Report 2025

Environmental footprint methodology margarine

Shadow PEFCR for the European Margarine Association

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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.

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List of Abbreviations

ADP-fossil – Abiotic Depletion Potential - fossil fuels

B2B – Business to Business

B2C – Business to Consumer

CFF – Circular Footprint Formula

COD – Chemical Oxygen Demand

CPA – Classification of Products by Activity

CTUe – Comparative Toxic Unit for ecosystems

DC – Distribution Centre

DEFRA – Department for Environment, Food & Rural Affairs (UK)

EF – Environmental Footprint

EoL – End-of-Life

FU – Functional Unit

GHG – Greenhouse Gas

GLO – Global (in datasets)

ISO – International Organization for Standardization

LANCA® – Land Use Indicator Value Calculation in Life Cycle Assessment

LCA – Life Cycle Assessment

LCI – Life Cycle Inventory

LCIA – Life Cycle Impact Assessment

LDPE – Low Density Polyethylene

LHV – Lower Heating Value

MJ – Megajoule

NH_3 – Ammonia

NO_3 – Nitrate

NO_x – Nitrogen Oxides

PA66 – Polyamide 66

PAS 2050 – Publicly Available Specification 2050

PBT – Polybutylene Terephthalate

PC - Polycarbonate

PEF – Product Environmental Footprint

PEFCR – Product Environmental Footprint Category Rules

PEI - Polyetherimide

PET – Polyethylene Terephthalate

PM – Particulate Matter

PO_4 – Phosphate

POM - Polyoxymethylene

PP – Polypropylene

Pt – Points (dimensionless)

PPE – Polyphenylene Ether

PPS – Polyphenylene Sulphide

PS – Polystyrene

PVC – Polyvinyl Chloride

ReCiPe – Life Cycle Impact Assessment Methodology

RED – Renewable Energy Directive

RoW – Rest of World

SAN – Styrene Acrylonitrile

SEBS – Styrene-Ethylene-Butylene-Styrene

SO_x – Sulphur Oxides

TDS – Total Dissolved Solids

TS – Technical Secretariat

UNEP – United Nations Environment Programme

VOC – Volatile Organic Carbon

WFLDB – World Food LCA Database

WRI-WBCSD – World Resources Institute – World Business Council for Sustainable Development

Table of contents

1. Introduction

This document provides complete and detailed guidance on how to conduct a comprehensive environmental footprinting study for margarine and other emulsified fats.

An environmental footprinting (EF) study, also referred to as a life cycle assessment (LCA), is a framework to evaluate the environmental impact of a product or system throughout all the stages of its life cycle, from extraction of raw materials to end of life. At each life cycle stage, it quantifies the necessary inputs (such as energy, materials, water, land) and outputs (such as co-products, waste streams and emissions to air, water and soil).

EF studies are carried out to gain a better understanding of the environmental performance of a product and to identify hotspots and potential strategies that can reduce its environmental impact. The results of an EF study can be used for internal purposes but can also be used for external communication.

An EF can be sensitive to methodological and data choices made by an LCA practitioner, which can potentially lead to different outcomes of an EF performed for the same product by different practitioners. These EF guidelines reduce the number of sensitive choices. They provide a harmonised and consistent set of rules that can be used to calculate the impact of margarine, ensuring the outcomes of the EF study are reproducible and use comparable principles.

For the entire life cycle of margarine, by providing detailed guidance for each of the production steps, these guidelines explain in detail:

- What data are needed, and whether it should be based on primary or secondary sources;
- What inputs, outputs and emissions should be included, and how these can be calculated;
- How to deal with margarine-specific situations (e.g. processing methods, packaging materials, distribution channels, manufacturing conditions, and use and end-of-life scenarios);
- Methodological choices, such as allocation, carbon removals, and recycling of packaging;
- What defaults and proxies may or should be used in case of unavailable data.

These guidelines align as much as possible with the guidance developed by the European Commission for the development of Product Environmental Footprint (PEF) studies, which build upon the international ISO LCA standards and is why they are referred to as “Shadow PEFCR”. At the time this document was developed, there was no opportunity to create an official PEFCR with the European Commission. Despite that, the aim was to stay as close as possible to current PEFCR guidelines to have a solid methodology that can serve as foundation for when a new opportunity arises to develop an official PEFCR.

For feedback on and questions about these guidelines, please contact: Davide Lucherini (davide@blonksustainability.nl)

2. General information

2.1 Development of the guidelines

This study was commissioned by the European Margarine Association (IMACE) and guided by Mérieux NutriSciences | Blonk. The content of these guidelines has been prepared and written by Mérieux NutriSciences | Blonk but has been decided upon and revised by the technical secretariat (TS) **Fout! Verwijzingsbron niet gevonden.** below lists the members of the technical secretariat.

Table 1 : Members of the technical secretariat.

Organization	Members
Vandemoortele	Carine Hintjens
Vandemoortele	Lieselot Delabie
Vandemoortele	Astrid de Paepe
Flora Food Group	Lizzette Butkiewicz
GF impact	Gaetan van de Laer
Puratos	Nuria Devos
Puratos	Roxane Detry
Mills	Kirsti Christiansen
Aigremont	Elise Lannoy
Royal Smilde	Ruud Tamsma

The TS has been supported by several employees from Mérieux NutriSciences | Blonk, as listed in Table 2.

Table 2: Functions of Mérieux NutriSciences | Blonk employees involved in the guideline development.

Mérieux NutriSciences | Blonk employees involved	Function in guideline development
Elisabeth Keijzer	Lead in set up phase
Lana Liem	Execution
Eline Disselhorst	Execution
Jasper Scholten	Support
Davide Lucherini	Lead & main author

2.2 Review statement

These guidelines were not reviewed by an external party outside of IMACE and Mérieux NutriSciences | Blonk.

2.3 Relations to other guidelines

Wherever possible, we aligned with existing environmental footprinting standards at the European level, particularly the Commission Recommendations (EU) 2021/2279 on the use of the Environmental Footprint method (European Commission, 2021). More specifically, alignment was sought with the Product Environmental Footprint (Annexes 1 to 2), also referred to as “generic PEF” in this document. At the time of publication, there is awareness of the future publication of the updated PEF guidance in 2026. Alignment with what is expected to be proposed on a methodological perspective has been integrated when possible, but full alignment cannot be guaranteed.

In addition to the generic PEF, this document has taken inspiration from the Product Environmental Footprint Category Rules (PEFCR) of Dairy and the Feed PEFCR in regarding certain modelling choices and default data (FEFAC, 2024; The European Dairy Association (EDA), 2025). Similarly, the Shadow PEFCR of Vegetable oils is used to set up the first part of the production system of margarine products (De Smet et al., 2022).

Disclaimer

This document is not an official PEFCR and cannot be used to claim PEFCR compliance. The guidelines differ from the official PEFCR development in several ways: no representative products were modelled, and no supporting studies were conducted, which are crucial for identifying relevant impact categories and life cycle stages. Instead, these were identified through literature and expert recommendations. Additionally, the guidelines were not reviewed by the European Commission's Technical Advisory Board (TAB) or through public consultation. The use of the European Environmental Footprint (EF) database, typically required for PEF-compliant studies, may only be used in the context of official PEFCRs and thus is also not allowed. According to direct communication with the TAB, the use of EF data might change when the new database will be published.

These guidelines aim to establish key methodological rules for measuring the environmental impact of margarine without providing exact quantifications for benchmarks. While not the main focus of the guidelines, this report provides recommended certain background datasets, subject to their specific terms and conditions. The intend of this document is to guide the reader into how to perform an LCA. Comparisons may be relevant with products in the same category/that fulfil the same function. For the margarine sector, comparison of a products environmental performance with dairy products with similar functions is highly relevant, an annex (Annex I) to this PEFCR is developed with extra guidance on how to make equal comparisons between these products.

2.4 Terminology

(Based on generic PEF)

These guidelines use precise terminology to indicate the requirements, the recommendations and options that could be chosen when executing an EF:

- *The term "shall" is used to indicate what is required for an EF report to be in conformance with these guidelines.*
- *The term "should" is used to indicate a recommendation rather than a requirement. Any deviation from a "should" requirement has to be justified when executing the EF and made transparent.*
- *The term "may" is used to indicate an option that is permissible. Whenever options are available, the EF report shall include adequate argumentation to justify the chosen option.*

2.5 Geographical validity

These guidelines are focused on margarine sold or used in the European Union, the UK (since the PEF framework formerly did apply to the UK before Brexit, leading to harmonized sustainability standards with the EU) and the European Free Trade Area. However, use of the guidelines is valid for all other geographical regions. It is expected that these guidelines will primarily be used by companies that manufacture or sell margarine.

2.6 Language

The guidelines are written in English. At this stage, there are no plans to make this document available in other languages. If conflicts arise between translated versions and the original English document, the English version prevails.

3. Goal and scope

3.1 Product classification

Margarine and other emulsified products can be defined as a food product made primarily from refined vegetable oils and/or fats, processed into a semi-solid or liquid form suitable for various culinary uses. The products in scope for these guidelines are margarine and other emulsified products for baking, frying, spreading, cooking and use as a greasing agent. These guidelines cover different packaging formats and functional uses of margarine and include intra-category comparisons between various margarine and other emulsified products as well as comparisons with dairy butter. The exact definition of the products in scope for this PEFCR is given below:

Products in the form of a solid, semi-liquid, malleable emulsion, principally of the water-in-oil type, derived from solid and/or liquid vegetable and/or animal fats suitable for human consumption (such as margarines, spreads, blends, melanges for spreading, cooking, baking) or to be used as an ingredient for other food products and food applications (B2C & B2B). Fat content 20-80% for B2C products, and 60-99% fat B2B products, in accordance with the EU Regulation 1308/2013 (see EU 1308/2013 Annex VII, Appendix II)

No products are explicitly out of scope. For reading purposes, from hereafter, margarine and other emulsified products, are referred to as margarine. It is important to use the correct legal definition in the product LCA performed in accordance with this PEFCR.

3.2 Functional unit

The Functional Unit (FU) provides a quantitative and qualitative description of the performance of a product, and is used as a reference unit, allowing equitable comparisons between products.

Within these guidelines, the functional unit will be defined as below, more information is given in Table 3.

For (semi-)solid margarines: 1 kg of margarine for use as a spread, baking, frying or cooking fat, or use as a greasing agent.

For liquid margarines 1 liter of margarine for use as a baking, frying or cooking fat, or use as a greasing agent*.

*For liquid margarines the functional unit may also be expressed with the mass units (kg) for comparative LCA's.

Table 3: Key aspects of the functional unit (FU).

