioner of the study;
5) Identity of the verifier.

## 2.2 Scope definition

### 2.2.1 Reference flow

The carbon footprint shall be performed with a reference flow of 1 kg of the food products (excluding the weight of the packaging materials) sold on the Danish market (Items No.11-15). According to PEF, in this guideline, the food losses along the supply chain within the system boundary (see section 2.2.2 of this guideline) shall be considered in the reference flow (Items No.12).

According to PEF, in this guideline, to indicate the quality aspect of the products, the national standards (if such exist) shall be used and cited when defining the reference flow, e.g., the regulated content of moisture, sugar, protein, etc (Item No.14). The reference flow may refer to section A.2.1.4 of Agribalyse report for agricultural stage[5] and section 1.2.3 of Agribalyse methodology report for food products [6], where some reference flows were corrected to standard moisture, sugar, protein contents.The effects of packaging on products' shelf-life are not considered in this guideline (Items No.13).

### 2.2.2 System boundaries

In this guideline, the system boundary shall be from the cradle to the retail store (when food products arrive at the retail store gate) (Item No.16-17). According to PEF, in this guideline, the system boundary shall be defined following a general supply-chain logic (Item No.17) including all upstream processes. This guideline only considered raw material acquisition and pre-processing, production of the main

[5] spaces/-M7H-JTDnDsswmNDPy-z/uploads/78a7sbhCCrPUID8pnaoT/AGB3.1_Methodology_Agricultural_Stage_vf.pdf (gitbook.io)
[6] Titre (gitbook.io)

product, and product distribution and storage, excluding the retailing stage, use stage, and end of life treatment of products (Item No.17).

According to PEF, in this guideline, a system boundary diagram (or flow diagram) shall clearly indicate the activities or processes that are included and those that are excluded from the analysis, and where company-specific data were used (Item No.19). Furthermore, the co-products, by-products, and waste streams of at least the foreground processes shall be clearly identified (Item No.18). Besides, the flow diagram shall be reported in the database documentation (Item No.20).

## 2.3 Environmental footprint impact categories

As opposed to the PEF guideline with 16 impact categories included, this guideline only includes one impact category, climate change (Item No.21).

## 2.4 Limitations/assumptions

The limitations of this guideline are included in the Limitation Report (Appendix 2).

According to PEF, in this guideline, all the limitations and assumptions in each life cycle stage while doing a carbon footprint study shall be transparently reported in the database documentation (Item No.29).

# 3. Life cycle inventory

According to PEF, in this guideline, an inventory of all material, energy, and waste inputs and output and emissions into air, water, and soil for the product supply chain shall be compiled as a basis for modelling the carbon footprint (Item No.30). Besides, the life cycle inventory (LCI) shall adopt the following classification of flows included: 1) elementary flows; 2) non-elementary (or complex) flows (e.g., product or waste flows) (Item No.31). Moreover, all non-elementary flows in the LCI shall be modelled up to the level of elementary flows, apart from the product flow (product and co-product) for the product in scope (Item No.32).

## 3.1 Screening step

A screening step is not required in this guideline.

## 3.2 Life cycle stages

In this guideline, the life cycle stages in a carbon footprint study shall be (Item No.34):

- Raw material acquisition and pre-processing (including agricultural and aquatic production);
- Manufacturing (food processing), which includes food processing, and packaging);
- Distribution (storageand distribution until retail store gate).
- End of life (CFF) for packaging materials.

According to PEF, in this guideline, splitting or adding life cycle stages shall be justified (Item No. 35).

### 3.2.1 Raw material acquisition and pre-processing (incl. agricultural and aquatic production)

This life cycle stage starts when resources are extracted from nature and ends when product inputs enter (through the gate of) the product's production facility. For food products, the processes (of raw material acquisition and pre-processing) that may occur in this stage include:

- mining and extraction of resources.
- pre-processing of all material inputs to the product in scope, including recyclable materials.

  e.g., fertilizers, pesticides, plastic films, packaging materials, electricity etc.

- Agricultural, (forestry), and aquatic activities
- transportation within and between extraction and pre-processing facilities, to the production facility.

For the agricultural production of primary agricultural products, the processes that may occur in this stage include, arable farming activities, e.g., ploughing, fertilization, irrigation, spraying pesticides, harvesting, etc.; animal husbandry activities, e.g., grazing, feeding, manure management etc.

For wild-caught aquatic products, the processes include fishing (all activities that the fishing vessel goes through to be able to deliver fish to shore) and preparation (transformation of the fish such as gutting, filleting, freezing, etc.). For farmed aquatic products, the processes include egg production, juvenile production, grow out, and preparation.

According to PEF, in this guideline, the production of packaging materials shall be modelled as part of this life cycle stage (Item No.37).

### 3.2.2 Manufacturing (food processing)

The food production stage begins when the product components enter the production site and ends when the finished food products leave the production facility.

For processed food products, the processes include food processing, e.g., slaughtering, dairy, cooking (recipes), refining, packaging, etc.

The waste of products used during manufacturing shall be included in the modelling for the manufacturing stage. Emissions from waste handling shall be included, but energy recovery should be excluded. The Circular Footprint Formula (CFF) shall not be applied.

### 3.2.3 Distribution

Products are distributed to the retail store and may be stored at various points within the system boundary. The distribution stage includes the transport of the products from the factory (farm) gate to the retail store. Examples of processes of distribution include: 1) Energy inputs for warehouse lighting and heating; 2) Use of refrigerants in warehouses and transport vehicles; 3) Fuel used by vehicles; 4) Roads and trucks.

Waste from products used during distribution shall be included in the modelling. Emissions from waste handling shall be included, but energy recovery should be excluded. The Circular Footprint Formula (CFF) shall not be applied.

According to PEF, in this guideline, the default loss rates of food products shall refer to part F of Annex 2 of the PEF guideline if specific information is unavailable (Item No.40). In this guideline, food loss or waste in the retail store and thereafter shall be excluded (Item No.41).

### 3.2.4 End of life (CFF) of packaging materials

The end of life stage begins when the packaging is discarded by the user and ends when the packaging materials are returned to nature as waste products or enter another product's life cycle (i.e. as a recycled input).

The end of life stage shall be modelled using the circular footprint formula (CFF) and requirements provided in section 3.4.8. The user of the PEF method shall include all EoL processes applicable to the packaging. Examples of processes to be covered in this life cycle stage include:

- Shredding and sorting;
- Wastewater from products used, dissolved in or with water (e.g. detergents, shower gels, etc.);
- Conversion into recycled material;
- Composting or other organic-waste treatment methods; 7
- Incineration and disposal of bottom ash;
- Landfilling and landfill operation and maintenance.

## 3.3 Nomenclature for the life cycle inventory

According to section 4.3 of the PEF guideline, in this guideline, the nomenclature of all elementary flows (refer to the most recent version of the EF reference package available on the EF developer's page[7]) and the process datasets and product flow (be compliant with the 'ILCD (International Reference Life Cycle Data System) Handbook – Nomenclature and other conventions'[8]) shall be EF-compliant (Item No.51).

## 3.4 Modelling requirements

This section provides detailed guidance and requirements on how to model specific life cycle stages, processes, and other aspects of the product life cycle, to compile the LCI. The structure of this section is in accordance with PEF, except for section 3.4.12 which is not included in Annex 1 of the PEF guideline. Section 3.4.12 is adapted from the Agribalyse methodology report for food products[6].

[7] https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml
[8] http://eplca.jrc.ec.europa.eu/repository/EF

### 3.4.1 Agricultural production

#### 3.4.1.1 Handling multi-functional processes

See Section 3.5 of this guideline (Item No.52).

#### 3.4.1.2 Crop type-specific and country, region, or climate-specific data

Consistent with PEF, crop type-specific and country/region/climate-specific foreground data shall be used, including yield, water and land use, land use change, fertilizer (artificial and organic) amount (N, P amount), and pesticide amount (per active ingredient), per hectare per year (Item No.53).In this guideline, for generic products, regional, national, or international statistical data shall be used; literature data or experts' opinions may be used if the statistical data are not available. For specific products, farm-specific foreground data shall be used to calculate the product-specific carbon footprint.

#### 3.4.1.3 Averaging data

(1) Crop production

The cultivation data shall be collected over at least 3 years (in general) to provide an average assessment of the LCI associated with the inputs and outputs for crop growing, according to the PEF guideline. Further details are described in section 4.4.1.3 of the PEF guideline (Item No.54).

(2) Animal production

In accordance with Agribalyse, the assessment should consider a full year-round, e.g., from January 1st to December 31st. If the production cycle is less than one year (e.g., rabbits, pigs, calves, poultry), the data is collected for a complete year considering several batches.

#### 3.4.1.4 Direct emissions

This guideline lists the methods that shall be used to model the emissions of agricultural production, including arable production and animal husbandry (Table 1). Among the emissions, only GHG emissions shall be considered in this guideline (Item No.57). According to PEF, N emissions shall be calculated from nitrogen applications by the farmer to the field and excluding external sources (e.g., rain deposition) (Item No.61). According to the PEF guideline, drained peat soils shall include $CO_2$ emissions based on a model that relates the drainage levels to annual carbon oxidation (Item No.68).

According to PEF, in this guideline, unless it is clearly documented that operations are carried out manually, field operations shall be accounted for through total fuel consumption or inputs of specific machinery, transports to/ from the field, energy for irrigation, or similar (Item No.70).

Table 1 Substances, processes, sources, methods, parameters, and emissions factors of GHGs during agricultural production