Dimension	Definition for (semi-)solid margarines	Definition for liquid margarines
Functional Unit Quantified performance of a product system, to be used as a reference unit	1 kg of margarine for use as a spread, baking, frying or cooking fat or use as a greasing agent.	1 Liter of margarine for use as a spread, baking, frying or cooking fat or use as a greasing agent.
What? The function/service provided	To provide a (partially) plant-based product for use as spread, baking, frying or cooking fat as a greasing agent.	To provide a (partially) plant-based product for use as spread, baking, frying or cooking fat as a greasing agent.
How much? The extent of the function or service	1 kg	1 Liter
How well? The expected level quality	For human consumption	For human consumption
How long? The duration/lifetime of the product	Until at least 2 months after production	Until at least 2 months after production

Reference flow Amount of product needed to fulfil the defined function	1 kg of margarine (2 margarine folds of 500 grams or 2 tubs of 500 grams)	1 Liter of liquid margarine (1 flask of 1 liter or 0.33 flask of 3 liter)

3.3 System boundaries

The system boundaries define which processes should be included or excluded from the study. A distinction is made between B2B and B2C products in terms of system boundaries. The B2C products are readily made at the margarine production stage and do not need further processing. B2B products have a wide variety of use cases and applications and generally need further processing before final consumption. Hence, there is little control of the margarine producer and LCA practitioners and is decided to follow different system boundaries.

The life cycle stages that shall be included within the system boundary for margarine are summarized below in Figure 1 and Figure 2 and Table 4 .

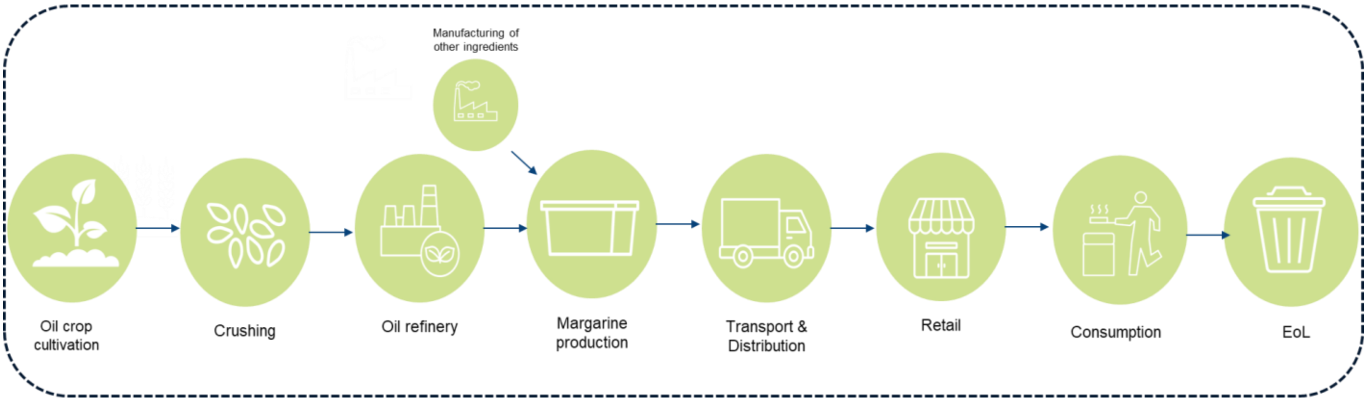

Figure 1 : System boundary diagram of the margarine life cycle for B2C product

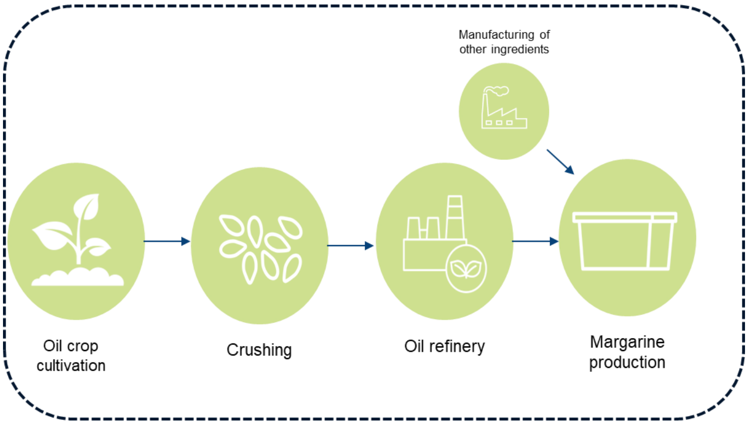

Figure 2: System boundary of the margarine life cycle for B2B products

All stages described in Table 4 below are relevant for B2C products. For B2B products, only up until distribution (stage 7) is included.

Table 4 : Life cycle stages of margarine

Main life cycle stage (generic PEF)	Specific life cycle stage (these guidelines)	Section (these guidelines)	Relevant activities
Agricultural inputs acquisition and pre-processing	**1. Oil crop cultivation**	5.1	• Production and inbound transport of cultivation inputs; application of the cultivation inputs (synthetic and organic fertilizers, pesticides, water, etc.); • Land use change: proof regarding absence of deforestation. • Cultivation: Co-products, field residues, yield, electricity use, fertilizer use, pesticide application, diesel and natural gas use • Drying: energy inputs (if relevant) • Waste & residue generation resulting from cultivation and harvest activities and its management.
	2. Oil crop pre-processing (crushing)	5.2	• Transport of inputs • Processing inputs; Raw materials (list of ingredients), electricity, steam, water, chemicals • Products, co-products & waste management
	3. Oil processing (refinery)	5.2	• Transport of inputs • Processing inputs: Raw materials (list of ingredients), electricity, steam, water, chemicals • Products, co-products & waste management
	4. Manufacturing of other ingredients / other raw material acquisition	5.3	• Raw material acquisition and manufacturing of other inputs: Salt, vitamins, flavourings, emulsifiers, thickeners (starch etc.), conservatives, colourants, antioxidant, minerals. • Inputs of processing of raw materials: refining steps, further processing.
Production of the main product	**5. Transport**	5.4	• Transport of refined oil to the point of manufacturing; • All local and international transportation steps; • Transport from point of processing to the point of manufacturing. • All transport legs include distance, mode and load factor
	6. Margarine Manufacturing (Including emulsification, cooling and crystallization)	5.4	• Processing inputs: Raw materials (list of ingredients), electricity, steam, water, chemicals Products, co-products, losses & waste management • Storage at margarine manufacturing facility: energy use, refrigerant leakage, storage time • Mass balance
	7. Consumer/B2B packaging	5.5	• All activities related to primary, secondary and tertiary packaging of margarine products; • Manufacturing of packaging of margarine products; • Production of their raw materials, processing of recycled materials, transport of packaging materials to manufacturing facility and the packaging process itself.

Main life cycle stage (generic PEF)	Specific life cycle stage (these guidelines)	Section (these guidelines)	Relevant activities
Product distribution and storage	**8. Distribution**	5.4	• Energy use and storage time at distribution centre or storage facility • Transport of packaged margarine to distribution centres • Transport of packaged margarine from distribution centres to points of sale; • The sale of margarine via retail stores, e-commerce etc..
	9. Retail or food service	5.5	• Energy use and storage time • Losses and waste management
Use stage (only to be included if manufactured product is final product)	**10. Consumption**	5.6	• Storage of product (ambient or refrigerated) • Energy use for preparation/intended use of the product • Waste generation at consumer
End-of-Life	**11. End-of-Life**	5.7	• End-of-life (EoL) of packaging waste etc. • Transport from point of disposal to point of final waste management.

3.4 Most relevant impact categories

A life cycle impact assessment (LCIA) method converts the life cycle inventory data into contributions to each of the environmental impact categories in scope of the LCA. This is also referred to as characterisation. To align as much as possible with current PEFCR guidelines, the most recent version of the EF impact assessment method shall be used for characterization of the EF. For internal purposes, also other impact assessment methods covering multiple impact categories, such as the internationally applicable ReCiPe method, may be used, either solely or in addition to the use of the EF method (Huijbregts et al., 2017).

For each individual EF study, the most relevant impact categories should be determined, jointly with the most relevant processes and elementary flows. This is part of the life cycle interpretation and serves to identify hotspots.

The most relevant impact categories are those that together contribute to at least 80% of the total environmental impact (single score). These cut-off percentages are defined in the generic PEF (European Commission, 2021).

For these guidelines, the identification of the most relevant impact categories was based on industry knowledge and the PEF report of vegetable oil and protein meal industry products written by FEDIOL (De Smet et al., 2022) and aligns with the PEF methodology. The list in Table 5 serves as the baseline set of relevant impact categories and shall be assessed when conducting an EF study in accordance with these guidelines. Depending on the goal and scope of the assessment, additional impact indicators may also be considered.

Table 5 : EF impact categories relevant to these guidelines.

Impact category	Unit	Reporting category
Climate change - Fossil	kg CO2eq	Shall
Climate change - Biogenic	kg CO2eq	Shall
Climate change - Land use and LU change	kg CO2-eq	Shall
Land use	Pt	Shall
Particulate matter	disease inc.	Shall
Ecotoxicity, freshwater	CTUe	Should
Acidification	mol H+ eq	Should
Eutrophication, terrestrial	mol N eq	Should
Eutrophication, freshwater	Kg P eq	Should
Eutrophication, marine	Kg N eq.	Should
Water use	m3 depriv.	Should

You shall report the impact categories climate change, land use and fine particulate matter. You should report freshwater ecotoxicity, acidification, freshwater, water use and terrestrial eutrophication. You may report on any other impact category. In direct comparison with dairy products it is recommended to also report the most relevant impact categories according to the dairy PEFCR. The most relevant impact categories are elaborated on below.

Note that the most relevant impact categories are based on the overall impact of margarine that cover at least 80% of the environmental burden. The LCA practitioner/company performing the LCA is encouraged to report on additional impact categories that are considered relevant in their context. external communication may focus on any chosen impact category, as long as the communicated results referred to the LCA report which discussed all most relevant categories as explained in the paragraph above.

Most relevant impact categories:

- **Acidification**: This EF impact category addresses impacts due to acidifying substances in the environment. Emissions of NO_x, NO_3 and SO_x lead to the release of hydrogen ions (H^+) when these gases are mineralized, which in turn acidify soils and water bodies. In areas where buffering capacity is low, this may result in forest decline and lake acidification.
- **Climate change:** This impact category can be divided into three sub-categories: fossil, biogenic and land use change. According to the generic PEF, the three indicators shall be reported separately if they show a contribution of greater than 5% each to the total score of climate change; this shall apply in these guidelines too. For land use change emissions, the generic PEF recommends using primary data. However, these guidelines acknowledge the dearth of primary data with regards to land use change (LUC).
    - **Climate change –** fossil: This sub-category includes emissions from peat and calcination/carbonation of limestone.
    - **Climate change –** biogenic: This sub-category covers emissions to air originating from the oxidation and/or reduction of biomass by means of its transformation or degradation and CO_2 uptake from the atmosphere through photosynthesis during biomass growth. A simplified modelling approach shall be used when modelling the foreground emissions. Only the emission 'methane (biogenic)' is modelled, while no further biogenic emissions and uptakes from the atmosphere are included. When methane emissions can be both fossil or biogenic, the release of biogenic methane shall be modelled first and then the remaining methane.

- **Climate change –** land use and land use change: This sub-category accounts for carbon updates and emissions originating from carbon stock changes caused by LUC and land use.

- **Ecotoxicity, freshwater:** This impact category addresses the ways in which the release of certain toxic substances can affect the health of an ecosystem. This is prominently occurring with the application of pesticides during cultivation.
- **Eutrophication (marine and freshwater):** Eutrophication is the enrichment of a water body with nutrients, usually an excess amount of nutrients that induces growth of plants and algae to the biomass load. The extreme growth may result in oxygen depletion of the water body and cause species to suffocate. Freshwater and marine eutrophication both have their distinct nutrients which cause excessive growth of plants and algae, since the limiting growth factor is different in both waterbodies. For freshwater waterbodies the limiting factor are phosphorus containing substances, usually from fertilizers or phosphorus containing detergents. Therefore, the reference unit for freshwater eutrophication is kg phosphor equivalents. For marine waters the limiting factor is nitrogen and therefore marine eutrophication potential is expressed in kg nitrogen equivalents. Only freshwater eutrophication is considered at end-point result for ecosystems domain
- **Land use:** This impact category refers to the land that is occupied for the production of a food product. Both land occupation for cultivation and all other steps in the life cycle are accounted for.
- **Particulate matter:** This impact category accounts for the adverse effects on human health caused by emissions of particulate matter (PM) and its precursors (NOx, SOx, NH_3).
- **Water use:** This impact category refers to the potential impacts of water consumption on both the environment and ecosystems, particularly due to deprivation of water resources in regions where water is scarce.

3.5 Limitations

As mentioned in section 2, these guidelines are not an official PEFCR, which entail limitations regarding PEFCR compliancy and data use. The total list of deviations from the PEFCR approach was already explained in section 2.2.

Another major limitation in this document is the absence of supporting studies. Whenever these guidelines are to be further developed (for example into an official PEFCR), the execution of supporting studies would be an essential addition.

3.5.1 Methodological limitations

There is a limitation with the impact category ecotoxicity when LCA practitioners use secondary databases with generic cocktails of some active ingredients, to model the ecotoxicity impacts from pesticides. The use of these generic cocktails can lead to very inaccurate results, as ecotoxicity is highly sensitive to the specific active ingredient involved. LCA databases often use outdated cocktails of crop protection products as this is a field in which innovation moves quickly.

3.6 Claims

Reporting organizations adhering to these guidelines may make claims, provided they comply with the following rules (on top of existing regulations regarding environmental claims in the country of publishing of these claims):

- If a non-comparative claim is to be made, an external reviewer shall verify the study to ensure it complies with these guidelines as per the ISO14040/14044 (ISO, 2006).
- If a comparative claim is to be made, a panel of 3 external reviewers shall verify the study, as per the ISO14040/14044 (ISO, 2006).

- If a comparative claim is to be made, the product shall be compared with existing/previous relevant comparable products in the market which provide the same function (same types and number of beverages). Comparison/claims with a (future) benchmark/representative product shall not be made.
- Data quality requirements for each life cycle stage being compared shall be similar. This means that primary data shall only be compared to primary data and the same holds for secondary data. The exact data quality rating (score) shall not be of significance.
- The functional units and system boundaries being compared shall be the same and for the same type of product.
- External reviewers shall be selected based on the requirements given in ISO 14071 (ISO, 2014).
- The verifier(s) of a study shall be attentive to the communication/wording of a claim and whether it is in line with the goal and scope and final results of the study.
- Any EF study adhering to these guidelines shall be a multi-impact study to investigate potential burden shifting.
- Claims shall be supported by publicly accessible additional information and shall include, at a minimum, the following details: functional unit, period of study, LCIA method and version, system boundaries applied, impact category results (disaggregated per life cycle stage including reduction percentages), critical review panel statement.
- Claim of superiority shall not be based on an aggregated single score. This also implies that the results of a footprinting study shall not serve as the basis to receive an ecolabel.

4. Life cycle inventory

The life cycle inventory is a compilation of all input and output flows for the defined product system, including material, energy and waste flows, as well as emissions to air, water and soil. This section defines generic principles related to the life cycle inventory, whereas the next section provides detailed guidance and requirements for individual life cycle stages. For any modelling requirements not covered in these chapters, the generic PEF (European Commission, 2021) ((EU commission, 2021), especially section A.4.4 shall apply.

A fundamental modelling requirement stated in the generic PEF is the cut-off rule: processes and corresponding background datasets can be excluded from the model if their cumulative environmental impact across all categories is less than 3%. The cut-off rule applies to both intermediate and final products. Examples of such processes are capital goods and secondary packaging. However, if data are available for these processes, it is advisable to also include them in the scope of the study as best practice, even if they fall under the cut-off rule.

In view of the cut-off rule, it is allowed to use the results of a screening study as a reference to define the processes that fall below the cut-off level**. However, the exclusion of such processes shall be consistent with the goal and scope of the study, and it shall be ensured that these out-of-scope processes are indeed not relevant to the assessment.**

4.1 Allocation

Allocation at the different life cycle stages will use as a default economic allocation for oil crop cultivation, oil crop pre-processing, oil processing and manufacturing of other ingredients. Impact of transport and distribution will be allocated based on volume (as per general PEF)

Allocation for vegetable oil

The vegetable oil shadow PEFCR is an oddity between the other PEFCRs as it uses energy allocation as the default method to allocate the environmental burdens between the oil produced and the meal. The margarine sector wishes to stay in line with both the general PEF guidance as well as the FEDIOL shadow PEFCR on vegetable oil. Therefore, it is recommended to perform a sensitivity analysis to show the impacts per type of allocation. In Figure 3-5, an example of several oil products is presented applying two allocation methods. The results are based on the database of Agri-Footprint 6.3 of 1 kg of oil.

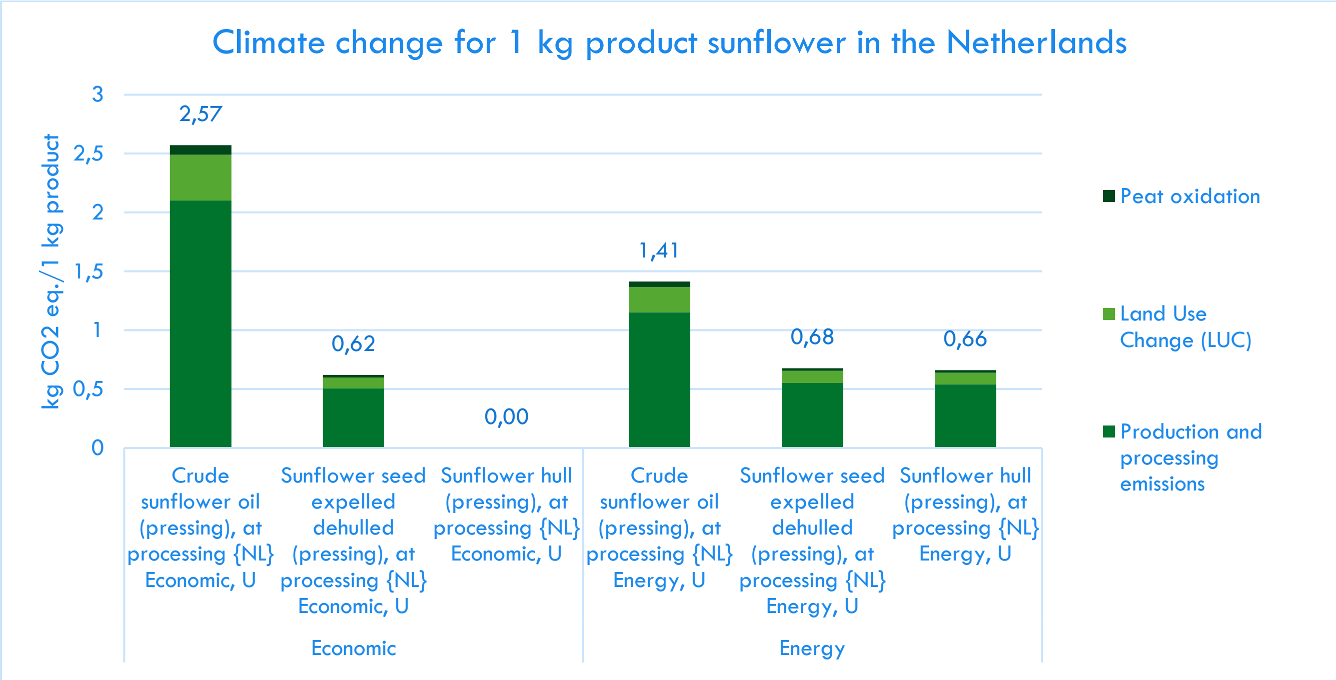

Figure 3. Climate change for 1 kg product sunflower in Netherlands

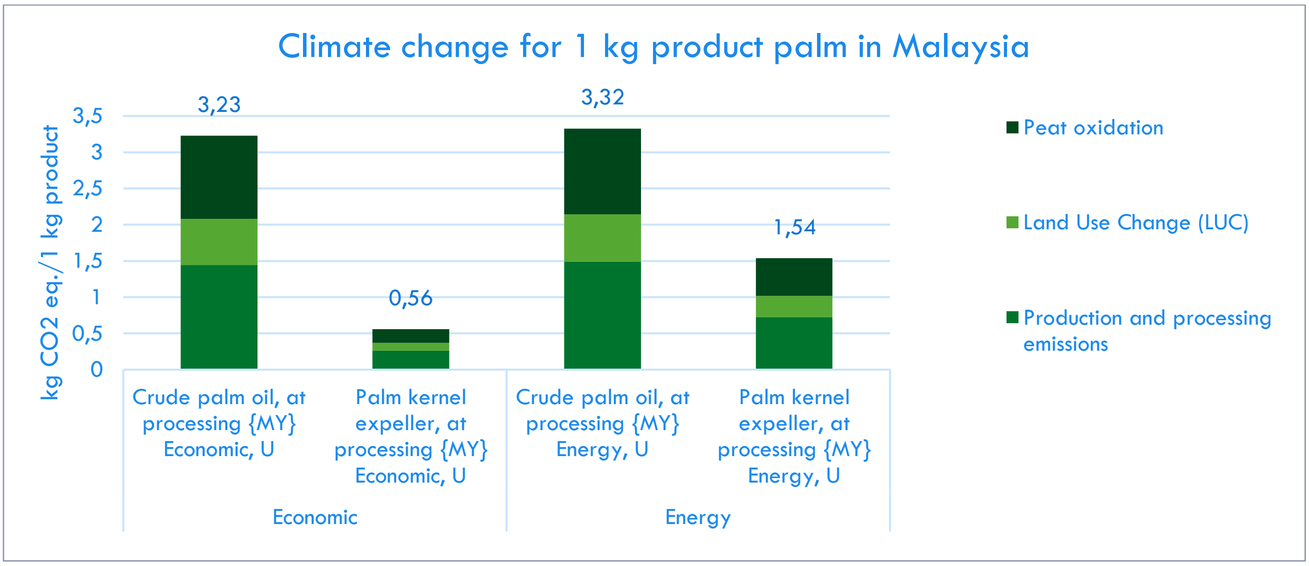

Figure 4. Climate change for 1 kg product palm in Malaysia.