| Substances | Processes | Sources | Parameters in methods shall be country-specific | EF [a] | References |
|---|---|---|---|---|---|
| $CH_4$ | Enteric fermentation | Dairy cattle | Feeding rations and gross energy | CS [b] | IPCC 2019 Tier 2 |
| | | Non-dairy cattle | Feeding rations and gross energy | D [c] | IPCC 2019 Tier 2 |
| | | Sheep | Feeding rations and gross energy | D | IPCC 2019 Tier 2 |
| | | Swine | Feeding rations and gross energy | D | IPCC 2019 Tier 2 |
| | | Other livestock - deer | Feeding rations and gross energy | D | IPCC 2019 Tier 2 |
| | | Other livestock - goats | Feeding rations and gross energy | D | IPCC 2019 Tier 2 |
| | | Other livestock - horses | Feeding rations and gross energy | D | IPCC 2019 Tier 2 |
| | | Other livestock - poultry | | OTH [d] | IPCC 2019 Tier 1 |
| | | Other livestock - other (Poultry, ostrich, pheasants, fur bearing animals) | | OTH | IPCC 2019 Tier 1 |
| | Manure management | Dairy cattle | Volatile solids, digestibility of feed, gross energy, ash content of feed, and manure management systems | CS | IPCC 2019 Tier 2/CS |
| | | Non-dairy cattle | Volatile solids, digestibility of feed, gross energy, ash content of feed, and manure management systems | CS | IPCC 2019 Tier 2/CS |
| | | Sheep | Volatile solids, digestibility of feed, gross energy, ash content of feed, and manure management systems | D | IPCC 2019 Tier 2/CS |
| | | Swine | Volatile solids, digestibility of feed, gross energy, ash content of feed, and manure management systems | CS | IPCC 2019 Tier 2/CS |
| | | Other livestock - deer | Volatile solids, digestibility of feed, gross energy, ash content of feed, and manure management systems | D | IPCC 2019 Tier 2/CS |
| | | Other livestock - goats | Volatile solids, digestibility of feed, gross energy, ash content of feed, and manure management systems | D | IPCC 2019 Tier 2/CS |
| | | Other livestock - horses | Volatile solids, digestibility of feed, gross energy, ash content of feed, and manure management systems | D | IPCC 2019 Tier 2/CS |
| | | Other livestock - poultry | Volatile solids, digestibility of feed, gross energy, ash content of feed, and manure management systems | D | IPCC 2019 Tier 2/CS |
| | | Other livestock - other (Poultry, ostrich, pheasants, fur bearing animals) | Volatile solids, digestibility of feed, gross energy, ash content of feed, and manure management systems | D | IPCC 2019 Tier 2/CS |
| | Agricultural soil management | Field burning of agricultural residues | | D | IPCC 2019 Tier 1 |
| | | Paddy field | | D | IPCC 2019 Tier 2 |
| Direct $N_2O$ | Manure management | Dairy cattle | Nitrogen excretion and manure management systems | D | IPCC 2019 Tier 2 |
| | | Non-dairy cattle | Nitrogen excretion and manure management systems | D | IPCC 2019 Tier 2 |
| | | Sheep | Nitrogen excretion and manure management systems | D | IPCC 2019 Tier 2 |
| | | Swine | Nitrogen excretion and manure management systems | D | IPCC 2019 Tier 2 |
| | | Other livestock - deer | Nitrogen excretion and manure management systems | D | IPCC 2019 Tier 2 |
| | | Other livestock - goats | Nitrogen excretion and manure management systems | D | IPCC 2019 Tier 2 |
| | | Other livestock - horses | Nitrogen excretion and manure management systems | D | IPCC 2019 Tier 2 |
| | | Other livestock - poultry | Nitrogen excretion and manure management systems | D | IPCC 2019 Tier 2 |
| | | Other livestock - other (Poultry, ostrich, pheasants, fur bearing animals) | Nitrogen excretion and manure management systems | D | IPCC 2019 Tier 2 |
| | Agricultural soil management | Inorganic N fertilisers | Nitrogen excretion and manure management systems | D | IPCC 2019 Tier1/CS |
| | | Animal manure applied to soils | | D | IPCC 2019 Tier 1 |
| | | Sewage sludge applied to soils | | D | IPCC 2019 Tier1/CS |
| | | Other organic fertiliser applied to soils | | D | IPCC 2019 Tier1/CS |
| | | Urine and dung deposited by grazing animals | | D | IPCC 2019 Tier 2 |
| | | Crop residue | Nitrogen content in crop residues and mass of crop residues | D | IPCC 2019 Tier1/CS |
| | | Mineralization | | D | IPCC 2019 Tier 1 |
| | | Cultivation of organic soils (peat land) | | D | IPCC 2019 Tier 1 |
| | | Field burning of agricultural residues | | D | IPCC 2019 Tier 1 |
| Indirect $N_2O$ | Atmospheric deposition | | | D | IPCC 2019 Tier2 |
| | Where $NH_3$ shall be modelled with: | Livestock manure - housing and storage | | CS | Nielsen et al., 2022 [e] |
| | | Livestock manure application | | CS | Nielsen et al., 2022 |
| | | Deposited animal manure during grazing | | CS | Nielsen et al., 2022 |
| | | Inorganic N fertilizers | Fertiliser type, fertiliser amount (mass) | CS | EMEP-EEA Tier 2 |
| | Nitrogen leaching and run-off | | | D | IPCC 2019 Tier 2 |
| | Where $NO_3^-$ shall be modelled with: | Nitrogen leaching | | | The alternative N modelling approach in the PEF guideline |
| $CO_2$ | Agricultural soil management | Liming | | D | IPCC 2019 Tier 1 |
| | | Urea application | | D | IPCC 2019 Tier 1 |
| | | Other carbon-containing fertilisers | | D | IPCC 2019 Tier 1 |
| | | Cultivation of peat land | | D | IPCC 2014 Tier 1 |

Note: [a] EF: emission factor; [b] CS: country-specific value as described in the latest National Inventory Report for Denmark (Nielsen et al., 2022); [c] D: default value in IPCC 2019; [d] OTH: other, which is from Wang and Huang (2005). DOI: 10.5713/ajas.2005.873; [e] Source: https://dce2.au.dk/pub/SR494.pdf.

### 3.4.2 Electricity use

The electricity use shall be modelled in a hierarchical order according to 4.4.2 of the PEF guideline (Item No.71-81). The electricity type and use amount shall be collected.

### 3.4.3 Transport and logistics

According to PEF, in this guideline, the following parameters shall be considered when modelling the environmental impacts of transportation (Item No.82).

- Transport type: type of transportation, e.g., by land (truck, rail, pipe), water (boat, ferry, barge), or air (airplane).
- Vehicle type: (the type of vehicle by transport type, e.g., European emission standards).
- Loading rate (utilisation ratio): environmental impacts are directly linked to the actual loading rate, which therefore shall be considered. The loading rate affects the vehicle's fuel consumption.
- Number of empty returns: the number of empty returns (i.e. the ratio of the distance travelled to collect the next load after unloading the product to the distance travelled to transport the product), when applicable and relevant, shall be considered. The kilometres travelled by the empty vehicle shall be allocated to the product. In default transport datasets this is often already considered in the default utilisation ratio.
- Transport distance: transport distances shall be documented, applying average transport distances specific to the context being considered.