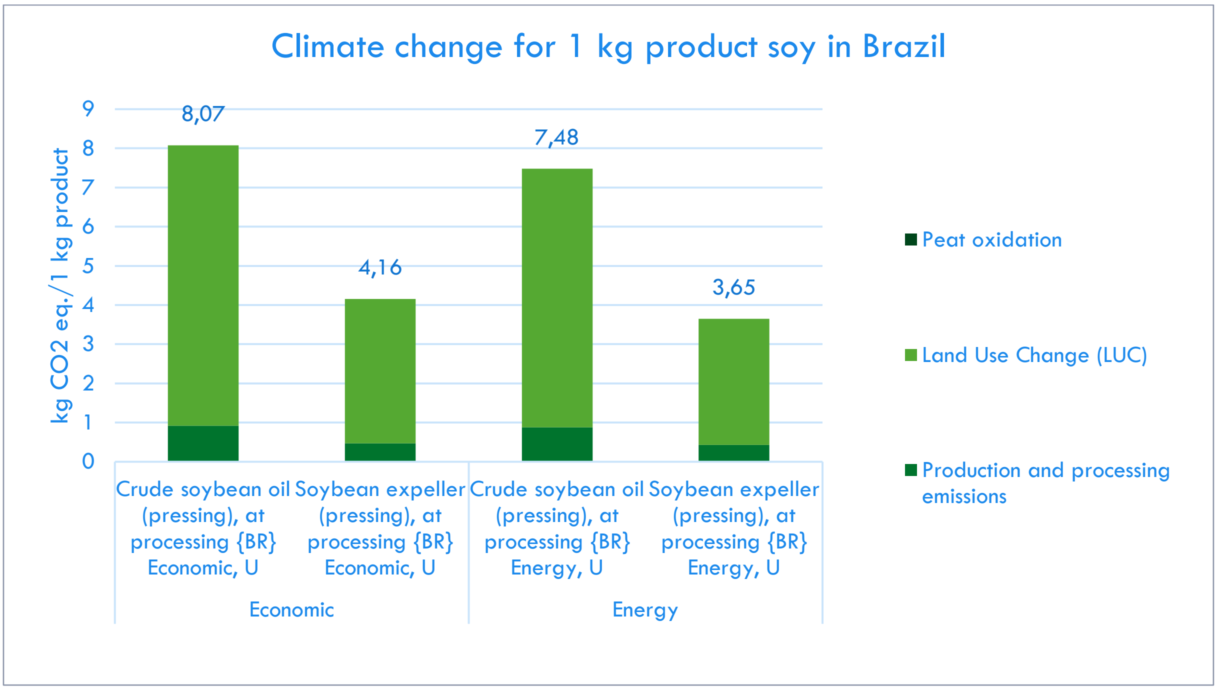

Figure 5. Climate change for 1 kg product soybean in Brazil.

For the manufacturing stage and the rest stream for feed production or energy, zero allocation, as described in GFLI (Global Metrics for Sustainable Feed), if:

1. The product is sold as it is at the point of production and has a very low contribution to the turnover of the entire basket of co-products
2. (co-)production and upstream process is not deliberately modified for generating the co-products
3. If the feed ingredient is not a zero-allocation product, the method of economic allocation should be specified

4.2 List of primary & secondary data

Table 6 lists the requirements with respect to primary data and secondary data for LCAs of margarine products. For any given data point, using secondary data or default values instead of recommended primary data shall be justified with a reasonable explanation. The impacts of all the inputs used at each life cycle stage should be calculated using background datasets. Section 4.3 outlines which databases to use, while section 5 details the specific datasets and default values. Use of alternative datasets may be permitted if there is a clear rationale and the data quality is demonstrably better than those of the default datasets recommended in these guidelines. Only those data points are required to be used, which are relevant for the product in scope.

For the life cycle stages that fall outside the company's direct sphere of control, the following hierarchy of data specificity is:

1. **Primary data from direct suppliers**
2. **Sector- or region-specific secondary data**
3. **Country-level averages**
4. **Global default or generic data**

Table 6: List of mandatory primary data and allowed secondary data.

Life cycle stage	Process	Mandatory primary data	Allowed secondary data
1. Oil crop cultivation	**Fertilizers**	No primary data required from this life cycle stage	Type, amount and impacts from the production of fertilizers (synthetic & organic) & soil amendments[1]
	Pesticides	No primary data required from this life cycle stage	Type, amount and impacts from the production of pesticides
	Energy	No primary data required from this life cycle stage	Amount, type and impacts from energy used by agricultural equipment.
	Irrigation	No primary data required from this life cycle stage	Amount and source of irrigation water
			Impacts from water sourcing (pumping, treatment etc.)
	Transport	No primary data required from this life cycle stage	Transport distances and modes for cultivation inputs
			Impacts from transport
	Yield	No primary data required from this life cycle stage	Yield of oil crops can be derived from secondary data **only if primary data are unavailable**. Planting density is recommended to validate farmer-reported data provided per hectare.
	Land use	No primary data required from this life cycle stage	Area of land used for cultivation
	Land use change	If LUC free cultivation is claimed for a commodity for which this is a hotspot in secondary data, adequate proof of this claim is needed (certificate).	Land use change equally discounted impacts compliant with the PEF guidance (i.e., following the PAS 2050;1)
2. Oil crop pre-processing (crushing) & 3. Oil processing (refining)	**Oil Crushing**	(If available, primary data are strongly recommended) Inputs and outputs from processing facility.	
		(If available, primary data are strongly recommended) The volume of wastewater generated and information on the type of wastewater treatment system	Impacts from waste and wastewater treatment
		(If available, primary data are strongly recommended) Amount and type of energy (fuel/electricity mix) used by the wet processing equipment	Impacts from energy use
		(If available, primary data are strongly recommended) Volume of water used	Impacts from water sourcing (pumping, treatment etc.)
	Oil refining	(Primary data are only required if crushing happens in Europe) Amount & type of waste/residues generated and type of waste management strategy	Impacts from waste treatment
		(Primary data are only required if crushing happens in Europe) Amount & type of energy	Impacts from energy use

Life cycle stage	Process	Mandatory primary data	Allowed secondary data
		(fuel/electricity mix) used (in case drying is mechanically carried out)	
	Transport	(Primary data are only required if crushing happens in Europe) Transport distances and modes from cultivation to processing & between processing facilities	Transport distances and modes from cultivation to processing & between processing facilities
3. Manufacturing of other ingredients		Type and amount of ingredients	Impact of these ingredients (e.g. vitamins, emulsifiers, minerals) may be sourced from LCA databases such as Agri-Footprint.
4. Margarine manufacturing	**Transport**		Transport distances and modes of transportation from oil processing facilities to margarine manufacturing plants and between manufacturing plants, i**f primary data are unavailable.**
	Ingredients	Entire recipe of product and amounts need to be based on primary data	For the impacts of ingredients, secondary data may be used. As described above.
	Energy	Amount of type of energy (fuel/electricity mix) used in manufacturing equipment	Impacts from energy use Energy mix if primary data are unavailable
	Raw & ancillary materials	Amount of all relevant raw & ancillary materials used in the manufacturing processes (e.g., solvents, water, cleaning agents etc.)	
	Waste	Amount & type of waste/residues generated and type of waste management strategy	Impacts from waste treatment
	Wastewater	The volume of wastewater generated and information on the type of wastewater treatment system	Impacts from wastewater treatment
	Packaging	Material, amount and recycling rate (if available, distinction between primary, secondary and tertiary packaging)	
	Co-products	Quantity and price of co-products	
	Losses	Losses at manufacturing	
	Storage	Refrigerants for chilled storage, electricity use for storage, average storage time	
5. Consumer / B2B packaging	**Packaging**	The type and amount of packaging material used	Impacts from packaging production
	Transport		Transport mode & distance of packaging materials **if primary data are unavailable**
			Impacts from transport
	Losses		Loss rate at packaging (losses happening when the final product is being packed)
	Packaging recycling	Post-consumer recycled content of packaging material (primary, secondary & tertiary)	This may only be included if it’s based on primary data

Life cycle stage	Process	Mandatory primary data	Allowed secondary data
6. Distribution	**Transport**		Transport distance and mode from factory to distribution center (ambient or chilled)
	Storage at distribution		Energy and water use during storage at distribution (PEF defaults)
7. Retail/ Food service	**Transport**		Transport mode & distance from factory to distribution centre/retail (ambient or chilled) **if primary data are unavailable**
			Impacts from transport
	Energy		Amount of type of energy (fuel/electricity mix) used at warehouse
			Amount of type of energy (fuel/electricity mix) used at retail
	Losses		Loss rates during distribution and at consumer stage (PEF defaults)
7. Use	**Use**		Transport distances and mode for transport from retail to consumer home.
			Amount and impact of energy use for storing of product (ambient or chilled)
			Amount and impact of energy for preparation of product (if applicable)
8. End-of-Life	**Wastewater**		Volume of wastewater at the use stage from product wasted/not consumed
	Transport		Transport mode & distance to end-of-life
			Impacts from transport of waste
	Waste		Impact of processing of waste

4.3 Recommended databases for secondary data

Since the use of the EF database is purposed for application in PEFCR studies, alternative databases shall be used. The following databases should be considered:

- Ecoinvent & Agri-footprint (also suppliers to the generic EF database);
- World Food LCA Database (WFLDB) which is usually free to use along with SimaPro (Quantis, 2020).

For the time being, no other transparent databases, either free or with a license, exist. Other databases could be considered for use, as long as their scope aligns with these guidelines. Table 7 provides a summary of the recommended databases to use, with more detailed suggestions available for each corresponding life cycle stages. The most recent version of the databases should be used, which is at the time of writing Agri-footprint 7.0 (Blonk et al., 2024) and Ecoinvent 3.11 (Ecoinvent, 2024).

Table 7: Summary of background databases.

Data type	Recommended database
Agricultural products	Agri-footprint
Means of transport (truck, train, barge, sea ship, plane)	Agri-footprint
Energy from diesel	Agri-footprint
Energy use (electricity, heat from natural gas, heat from wood chips etc.)	Ecoinvent, cut-off
Manufacturing of other ingredients (e.g. vitamins, emulsifiers)	Ecoinvent, cut-off
Fertilizers	Agri-footprint
Other chemicals	Ecoinvent, cut-off
Solid waste treatment	Ecoinvent, cut-off
Wastewater treatment	See section 5.2.1

4.4 Data gaps

Several data gaps have been identified during the development of these guidelines. Most data gaps have been covered by identifying appropriate secondary datasets; however, a few data gaps remain:

- Origin of oil/ country of cultivation often unknown due to global supply chain (no segregated flows). This leads to low transparency in the supply chain, which prove especially problematic for LUC impacts, as they form an important hotspot for some commodities used in margarine production.
- Lack of secondary data of oil crop cultivation (palm), low quality secondary data available
- Land use change: The generic PEF recommends basing land use change on primary data, but primary data are not always available or reliable. Primary data refers to concrete proof that no land use change occurred in the 20 years preceding the year of assessment. This can be, for instance, municipal documents, documents from the agricultural department, satellite high granularity images, and land survey data.
    - Traceability and Chain of Custody: when collecting data on sourcing of certified ingredients (deforestation-free or coming from regenerative farming), guaranteeing traceability can be very difficult. The ISO 22095 defines several types of chain of custody models. While identity preserved and segregation imply that the used ingredients are certified, mass balance and book & claim include mixing sources of ingredients and no physical traceability. As at the time of writing this guidance the PEF has not clarified its position on the admissibility of the last two models (and if so, which type), in this LCA guidance mass balance and book & claim are not allowed.

4.5 Data quality requirements

The data quality rating of the primary and secondary data shall be calculated as prescribed by the generic PEF. For primary data, each data point shall include documented values for the following data quality indicators: Precision (P) and Representativeness in terms of Time (TiR), Technology (TeR), and Geography (GeR). For secondary data, only Representativeness (TiR, TeR, GeR) shall be reported as a minimum.[1] No specific DQR value is to be achieved in order to be aligned with these guidelines. However, as mentioned in the generic PEF, the DQR of primary data for all four criteria (P, TiR, TeR & GeR) cannot be greater than 3, whereas, for TeR and GeR it cannot exceed 2.

[1] See section 4.6.5 of Annexes 1 to 2 of the generic PEF.

5. Life cycle stages

5.1 Oil crop cultivation

This life cycle stage encompasses the cultivation and harvest of oil crops. The cultivation stage is often one of the most relevant life cycle stages in a margarine EF, especially when palm oil is used as a raw material and shall be investigated appropriately.

5.1.1 Cultivation inputs

Cultivation includes the following activities, namely:

- Application of synthetic and organic fertilizers
- Application of pesticides
- Application of lime
- Irrigation
- Land use and land use change
- Energy use in agricultural machinery
- Packaging

The transport of cultivation inputs from manufacturing location to the farm shall be included in the scope, e.g., through market datasets. This should ideally be farm-specific data; however, if this is unavailable, a default distance of 50 km shall be applied, assuming that this transport happens locally. An example of a secondary process that may be used to model the impacts from transport of cultivation materials is *Transport, truck >20t, EURO4, 80%LF, default/GLO* from the secondary database Agri-footprint. Packaging of cultivation inputs at point of production may be excluded from the scope.

For all inputs at cultivation, the use of secondary data are allowed. It is recommended to use Agri-Footprint as a database to determine impact of cultivation. If primary data are used the generic PEF method needs to be followed to model the impacts (Haslinger & Giljum, 2012). Impacts from the application of fertilizers, lime and pesticides shall be modelled following the generic PEF. Table 8 lists the mathematical models to be used as recommended by the generic PEF to model emissions from N & P fertilizers, as well as lime application. Heavy metals emissions from fertilizers and pesticides application shall be modelled following generic PEF methodology.

Table 8: Generic PEF recommended models to quantify emissions from fertilizers, lime & urea application.[2]

Emission	PEF recommended model	Compartment	Relevant impact category
$NH_{3volatilization}$ (synthetic fertilizer)	(0.11*quantity of synthetic N + 0.21*quantity of organic N (compost per example)) *17/14	Air	Climate change & acidification
N_2O direct	((synthetic N+ organic N) *0.01) *44/28	Air	Climate change

[2] This is not an exhaustive list of methods used to calculate emissions from the cultivation stage. For a comprehensive assessment, additional guidance documents should be consulted. Specifically for GHG emissions, the IPCC provides emission factors (EFs) that vary by climate zone.

Emission	PEF recommended model	Compartment	Relevant impact category
N_2O indirect	$(NH_{3\,volatilization}$*Frac $_{volatilisation}$*0.01+$NO_{3\,leaching}$*0.24*0.011) *44/28	Air	Climate change
CO_2 from lime	(Quantity of lime*0.12) *44/12	Air	Climate change
CO_2 from urea	(Quantity of urea*0.2) *44/12	Air	Climate change
NO_3 leaching	0.24*N from fertilizers/constituents*62/14	Soil & water	Eutrophication
PO_4 leaching & runoff	0.05*quantity of P applied	Soil & water	Eutrophication

As for impacts from pesticide application, the generic PEF recommends using the USEtox life cycle impact assessment method to simulate their fate. The applied pesticides active ingredients shall be modelled as:

- *90% emitted to the agricultural soil compartment*
- *9% emitted to air*
- *1% emitted to water*

However, as stated by the generic PEF, more specific emissions data should be used if available.

Irrigation water

When it comes to modelling irrigation water use, the decision tree presented in Figure 3 shall be followed. It is recommended to model this as country-average practices; however, if sub-national level data on irrigation are available, they may be used. Any energy used for the irrigation system shall be modelled along with other agricultural machinery.

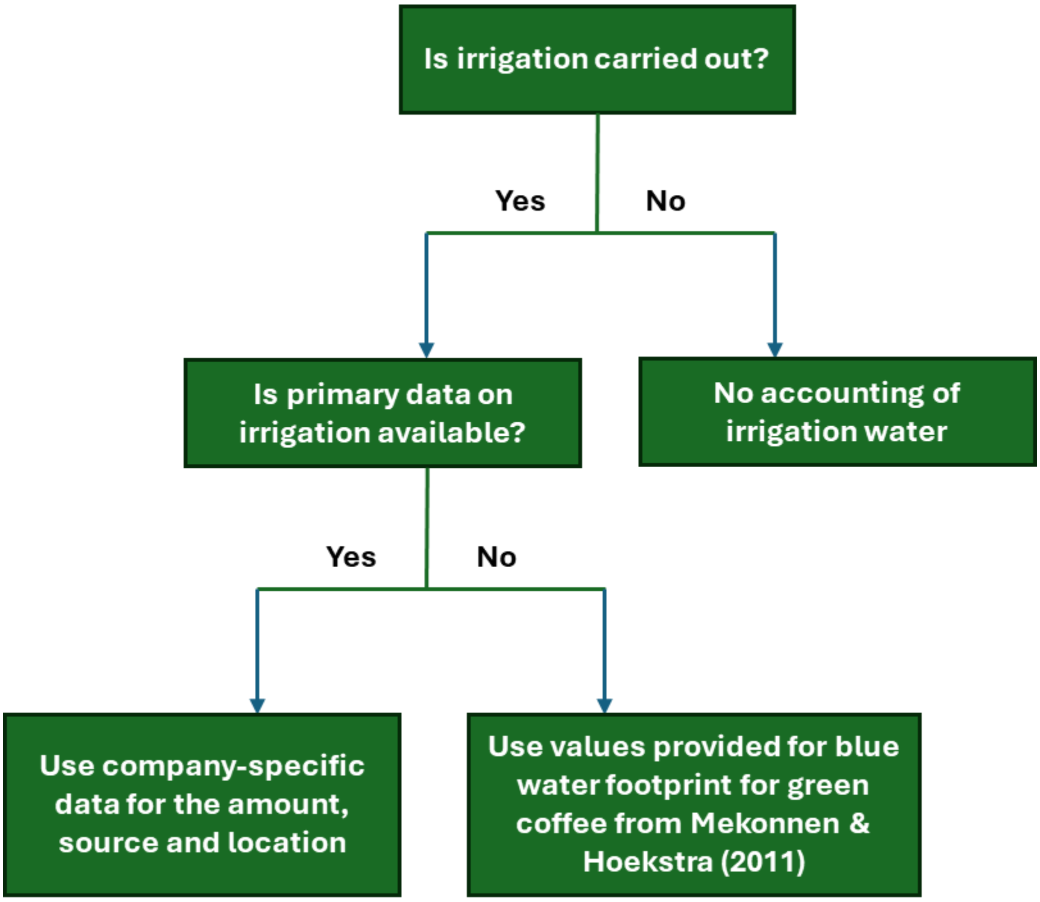

Figure 3: Decision tree for modelling irrigation water.

While Mekonnen & Hoekstra (2011) provide some global average water footprints, it should be noted that these represent very low data quality to investigate water scarcity impacts in EF which are sensitive to local conditions. Hence, it is strongly recommended to retrieve primary data for irrigation water if applicable. Alternatively, country-specific information should be used. If this is not possible and a global average is used, this shall be explicitly mentioned as a limitation in the EF study report.

Land use

The yield of oil crops should be reported per hectare of farmland. The yield should ideally be primary data, however, in case this is not possible to retrieve, then the yield can be derived from secondary data. Additionally, a reasonable explanation shall be provided for why it was not possible to collect primary data on yield.

Land use change

The generic PEF recommends basing land use change on primary data, but primary data are not always available or reliable. Primary data refers to concrete proof that no land use change occurred in the 20 years preceding the year of assessment. This can be, for instance, municipal documents, documents from the agricultural department, satellite high granularity images, and land survey data.

While identity preserved and segregation imply that the used ingredients are certified, mass balance and book & claim include mixing sources of ingredients and no physical traceability. As at the time of writing this guidance the PEF has not clarified its position on the admissibility of the last two models (and if so, which type), in this LCA guidance mass balance and book & claim are not allowed.

Energy used in agricultural machinery

The amount of energy used in agricultural machinery (whether fuel/electricity) shall be modelled and shall be reported as total energy used (in MJ or kWh for fuel or electricity, respectively). The use of any renewable energy source shall be verified using proof from the energy provider (in case purchased), or proof of ownership or production (if self-produced).

5.1.2 Sampling of farms

Sampling of farms is only relevant if primary data are collected for this life cycle stage. Users of these guidelines may apply a sampling approach to reduce the number of representative oil crop farms from which data should be collected. For sampling the approach of the general PEF needs to be followed (European Commission, 2018). This means that homogeneous sub-samples need to be made from the total group of farmers. Factors to at least consider when making homogeneous sub-groups are geography, farm size and technology. From each homogeneous sub-sample, at least from the square root data needs to be collected.

5.1.3 Carbon removals

Carbon removals generally refer to processes that sequester carbon from the atmosphere and store it in a specific pool for an extended period of time. In the case of oil crop cultivation, carbon removals can for instance refer to biogenic carbon removals by palm oil plantations.