For specific products, the transportation from supplier to factory and from factory to retail store (distribution centre or directly to final client) shall be based on the specific data. If specific data are not available, then, the default scenarios in section 4.4.3.4 (supplier to factory) (Items No. 90) and section 4.4.3.5 (from factory to retail store or distribution centre) (Items No. 91-92) of the PEF guideline shall be complied with. The transportation from retail stores and distribution centres to final clients, and from factors (farms) to the final clients shall be excluded. The default scenarios shall also be applied to generic products if national data are not available.

For specific products, the loading rate and number of empty returns shall be based on the specific data. If the specific data are not available, it shall be based on the default information based on the corresponding datasets from LCA databases according to the Agribalyse methodology, e.g., Ecoinvent (Item No. 82), which also applies to the generic products.

For the transportation of packaging materials, the default scenarios in the PEF guideline (section 4.4.3.6) shall be referred to when detailed or specific data are not available (Items No. 95).

According to PEF, in this guideline, allocation rules on energy consumption at transportation (within the system boundary of the current guideline) shall refer to sections 4.4.3.1 for truck transport, 4.4.3.2 for van transport (Items No. 83-88).

### 3.4.4 Capital goods (infrastructure and equipment)

According to the AGB, capital goods including buildings and machineries should be included (Item No. 96). Reasons for the exclusion of capital goods shall be clearly documented and reported in the database documentation and verified by the verifiers.

### 3.4.5 Storage at distribution centre

Storage activities consume energy and refrigerant gases. According to PEF, in this guideline, the default data provided by PEF in section 4.4.5 shall be applied unless specific data are available (Item No.97), including, energy consumption at the distribution centre, refrigerant gases consumption and leakages at distribution centres with cooling systems. However, the energy consumption at retail shall be excluded as it is outside of the considered system boundaries. The allocation of this stage shall refer to section 4.4.5 of the PEF guideline (Items No. 97-99) . Storage at the retail stage and there after shall not be included.

### 3.4.6 Sampling procedure

A sampling procedure may be applied to limit the data collection to only a representative sample of plants, farms, etc. The sampling procedure may be needed where multiple production sites are involved in producing the same products, e.g., if the same raw material/ input material comes from multiple sites or if the same process is outsourced to more than one subcontractor/ supplier. The sampling procedure shall refer to 4.4.6 of the PEF guideline (Item No.98-103).

### 3.4.7 Modelling requirements for the use stage

Use stage is not included in this guideline (Item No.104-110).

### 3.4.8 Recycled content and end of life modelling

End of life and the circular footprint formula (CFF) is only considered for packaging materials (Item No. 111-152) (see section 3.4.12.5 of this guideline).

### 3.4.9 Extended product lifetime

Extended product lifetime is only considered for the packaging materials, which shall be referred to section 4.4.9 of PEF guideline (Item No. 153-160).

### 3.4.10 GHG emissions and removals

According to PEF, in this guideline, the impact category 'climate change' shall be modelled considering three sub-categories, climate change-fossil, climate change- biogenic, and climate change- land use and land use change (Item No.162).

#### 3.4.10.1 Climate change - fossil

This sub-category covers GHG emissions to any media originating from the oxidation and/or reduction of fossil fuels using their transformation or degradation (e.g., combustion, digestion, landfilling,

etc.). This impact category includes emissions from peat (used as a fuel) and calcination/carbonation of limestone, and uptakes due to carbonation.

Fossil $CO_2$ uptake and corresponding emissions (e.g., due to carbonation) shall be modelled in a simplified way when calculating the PEF profile (meaning no emissions or uptakes shall be modelled). (Item No. 163).

#### 3.4.10.2 Climate change - biogenic

According to PEF, in this guideline, when dealing with biogenic carbon, the following rules apply:

1) only the emission 'methane (biogenic)' is modelled;
2) no further biogenic emissions and uptakes from the atmosphere are modelled;
3) if methane emissions are both fossil and biogenic, the release of biogenic methane shall be modelled first, followed by the remaining fossil methane (Item No.167).

According to PEF, in this guideline, the mass allocation shall be applied to model the biogenic carbon flows (Item No.166).

#### 3.4.10.3 Climate change - land use and land use change

The modelling of the GHG emissions due to direct land use change fully complies with section 4.4.10.3 in the PEF guideline (Item No. 169-184). This sub-category accounts for carbon uptakes and emissions ($CO_2$, CO, and $CH_4$) originating from carbon stock changes caused by land use change and land use. This sub-category includes biogenic carbon exchanges from deforestation, road construction or other soil activities (including soil carbon emissions). Only direct land use change (dLUC) is considered while indirect land use change (iLUC) shall be excluded due to the lack of agreed methodology (Item No.169). According to PEF, in this guideline, biogenic carbon uptakes and emissions shall be inventoried separately for each elementary flow (Item No.170). For land use change, all carbon emissions and removals shall be modelled following the modelling guidelines of PAS 2050:2011 (BSI 2011) and the supplementary document PAS2050-1:2012 (BSI 2012) for horticultural products (Item No.171).

According to PEF, in this guideline, soil carbon sequestration due to land use shall be excluded from the results (Item No. 183 and 161). Though soil carbon sequestration is significant to climate change mitigation, there is no widespread method to quantify the soil carbon change in the LCA area. However, this guideline shall include soil carbon sequestration as soon as a widespread method is available.