There are several methods for removals accounting, typically based on either annual quantification of carbon fluxes or annualization of the total expected removals over the long term (i.e., dividing the total by the number of years taken into account). The GHG Protocol (WRI-WBCSD, 2022) describes multiple accounting methods that work with remote sensing, empirical models, and direct measurement. In life cycle assessment methodologies within the PEF framework, there is no carbon removals accounting method that is widely recognized and used, due to the high uncertainty of the models and the difficulty in comparing actual carbon emissions to estimated removals. Also, the Carbon Removal Certification Framework Regulation (CRCFR) further specifies what carbon farming activities can be considered for carbon sequestration in agricultural activities. Carbon removals **shall not be reported as negative emissions** in the climate change impact category, following the guidance from the generic PEF. If calculated according to the CFCFR, net carbon removals may be reported **separately** in the LCA report.

In all cases, certification of offsetting is not allowed.

5.2 Pre-processing (crushing) & oil processing (refinery)

These life cycle stages cover the post-harvest processing steps such as oil crop crushing and oil refining.

'This life cycle stage starts with the reception and storage of the raw materials. The life cycle stage includes the production of electricity, steam, water and chemicals needed for crushing. The life cycle stage also includes emission to air (e.g. hexane emission or emissions from burning of fuels) and the release of emissions to water via wastewater treatment. Crushing uses hexane, most of which is released during the crushing process itself. However, part of the hexane will be released further down the value chain. The emissions of hexane are modelled according to the instructions of the PEFCR, which means that all hexane is emitted during the crushing phase. Crushing of palm, palm kernel and coconut does not take place in Europe by FEDIOL member companies. Data on the crushing of these products has therefore been taken from the Agri-footprint database and is for these products included in the life cycle stages 'raw materials acquisition and preprocessing', see section 4.3.2.Life cycle inventory manufacturing: transport to oil processing The transport of crude palm, crude palm kernel and crude coconut oil is already included in the life cycle stage 'raw materials acquisition and pre-processing: crude oil and transport. In case of rapeseed, sunflower, soybean, maize, it can happen that externally crushed oils (this can concern crushing by the same company at another location or

crushing by another company) are processed by the refining company. The crude oil is transported to the oil processing facility.'

5.2.1 Transport to manufacturing

This life cycle stage covers all the transportation steps that take place to transport packaged refined oil from point of processing to point of manufacturing (both domestic and international).

In case primary data on transport distances and modes is unavailable, the most up to date generic PEF defaults for combination of transport modes shall be used, at the moment of publication these are:

Within Europe:

- *130 km by truck (>32 t, EURO 4);*
- *240 km by train (average freight train);*
- *270 km by ship (barge)*

For suppliers outside of Europe (and exporting to Europe):

- *1000 km by truck (>32 t, EURO 4);*
- *18000 km by ship (transoceanic container) or 10000 km by plane (cargo);*
- *If producers' origin country is unknown, distance to be determined using specific calculators[3];*
- *In case the supplier's location is unknown, transport to be modelled as if supplier is located outside Europe.*

However, it must be noted that most of these generic PEF defaults only apply in the European context. For transportation steps occurring within the country of cultivation (non-EU countries) and within non-EU receiving countries, defaults presented here should be used.

5.3 Manufacturing of other ingredients

Other ingredients (next to oils and fats) must be incorporated in the LCA, but the use of secondary data are allowed. Other ingredients could be additives like vitamins, emulsifiers and minerals. The recommended database for these ingredients is AgriFootprint.

5.4 Margarine Manufacturing & distribution

This life cycle stage encompasses the manufacturing of refined oil to the end product: margarine

5.4.1 Manufacturing

During manufacturing different oils and fats are made into margarine by emulsification, cooling and crystallization. This life cycle stage starts with the reception and storage of raw materials. The production of electricity, steam water and chemicals are needed for manufacturing. This life cycle stage also includes emissions to air (e.g. emissions from burning of fuel) and the release of emissions to water via wastewater treatment. For this life cycle stage, primary data needs to be collected. All in and outputs (products, co-products and waste) of the production process need to be based on primary data, as well as energy, refrigerant and water requirements for processing. An example of a margarine production system is shown in Figure 4.

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[3] https://www.searates.com/services/distances-time/ or https://co2.myclimate.org/en/flight_calculators/new

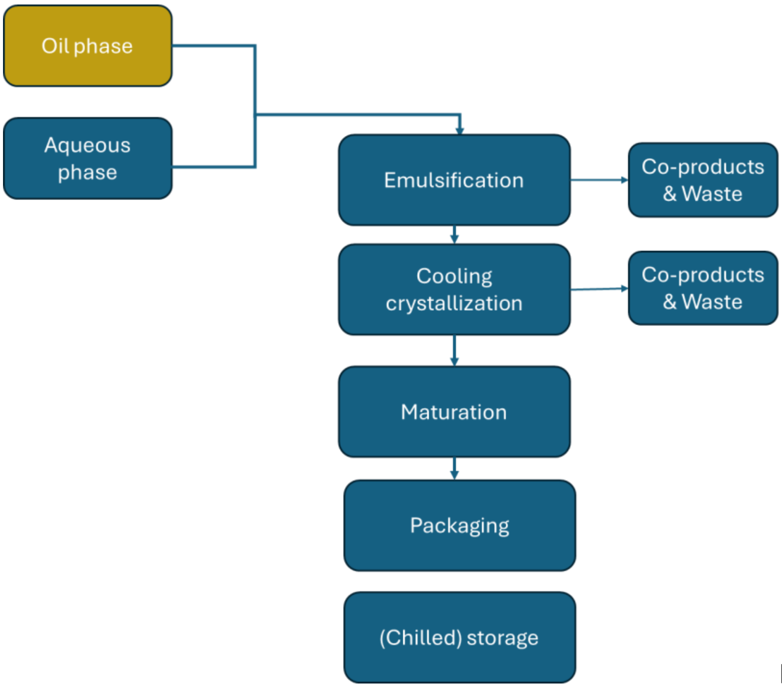

Figure 4: Simplified visualization of margarine production process

Figure 4: Simplified visualization of margarine production process

5.4.2 Distribution

This life cycle stage includes all transport and storage activities required to deliver the packaged margarine to retail.

5.4.2.1 Distribution channels

Distribution may happen through various channels

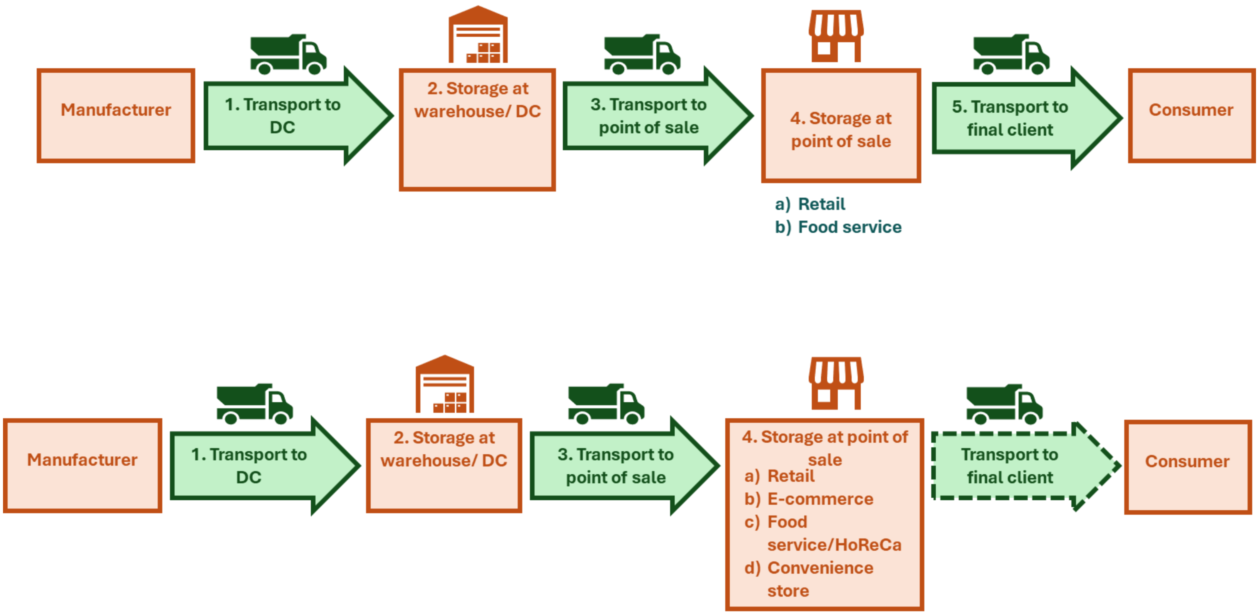

Figure 5 : Most common distribution channels for margarine.

5.4.2.2 Distribution data

For a comprehensive margarine distribution model, the following data points should be considered:

- Transportation data, encompassing modes of transport, distances travelled, fuel types and quantities used, and load factors;
- Handling data, which covers energy usage in warehouses and retail environments;
- Data on all losses during distribution.

Transportation data from manufacturing to retail

Transport distances and modes should be primary data. If unavailable, refer to the transport distance and mode specified in PEF. Optionally, tools like SeaRates may be used for more precise calculations when applicable.

Transport data from retail to the final client

Transport data from retail to consumer should be based on secondary data from generic PEF (European Commission, 2021):

- 62% traveling 5 km by passenger car (average),
- 5% covering a 5 km round trip by van (lorry <7.5 t, EURO 3 with a utilization ratio of 20%)
- 33% with no modelled impact.

Handling data

Handling data should be based on secondary data from generic PEF (European Commission, 2021):

- Energy consumption at warehouses: 30 $kWh/m^2 \cdot year$ for ambient storage and an additional 40 $kWh/m^3 \cdot year$ for chilled storage.
- Energy consumption at retail: 400 kWh/m^2 per year for general building energy consumption, with additional requirements of 1,900 kWh/m^2 per year for chilled storage and 2,700 kWh/m^2 per year for frozen storage.

Loss rates during distribution

Losses should be based on secondary data from generic PEF (European Commission, 2021), the category chosen is oils and fats:

- 1% loss during distribution

5.4.3 Retail / food service

Energy use for (chilled) storage at retail or food service should be included in this life cycle stage. As well as losses during this life cycle stage. The most up to date PEF defaults should be used to model this life cycle stage.

5.5 Consumer packaging

The transport from packaging materials to the manufacturing location shall be included. The distance and transport mode should be based on primary data. When primary data are not available, generic and most recent PEF defaults shall be used, at the moment of publication these are:

1. 230 km by truck (>32 t, EURO 4);
2. 280 km by train (average freight train);
3. 360 km by ship (barge).