Agribalyse 3.1 offers a temporary soil carbon patch on agricultural inventories in order to provide a first approach for taking carbon storage/destocking into account. However, the current guideline doesn't include it.

### 3.4.11 Offsets

In accordance with PEF, offsets shall not be included in the impact assessment of a PEF study (Item No.185). The term 'offset' is frequently used to refer to third-party GHG mitigation activities, e.g.,

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

## 3.4.12 Food processing

### 3.4.12.1 Cross-cutting aspects

The cross-cutting aspects includes the raw to cook ratio, inedible loss, and food density For generic products, the data from the Danish database Frida[9] shall have priority when handling the cross-cutting aspects, followed by other Danish databases or studies. For specific products, the cross-cutting aspects should be calculated based on the company-specific data if available. Otherwise, the requirements for generic products shall be applied to specific products.

**(1) Raw to cook ratio**

The weight of some food items differs when raw or cooked. The weight of a cooked food item shall be converted into a raw material weight based on the weight ratio from raw to cook (R2C ratio) [6]. If the water content of a specific food item is not available, an average R2C ratio of the same product category should be used.

$$\text{Ratio R2C} = \frac{Weight\ when\ cooked}{\text{Weight when raw}} = \frac{1-H_2O\%_{raw}}{1-H_2O\%_{cooked}} \qquad \text{Equation (1)}$$

Where $H_2O\%_{cooked}$ is the water content of the cooked food item, ranging from 0 to 1;

$H_2O\%_{raw}$ is the water content of the raw food item, ranging from 0 to 1.

**(2) Inedible loss**

Inedible loss (peels, kernels, etc.) during the food processing stage shall be considered in mass flow calculation.

**(3) Food density**

The density shall be used for conversions when units between datasets and recipes are different, e.g., from L to Kg.

### 3.4.12.2 Raw material origin

While mapping the datasets and raw material (ingredients of the processed food products) origins, the user of this guideline shall consider the production country of the raw material. Besides, different

[9] Frida - Food data published by DTU Food

production technologies/systems should also be considered, e.g., products for direct consumption and for processing, heated and non-heated greenhouse, greenhouse and open field, organic and conventional systems, in and off season, etc. The raw material origin of specific and generic products shall refer to sections (1) and (2), respectively, as follows:

**(1) For specific products**

The material origins should be based on company-specific data. If the exact material origin of a product is missing, the guidance for generic products (below) should be followed..

**(2) For generic products**

The consumption breakdown per country of origin shall be calculated at the Danish national level based on Equation (2) and Equation (3). Equations are modified from the Agribalyse methodology report for food products[6] (exports were considered in this guideline). All quantities shall be expressed in mass (ton) and averaged within 5 years.

$$Origin\ ratio_{m,DK} = \frac{Production_{m,DK} - Exports_m}{(Production_{m,DK} - Exports_m) + \sum_{i=1}^{n} Imports_{m,from\ country\ i\ to\ DK}} \quad \text{Equation (2)}$$

$$Origin\ ratio_{m,i} = \frac{Production_{m,from\ i\ to\ DK}}{(Production_{m,DK} - Exports_m) + \sum_{i=1}^{n} Imports_{m,from\ coutnry\ i\ to\ DK}} \quad \text{Equation (3)}$$

Where:

Origin ratio$_{m,DK}$ is the fraction of the total Danish consumption of product m that originates from Danish production (%).

Origin ratio$_{m,i}$ is the fraction of the total Danish consumption of product m that originates from country i (%);

Production$_{m,DK}$ is the quantity of product m that is produced in Denmark (t);

Export$_{m,DK}$ is the quantity of product m that is exported from Denmark (t);

Imports$_{m,\ from\ i\ to\ DK}$ is the quantity of product m that is imported by Denmark from country i (t);

n is the number of countries that Denmark imports the product m from.

In line with the Agribalyse methodology, countries of origin shall be determined using data from databases with an average of five years of data. However, data from the Danish national statistical database shall have priority, followed by FAOSTAT[10]. The detailed origin of each raw material by country shall not be lower than 70%. Then, the origins of raw material shall be normalized into 100%.

[10] FAOSTAT

#### 3.4.12.3 Processing processes (food industry)

Processing processes include the necessary treatments of raw materials for producing processed food products. Mechanical operations (e.g., slicing, pressing, etc.) should be given less attention. The cross-cutting aspects described in section 3.4.12.1 of this guideline are in principle applied at this stage.

(1) For specific products

For specific products, the modelling of processing processes shall refer to section 3.6.6 of this guideline.

(2) For generic products

The considered processes are listed below (not limited). The modelling of corresponding processes may refer to section 3.2 of the Agribalyse methodology report for food products[6].

(1) Slaughtering, grinding, cutting
(2) Drying
(3) Processing of dairy products
(4) Processing of cereal and legume products
(5) Processing of coffee, chocolate, tea, pasta
(6) Processing of soups
(7) Cooling and freezing
(8) Processing of sugar and sweets
(9) Canning
(10) Recipe pre-processing for ingredients (peeling, unshelling, fileting, pitting, smoking, etc.)

#### 3.4.12.4 Recipes

For recipe processing (e.g., frozen pizza), energy is used at the plant. All process datasets shall be defined for 1 kg of the recipe (excluding the weight of the packaging). If the ingredient is cooked, the actual quantity of the ingredient shall be computed as raw, using the 'raw to cook' ratio. The removed inedible part of most fruits, vegetables, and meat ingredients shall be applied upstream, prior to entering the recipe. According to the Agribalyse methodology report for food products[6], a 95% mass cut-off should be applied for recipes. The remaining ingredients after cut-off shall be normalised to 100%. However, for some products in particular, ingredients representing less than 5% by weight may still be counted if they have high carbon footprints (>3% of total product impact), e.g., chocolate milk: taking cocoa into account.

For specific products, the recipe processing shall be modelled according to the Data Needs Matrix (DNM) in section 3.6.6 of this guideline.

For generic products, the modelling of recipe processing may refer to section 3.3 of the Agribalyse methodology report for food products[6]. Recipe databases from Denmark shall have priority. Necessary modifications (e.g., ingredient types and amount) shall be done to adapt to Danish consumption and eating preferences when referring to foreign recipe databases.

#### 3.4.12.5 Packaging

Packaging material production, transportation, and packaging stages are considered. According to PEF, in this guideline, the production and transportation of packaging shall belong to the 'Raw material acquisition and pre-processing' stage (Item No. 37). The packaging (e.g., electricity use) is part of the food production phase. For the use of packaging materials, the circular footprint formula (CFF) shall be applied with the company-specific data, if available; or datasets with CFF embedded shall be used, if available (Item No. 111).

For specific products, the packaging material, transportation, and packaging shall be modelled according to the Data Needs Matrix (DNM) in section 3.6.6 of this guideline.

For generic products, the following rules shall be applied, according to Agribalyse methodology [6]:

(1) The packaging material should be based on the weighted market data in Denmark.
(2) The transportation distance of packaging materials may refer to the default scenarios in 4.4.3.4 and 4.4.3.6 of the PEF guideline if specific data are not available.
(3) All B2B (business-to-business) packaging is not accounted for in this guideline. Regarding B2C (business-to-consumer) packaging, only the production and forming of primary packaging are considered. Primary packaging material is defined for each food group.
(4) The packaging mass ratio (e.g., the ratio between the packaging mass and the ingredient mass) should be used for calculating the mass of packaging material, which may refer to Annex 17 of the Agribalyse methodology report for food products[6].
(5) Plastics should be taken at the granulate production level.
(6) When available, material grade (e.g., plastic grades include PET, HDPE, PVC, LDPE, PP, PS, and O) is chosen according to the packaging application.

## 3.5 Handling multi-functional processes

If a process or facility provides more than one function, i.e., it delivers several goods and/or services ('co-products), it is 'multi-functional'. According to PEF, in this guideline, in these situations, all inputs and emissions linked to the process shall be partitioned between the product of interest and the other co-products in a principled manner (Item No.186). Systems involving multi-functionality of processes shall be modelled in line with the following decision hierarchy.

Specific allocation requirements in other sections of this method always prevail over the ones available in this section (e.g., sections 3.4.2 on electricity, 3.4.3 on transportation, 3.4.10 on GHG emissions, or 3.5.1 on slaughterhouses).

The following hierarchy based on EN ISO 14044:2006 shall be followed (Item No.187):

1) Wherever possible, the allocation should be avoided by (Item No.188),
    a) Dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes., or

b) Expanding the product system to include additional functions related to the co-products.

2) Where the allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them (Item No.189).
3) Where physical relationships alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them, e.g., economic value (Item No.190).

### 3.5.1 Allocation in animal husbandry

For the cattle, sheep, goat, and pig production within the farm, handling of multi-functional processes shall refer to section 4.5 of the PEF guideline (Item No. 52, 192-205). The International Dairy Federation (IDF) allocation method between milk, cull cows and surplus calves shall be used (Item No. 197). However, the requirements from IDF (International Dairy Federation) 2015 shall be replaced with those from the latest IDF standard. Allocation at farming stage between piglets and sows shall be made applying economic allocation. The prices shall be based on the Danish market prices (use the average values in the past 5 years) (Item No. 205). Dead animals shall be regarded as waste (Item No. 201), but the Circular Footprint Formula (CFF) shall not be applied. Instead potential emissions from handling dead animals should be included, but energy recovery shall be excluded. In the Danish context, manure can be considered a residual or a co-product, but not a waste (Item No. 196).

### 3.5.2 Allocation in crop production

According to PEF, in this guideline, the rules described in the LEAP Guideline shall be followed[11] (Item No.52).

### 3.5.3 Allocation in aquatic production

According to the latest version of Marine Fish PEFCR, economic allocation shall also be applied to marine fish products, including process/stage of fishing (allocation of fishing effort between products landed), aquaculture fish farm (allocation of products for human consumption and other products), feed production, preparation (allocation between main products and by-products).

### 3.5.4 Allocation in food processing

At the slaughterhouse level, when subdivision of processes is not possible, economic allocation shall be used. Actual mass fractions and Danish market prices (use the average values in the past 5 years) should be used to determine allocation factors. If data are not available regarding the actual mass and prices, the procedure described in the PEF guideline (Item No. 206-212) can be applied.

[11] Environmental performance of animal feed supply chains (pages 36-43), FAO 2016, available at http://www.fao.org/partnerships/leap/publications/en/

EoL using CFF shall not be considered for waste products (products which the holder intends to/or are required to dispose of e.g. waste water). However, potential emissions in the waste treatment should be included and potential energy recovery should be excluded.

Allocation in food processing shall follow the hierarchy stated in section 3.5 of this guideline shall be followed. For multi-functional processes in dairy processing, the allocation shall refer to PEFCR for Dairy Products.