5.6 Use

This life cycle stage is mostly modelled with defaults from the generic PEF and the dairy PEFCR. The most recent edition of these documents and defaults must be used, the numbers included here include the defaults in the PEF and dairy PEFCR at time of publication of this document. This life cycle stage starts with the consumer transporting the product to their home. This transport needs to be modelled as in the general PEF. During use phase, chilled storage at consumer needs to be taken into account, ambient storage can be neglected. To be in line with the dairy PEFCR 10 storage days are accounted for (The European Dairy Association (EDA), 2025). The storage volume is assumed to be 3 times the product volume and electricity use for chilled storage is 1350 kWh/m3/year. Energy consumption for chilled storage which is currently: 0.0037 kWh/L-day, thereby is the fridge production and end-of-life 15 years of lifetime. (European Commission, 2021, Annex 2, part D.) Losses at consumer are assumed to be 4% (according to most recent generic PEF). The impacts of the dishwasher should be modelled for one knife as allocation of 0.5% of a dishwashing cycle per piece). If the end-use of the product is unknown (for instance for margarine for baking and frying) these steps can be disregarded. In this case only the storage and waste at consumer should be modelled in the use phase.

5.7 End-of-Life (EoL)

This section examines the destination and treatment of various elements leaving the margarine life cycle after the use phase, being primarily consumer packaging like a wrap for margarine for baking/frying, or a tub for margarine for spreading, made of plastic and aluminium foil.

5.7.1 Transport to end-of-life

In many cases, waste treatment datasets already account for the transportation of materials to the recycling plant or waste treatment facility. If this is covered, there is no need to include transportation separately. It is essential to always verify this detail to ensure accurate data representation.

Unless primary data are available, the most recent generic PEF defaults should be used, at the moment of publishing these are:

(a) consumer transport from home to sorting place: 1 km by passenger car and,

(b) transport from collection place to methanisation: 100 km by truck (>32 t, EURO 4) and,

(c) transport from collection place to composting: 30 km by truck (lorry <7.5 t, EURO 3).

5.7.2 Overview Circular Footprint Formula (CFF)

(Based on generic PEF)

To evaluate the environmental performance of margarine products the use of the CFF is recommended when the packaging material is a hotspot or when claims want to be made about the sustainability of the packaging of the product. The CFF is defined in Table 18 providing a definition of the factors used in the formula. The next section describes in more detail how to apply the formula, breaking it down into tangible pieces, and explaining what data can be used.

In case the focus of the study is to analyse the environmental performance of a packaging type, the CFF is essential in the analysis. However, if the packaging material is not the focus of the analysis, a simplified version of the CFF may be applied.

Table 9: The equations of the circular footprint formula (CFF).

Element	Formula
Material	$(1-R_1)\ Ev + R_1 \times (AE_{recycled} + (1-A)Ev \times Qsin/Qp) + (1-A)R_2\ x\ (E_{recyclingEoL} - E^*_v \times Qsout/Qp)$
Energy	$(1-B)\ R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$

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

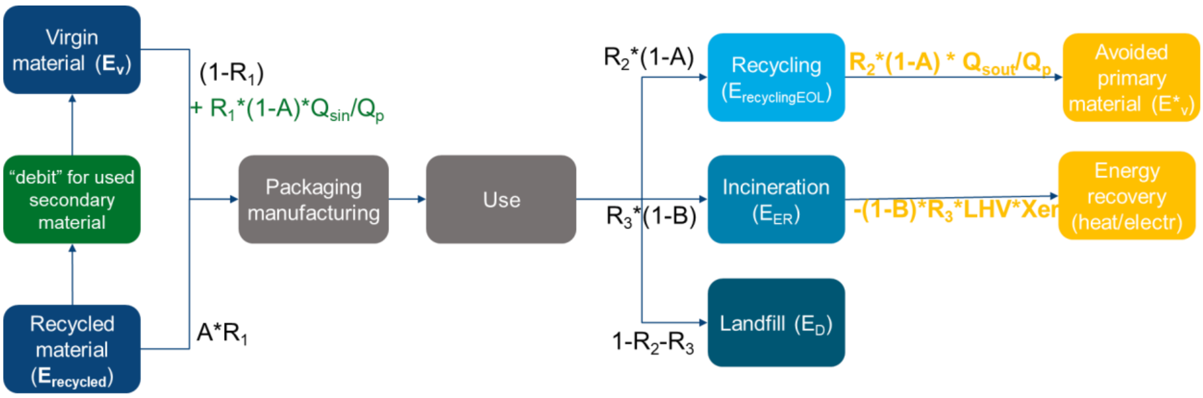

Figure 6 schematic overview of the circular footprint formula (CFF). Please note that packaging manufacturing (e.g. blow moulding, metal sheet rolling, can making) is not part of the CFF and must be added separately.

Table 10: Parameters used in the CFF.

Key parameters	
A	*Allocation factor of burdens and benefits (credits) between supplier and user of recycled materials*
B	*Allocation factor of energy recovery processes*
Q_{sin}/Q_p	*Quality ingoing secondary material/quality primary material*
Q_{sout}/Q_p	*Quality outgoing secondary material/quality primary material*
R_1	*Proportion of material in the input to the production that has been recycled from a previous system*
R_2	*Proportion of the material in the product that will be recycled (or reused) in subsequent system*
R_3	*Proportion of the material in the product that is used for energy recovery at EoL*
$X_{ER,heat}$	*Efficiency of the energy recovery process for heat*
$X_{ER,elec}$	*Efficiency of the energy recovery process for electricity*
LHV	*Lower heating value of the material in the product that is used for energy recovery*
Parameters indicating processes/ emission factors (to be linked to LCA datasets)	
E_V	*specific emissions and resources consumed arising from the acquisition and pre-processing of **virgin material***
$E_{recycled}$	*specific emissions and resources consumed arising from the **recycling process of the recycled (reused) material**, including collection, sorting, and transportation process.*
$E_{recylingEoL}$	*specific emissions and resources consumed arising from **the recycling process at EoL**, including collection, sorting, and transportation process.*

E^*_V	*specific emissions and resources consumed arising from the acquisition and pre-processing of* ***virgin material assumed to be substituted*** *by recyclable materials.*
E_{ER}	*specific emissions and resources consumed arising from the* ***energy recovery*** *process (e.g., incineration with energy recovery).*
$E_{SE,elec}$	*specific emissions and resources consumed that would have arisen from the specific* ***substituted energy source****, in this case electricity*
$E_{SE,heat}$	*specific emissions and resources consumed that would have arisen from the specific* ***substituted energy source****, in this case heat*
E_D	*specific emissions and resources consumed arising from* ***disposal of waste material*** *at the EoL of the analysed product (landfill), without energy recovery*

5.7.3 Consumer packaging end-of-life

The end-of-life consumer packaging is assessed using the Circular Footprint Formula (CFF), a standardized methodology for evaluating circularity and environmental impact. This formula defines the rule to allocate the environmental burdens or benefits of recycling, reusing, or recovering energy between, for example, the supplier and the user of recycled materials implemented in the generic PEF guidance (European Commission, 2021).

In the following sections, an overview of the CFF and its key principles is first provided. This is followed by an exploration of its application to consumer packaging. Finally, the CFF parameters specific to the European average are presented.

5.7.3.1 Application of Circular Footprint Formula for packaging

(Based on generic PEF)

To facilitate application of the Circular Footprint Formula, it has been split up into 4 different components, as indicated in Figure 7. For each of these sections, exact formulae are provided that can be used in an LCA, along with guidance on how the different parameters are defined and can be.

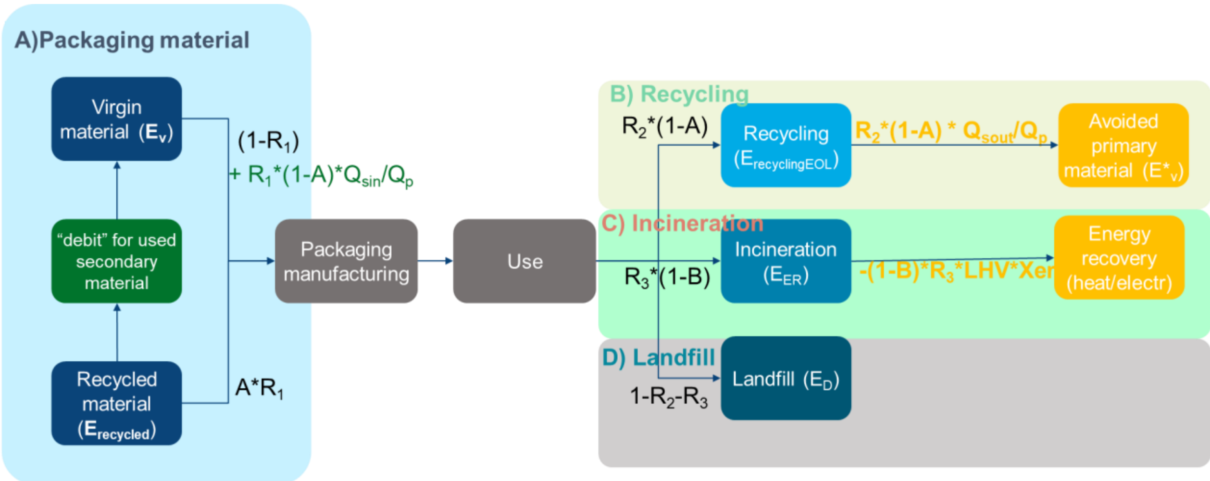

Figure 7 schematic overview of the CFF, indicating the 4 different components: A) packaging materials, B) recycling, C) incineration and D) landfill

A) Packaging materials

Packaging production needs to be modelled using the CFF since this is part of the packaging production life cycle stage.

B) Recycling

The impact of recycling, and associated avoided materials, can be calculated as follows:

Recycling:	*$E_{recyclingEoL}$ × weight packaging material × (1-A) × R_2*
Avoided primary material:	*$-E^*_V$ × weight packaging material × (1-A) R_2 × Q_{sout}/Q_p*

It should be noted that the second part of the formula, the credit for avoided primary material, results in a negative outcome. In an LCA, it can also be modelled as avoided product (in that case the minus needs to be removed).

The following explains how the different parameters can be obtained:

R_2	*Recycling rate/ recycling output rate. It is the proportion of the material in the product that will be recycled (or reused) in a subsequent system. R_2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R_2 shall be measured at the output of the recycling plant.*
A	*Allocation factor of burdens and credits between supplier and user of recycled materials. It allocates burdens and credits from recycling and virgin material production between two life cycle stages: the one supplying recycled material, and the one using recycled material. It aims to reflect market realities.*
Q_{sout}/Q_p	*Quality of outgoing secondary material (at the point of substitution) / Quality of primary material (at the point of substitution)* *Mostly it is assumed that E^*_V equals E_V, which means it is assumed that the recyclable material at EoL replaces the same virgin material which was used to produce the recycled material.* *If $E^*_V = E_V$, then both the quality ratios Qsin/Qp and Qsout/Qp are needed, which capture the downcycling of a material compared to the original primary material.* *If $E^*_V \neq E_V$, one quality ratio is needed: Qsin/Qp associated to the recycled content. The Qsout/Qp is already indirectly integrated in E^*_V. Also, evidence needs to be provided that a recyclable material is substituting a different virgin material than the one producing the recyclable material.*

C) Incineration

The impact of incineration, and associated energy recovery, can be calculated as follows:

Incineration:	*E_{ER} × weight packaging material × (1-R_2) × R_3 × (1-B)*
Energy recovery from incineration:	Heat: *- $E_{se,heat}$ × weight packaging material × (1-R_2) × R_3 × (1-B) × LHV × $X_{er,heat}$* Electricity: *- $E_{se,elec}$ × weight packaging material × (1-R_2) × R_3 × (1-B) × LHV × $X_{er,elec}$*

It should be noted that the second part of the formula, the energy recovery from incineration, results in a negative outcome. In an LCA, it can also be modelled as avoided product (in that case the minus needs to be removed).

In Ecoinvent (cut-off) datasets for incineration, energy recovery is often excluded and needs to be modelled separately.

Where:

R_3	*Proportion of the material in the product that is used for energy recovery at EoL. Available from PEFCR's Annex C* *Note that (1-R_2) is added to the original formula. This is because the R_3 data as provided in Annex C concerns only the percentage of waste (non-recycled material) that goes to incineration, thus not the percentage of the total packaging going to incineration. It first needs to be multiplied by (1-R_2) to account for the share of packaging going to municipal waste (= share not recycled). It is then multiplied by the percentage of waste going to incineration. E.g. If the recycling rate of a product (R_2) is 40%, this means that 60% goes to waste. If the incineration share = 90%, this means (1-0.4) *0.9 = 0.54, or that 54% of the original material is going to incineration.*
B	*allocation of energy recovery process, applying to both burdens and credits. In PEF studies the B value shall be equal to 0 as default.*
E_{ER}	*specific emissions and resources consumed arising from the energy recovery process (e.g. incineration with energy recovery)*
$E_{se,heat}$	*specific emissions and resources consumed that would have arisen from the specific substituted energy source, in this case electricity*
$E_{se,elec}$	*specific emissions and resources consumed that would have arisen from the specific substituted energy source, in this case heat*
LHV	*Lower heating value of the material in the product that is used for energy recovery. This is integrated in EF datasets. If no EF dataset is used, LHV can be derived from other sources, for example the Phyllis database[4]*
$X_{er,heat}$	*Efficiency of the energy recovery process for heat. This is integrated in EF datasets. If no EF dataset is used, X can be derived from other sources, for example from Ecoinvent datasets.*
$X_{er,elec}$	*Efficiency of the energy recovery process for electricity. This is integrated in EF datasets. If no EF dataset is used, X can be derived from other sources, for example from Ecoinvent datasets.*

D) Landfill

Everything that is not being recycled, or going to incineration, is going to landfill. This is captured in the following formula.

Landfill:	*weight packaging material* $\times E_D \times (1 - R_2 - (1-R_2) \times R_3)$

Where:

[4] https://phyllis.nl/Browse/Standard/ECN-Phyllis.

E_D *Specific emissions and resources consumed arising from disposal of waste material at the EoL of the analysed product, without energy recovery (landfill), these can be taken from databases such as EcoInvent.*

5.7.3.2 CFF parameters for consumer packaging

The section below details the standard parameters for CFF, aligned with Annex C of the PEF guidelines.

Table 11 provides an overview of default CFF parameters on a European level for different consumer packaging material.

Table 11: Default CFF parameters, European average.

Packaging type	A	R1	R2	R3	1-R2-R3	(Qsin/Qp)	(Qsout/Qp)
Polyethylene terephthalate	0.5	0	0.42	0.32	0.26	1	1
Polyethylene, low density	0.5	0	0.275	0.40	0.33	0.75	0.75
Polypropylene	0.5	0	0.183	0.45	0.37	0.9	0.9
Aluminium, primary, ingot	0.2	0	0.60	0.22	0.18	1	1
Kraft paper	0.2	0	0.75	0.14	0.11	0.85	0.85
Packaging glass	0.2	0.52	0.66	0.19	0.15	1	1
Tin plated chromium steel sheet	0.2	0.58	0.80	0.11	0.09	1	1
Corrugated board box	0.2	0.47	0.75	0.14	0.11	0.85	0.85
EUR-flat pallet	0.8	0	0.3	0.38	0.32	1	1

5.8 Other

5.8.1 Renewable energy

While the use of renewable energy certificates has been discussed earlier, it is important to reiterate a specific requirement in cases where renewable energy falls under the scope of the Renewable Energy Directive (RED) or ISCC certification. In such cases, any energy that qualifies for a multiplier—allowing it to be sold or counted more than once—must be corrected for in the study. This ensures that a single unit of renewable energy is not double counted in the environmental assessment, preserving the accuracy of the model. This principle aligns with the guidance provided in section 4.4.2 of the generic PEF.

6 Environmental footprint reporting

The user of this LCA guidance shall calculate the environmental footprint of its product(s) in compliance with all requirements. The following information shall be included in the final LCA report:

- life cycle inventory
- characterised, normalized, and weighted results in absolute values, for all impact categories
- the aggregated single overall score in absolute values
- interpretation of the most relevant impact categories
- limitations of the study (including data gaps)

in the case that results are externally communicated, it is mandatory that the LCA report and LCA results are verified by an external party. In all cases the independence of the verifiers shall be guaranteed. The review is performed in alignment to the requirements included in Section 9 of the Annex I of the PEF (European Commission, 2021)

6.1 Use of this guidance

This LCA guidance has been created to encourage the sector to create high quality Environmental Footprint studies of margarine and other emulsified fats. Consistency, replicability, and comparability are ensured by the correct application of this guidance. It is expected that with continuous application and practical feedback, this guidance will undergo future updates not only to align with the latest LCA methodological advancements, but to be of practical use for the sector.

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Appendix I – Direct comparison with dairy-based fat products

For the margarine sector, comparison of the environmental performance of their products with other products (e.g., dairy products) with the same function is important. Margarine offers a (mostly plant-based) alternative to butter, potentially reducing impacts by excluding the animal production system. This PEFCR was developed with the dairy PEFCR in mind, to allow for fair comparison. This annex gives extra guidance on the comparison of the environmental performance of margarine products to dairy-based fat products.

Requirements for comparison

The ISO standards 14040 and 14044 and general PEF guidelines prescribe requirements for comparing environmental performance of different products/production systems. The most important ones are listed here and should be followed for comparisons between butter and margarine:

- Systems shall be compared using the same functional unit
- Systems shall be compared using equivalent methodological considerations (performance, system boundary, data quality, allocation procedures, decision rules on evaluating inputs and outputs and impact assessment).
- Any differences regarding these systems shall be identified and reported.
- The LCIA shall employ a sufficiently comprehensive set of impact indicators
    - The comparison shall be conducted category indicator by category indicator.

Modelling requirements for margarine products for direct comparison with dairy-based butter

For direct comparison with the environmental performance of dairy-based fats, it is of importance that the methodology used of the environmental assessments are comparable.

For comparison the functional unit of both systems should include the same quantity, the same function (e.g. spreading, baking or frying) and sales market. For fair comparison, the entire life cycle needs to be considered (cradle-to-end-of-life). Some life cycle stages differ greatly between dairy products and alignment is not always possible. The life cycle stage raw material acquisition is the most evident example of this. Where for dairy butter, cow's milk production needs to be modelled, while for margarine, this life cycle stage contains the modelling of cultivation of oil seed crops. Additionally, when comparing dairy and margarine products, it's important that the same impact categories are analyzed and compared. Per product, the most relevant impact categories might vary but for the comparison it is important that the same categories are compared.

The Table 1 below summarizes the most important aspects to consider while modelling the environmental performance of margarine products for comparison with dairy butter.

Table 1. Specific guidance per life cycle stage to compare butter with margarine products

Main life cycle stage	Life cycle stage	Specific guidance
Agricultural inputs acquisition and pre-processing	**1. Oil crop / feed cultivation**	• Ensure the data for crop protection for the margarine LCA is feed PEFCR aligned, to ensure alignment with dairy LCA (e.g. economic allocation between main and co-products)
	2. Oil crop pre-processing (crushing)	• As described in main text of these guidelines
	3. Oil processing (refinery)	• As described in main text of these guidelines
	4. Manufacturing of other ingredients / other raw material acquisition	• As described in main text of these guidelines
Production of the main product	**5. Transport**	• For refrigerated bulk transport use 0.4 L diesel/km travelled, or 0.0023 L diesel / kg oils and fats/milk transported (as per dairy PEFCR)
	6. Margarine / Butter Manufacturing (Including emulsification, cooling and crystallization)	• Include, cleaning agents, energy, water and refrigerants
	7. Consumer/B2B packaging	• As described in the main text of this guidance. • For dairy butter, if the comparison is not to a specific product, packaging of 1.44 grams of paper per 250 grams of butter need to be considered, when comparing to a market average (as per dairy PEFCR)
Product distribution and storage	**8. Distribution**	• For transport, allocation on mass should be applied • For storage model 1 week chilled storage for butter at distribution • For storage, a storage space of 3 times the product volume needs to be considered.
	9. Retail or food service	• Modelling approach should be identical.

Main life cycle stage	Life cycle stage	Specific guidance
		• Approaches in dairy PEFCR and shadow margarine PEFCR are identical • Model storage time of 3 days.
Use stage (only to be included if manufactured product is final product)	**10. Consumption**	• Include storage of product only if it needs to be chilled • Assume spreading as intended use of butter/margarine (only use case for butter elaborated in diary PEFCR), if this is not the use case of the margarine product, exclude the use phase • Include dishwashing of one knife, as per dairy PEFCR
End-of-Life	**11. End-of-Life**	• Use CFF

Environmental data quality for butter production

In practice, when a margarine producing company wants to compare their production to a dairy product, they are likely to have better access to primary data from their own production, than dairy production. Therefore, it is allowed to compare the environmental performance of their product with the environmental performance of a butter, calculated with secondary data, but only when the criteria listed here are met.

When comparing the environmental performance of a margarine product calculated according to these guidelines and the specifications of this annex, a secondary data source needs to be chosen for the environmental performance of the dairy-based fat product. This deviates from the ISO requirement that requires similar data quality used for both products. But this exemption is necessary due to data availability to the practitioner. This difference should always be mentioned when communicating results. This data should be:

- Market specific: the dairy product should be representative of the same market (data that represents the system behind the product sold in the same market as the margarine product)
- From a recognized LCA database or scientific literature
- Calculated in accordance with the Dairy PEFCR

A preferred database for the environmental performance of dairy products is Agri-footprint 7. This database covers a wide range of milk producing countries, and data are modelled in line with the dairy PEFCR, allowing for fair comparison.

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