## 3.6 Data collection requirements and quality requirements

### 3.6.1 Generic product data

The users of this guideline shall apply the classification of products by activity (CPA)[12]. Based on CPA, the product categories and subcategories shall be defined, which shall refer to section A.3.1. of the PEF guideline.

After the product classification system has been decided, the generic product (the same as the 'representative product (model)' in the PEF guideline) under each sub-category shall be defined. A generic product may be a real or virtual (non-existing) product. A virtual product should be calculated based on average Danish market sales-weighted characteristics (based on mass (a ton of material)) for all existing technologies/materials covered by the sub-category.

The users of this guideline shall provide information about all the steps taken to define the 'model' of a generic product for each product sub-category in the database documentation (Item No.20). A generic product reflects the current situation of technologies, transportation scenarios, energy scenarios, etc. The data used shall reflect realistic market averages (products sold on the Danish market) and be the most recent, both for imported and products produced in Denmark. Geographical information shall be considered only when evidence shows the environmental impacts of a product vary among the production sites. Technological information shall be considered, e.g., certification type (organic or conventional), intended use (for direct consumption or processing), fat content (3.5%, 1.5%, 0.4%), etc. Technological classification of products may refer to Appendix A of the Agribalyse methodology report for food products[6].

The carbon footprint of a generic product serves as a generic carbon footprint of a product sub-category. It should be noted that a generic carbon footprint is not the average value of every single product under a product sub-category (bottom-up approach). It is calculated based on the statistical data or expert opinion (top-down approach). A generic product is also the basis for identifying the environmental benchmark of a corresponding product sub-category. A benchmark is a standard or point of reference against which any comparison may be made. In the context of this guideline, a generic carbon footprint works as a benchmark of a specific product under the corresponding product

[12] Europa - RAMON - Classification Detail List

sub-category. While calculating the generic carbon footprint for generic products, requirements on company-specific data in this guideline are exempted.

### 3.6.2 Company-specific data

Company-specific data are directly measured or collected at a farm/field(s), a food processing company, a specific facility, or a set of facilities. They represent one or more activities or processes within the system boundary. Company-specific data are used to calculate the carbon footprint of a specific product. Company-specific data shall include all known inputs and outputs for the processes unless it complies with the corresponding cut-off rules in this guideline (Item No.213). GHG-related emissions are divided into two compartments, air (e.g., $CH_4$, $CO_2$, $N_2O$, $NH_3$ for indirect $N_2O$ calculation, etc.) and water (e.g., $NO_3^-$ for indirect $N_2O$ calculation).

All new datasets created shall comply with the present guideline. The modelling of the food production processes shall be based on company-specific data (Item No.217). All company-specific data shall be modelled in company-specific datasets (Item No.215). The bill of materials (BoM) shall include the list of materials/ingredients and the quantity used for each of them. The activity data of the BoM shall be specific to the product in scope and modelled with company-specific data based on the current guideline (Item No.216). Besides, for companies producing more than one product, the activity data used (including the BoM) shall be specific to the product covered by the study (Item No.4, 216).

### 3.6.3 Secondary data

Secondary data refers to data not based on direct measurements or the calculation of the respective processes in the system boundary. Secondary data are either sector-specific, i.e., specific to the sector being considered for the carbon footprint study, or multi-sector, which includes data from literature or scientific papers, and industry average life-cycle data from LCI databases, industry association reports, government statistics, etc.

All secondary data shall be modelled in secondary datasets which shall fulfil the data hierarchy in Sections 3.6.4 and 3.6.6 of this guideline (Item No. 218). The quality of the secondary data shall comply with the requirement described in section 3.6.4 of this guideline (Item No. 218). The sources of the data used shall be clearly documented and reported in the database documentation (Item No. 218).

### 3.6.4 Datasets to be used

According to the requirements of 4.6.3 in the PEF guideline, EF-compliant secondary datasets shall be used, when available (Item No. 219). New secondary datasets shall comply with the present guideline. For imported food products, inventory data from secondary datasets shall be used, the carbon footprint of which shall be calculated based on the current guideline. The secondary datasets of imported products shall be as accurate as possible, in terms of production systems, geographical location, seasonality, etc. Otherwise, the national average dataset shall be used. If an EF-compliant secondary dataset does not exist or cannot be developed, the selection of the datasets to be used shall be done according to the following rules, provided in hierarchical order.

1) Use an EF-compliant proxy; the use of proxy datasets shall be reported in the database documentation; data converted from previous EF compliance systems (e.g., EF 2.0 to EF 3.0) are considered proxies;
2) Use an ILCD-EL (International Reference Life Cycle Data System-entry level) compliant dataset (from e.g., Ecoinvent, Agri-footprint, etc.) as a proxy; the overall background datasets may be derived from ILCD-EL compliant datasets (Item No. 221);
3) If no EF-compliant or ILCD-EL compliant dataset is available, use another ISO 14040 compliant dataset. A maximum of 10% of the carbon footprint may be derived from those datasets. This shall be clearly stated in the database documentation.

Proxies should be determined depending on:

1) the biological proximity of the food items,

2) the proximity of the farming methods, and

3) the proximity of production conditions (soil, seasons of cultivation, climate, etc.).

The use of proxies shall be accounted for in DQR (Data Quality Rating).

### 3.6.5 Cut-off

Following the Agribalyse methodology, there are no cut-off rules for food products in general. However, it is stated explicitly whether an input is excluded from the system (Item No.222). Specific cut-off rules are stated in, sections 3.4.12.2 and 3.4.12.4 of the present guideline. Any other exclusions of inputs or processes in the carbon footprint analysis shall be stated and approved by the reviewers. It should be noted that cut-offs exist in secondary datasets.

### 3.6.6 Data quality requirements

The data quality shall be assessed according to 4.6.5 in the PEF guideline (Item No.223). The Data Quality Rating method shall be applied to calculate the data quality, which shall comply with section 4.6.5.1 in the PEF guideline (Item No.224). The quality of the company-specific datasets and the secondary datasets shall be assessed based on the requirements in sections 4.6.5.2 (Item No.225-230) and 4.6.5.3 in the PEF guideline (Item No.231), respectively. As for company-specific datasets, the sub-processes shall be assessed through the Data Needs Matrix (DNM) in Table 2.

According to PEF, in this guideline, to calculate the DQR, the users shall calculate the TeR (Technological representativeness), TiR (Time representativeness), GeR (Geographical Representativeness), and P (Precision), separately (Item No.242). They shall be calculated as the weighted average of the DQR scores of all most relevant processes, based on their relative environmental contribution to the total carbon footprint, using Equation 20 in the PEF guideline (Item No.242).

The Data Needs Matrix (DNM) shall be used to evaluate the data requirements of all processes required to model the product in scope, according to the PEF guideline. There are three situations in the DNM:

DNM Situation 1: the process is run by the company that owns the product. Company-specific data (both activity data and direct emissions) shall be used, creating a company-specific dataset that is compliant with this guideline (Item No.214).

DNM Situation 2: the process is not run by the company that owns the product, but this company has access to (company-) specific information.

Option 1: provide company-specific data and create a company-specific dataset; or

Option 2: use an EF-compliant secondary dataset and apply company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets. The overall background datasets may be derived from ILCD-EL compliant datasets (Item No.234).

DNM Situation 3: the process is not run by the company that owns the product and the company that runs the process does not have access to (company-) specific information. Use EF-compliant secondary datasets or ILCD-EL compliant secondary datasets or other ISO 14040-compiant secondary dataset (only 10% of the carbon footprint). For these datasets the DQR shall not be recalculated. Section 3.4.6 of this guideline shall be complied with in this situation.

Table 2 DNM – requirements for a company-specific datasets

| | | Data requirements |
|---|---|---|
| Situation 1:<br>Process run by the company | Option 1 | Provide company-specific data (both activity data and direct emissions) and create a company-specific dataset (DQR $\leqslant$ 1.5). Calculate DQR of the dataset following the rules in Section 4.6.5.2 of the PEF guideline. |
| Situation 2:<br>Process not run by the company but with access to company-specific information | Option 1 | Provide company-specific data and create a company-specific dataset (DQR $\leqslant$ 1.5). Calculate DQR of the dataset following the rules in Section 4.6.5.2 of the PEF guideline. |
| | Option 2 | Use an EF-compliant secondary dataset and apply company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF-compliant datasets (DQR $\leqslant$ 3.0). Recalculate DQR of the dataset used (see Section 4.6.5.6 of the PEF guideline). |
| Situation 3:<br>Process not run by the company and without access to company-specific information | Option 1 | Use an EF-compliant secondary dataset in aggregated form (DQR $\leqslant$ 3.0). Recalculate DQR of the dataset if the process is most relevant (see Section 4.6.5.7 of the PEF guideline). |

The users of this guideline shall match each process of the product with one of the three situations and list them in a table in the database documentation. Data requirements for each situation shall refer to sections 4.6.5.4, 4.6.5.5, 4.6.5.6, and 4.6.5.7 in the PEF guideline.

# 4. Carbon footprint impact assessment

In this guideline, only characterization is included (Item No.243-253). The impact category indicator is global warming potential (GWP 100) and the characterization model shall be the Bern model- Global warming potentials over a 100-year time horizon. The characterization factors and related methodological materials are available in the EF reference package 3.1 on the JCR's website[13].

According to PEF, in this guideline, three sub-categories of GHGs as shown in section 3.4.10 of this guideline, shall be reported separately if they show a contribution of more than 5% each to the total score of climate change (Item No. 162). Moreover, the flows falling under each category shall be modelled consistently with the elementary flows in the most updated EF reference package and use names that end with '(fossil)', '(biogenic)', and '(land use change)' if available (Item No.164,166, 170).

# 5. Interpretation of product carbon footprint results

The interpretation phase shall be performed as required by the PEF guideline in section 6 (Item No. 254-281). In the step 'identification of hotspots', the 'most relevant impact categories' shall be excluded from the interpretation since this guideline only includes one impact category (climate change) (Item No. 256-257). The most relevant processes and direct elementary flows are only investigated for the impact category climate change (Item No. 267-279).

# 6. Product carbon footprint reports

The product carbon footprint reports shall be performed according to the PEF guideline in section 7 (specifically according to the reporting template in Annex II – Part E of the PEF guideline) (Item No. 282-288). Part of the information from carbon footprint reports (e.g., inventory data) may favourably be embedded into the database documentation.

# 7. Verification and validation of carbon footprint studies, reports, and communication vehicles

The verification and validation of the carbon footprint study is mandatory whenever the study or part of the information therein, is used for any type of external communication, i.e., communication to any interested party other than the commissioner or the user of the carbon footprint study. The verification of the carbon footprint study shall ensure that the carbon footprint study is conducted in compliance

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

with this guideline (Item No. 340). The verification and validation shall be performed according to the PEF guideline in section 8 (Item No. 289-350). The validation of the most relevant impact categories shall be excluded (Item No. 315). The developed datasets are not required to be available to the European Commission (Item No. 324). Confidential information shall only be shared with the verifiers and the Danish authorities related to certification and accreditation (Item No. 339).