Report 2025

Environmental footprint methodology for coffee

Shadow PEFCR of the European Coffee Federation

Mérieux NutriSciences | Blonk

EUROPEAN COFFEE FEDERATION

Project information

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Environmental footprint methodology for coffee – shadow PEFCR of the European Coffee Federation

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List of Abbreviations

ADP-fossil – Abiotic Depletion Potential - fossil fuels

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)

ECF – European Coffee Federation

EF – Environmental Footprint

EoL – End-of-Life

FU – Functional Unit

GHG – Greenhouse Gas

GLO – Global (in datasets)

HoReCa – Hotel/Restaurant/Café

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

N_2O – Nitrous Oxide

OCS – Office Coffee Services

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

SCG – Spent Coffee Grounds

SEBS – Styrene-Ethylene-Butylene-Styrene

SO_x – Sulfur 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 coffee, specifically black coffee. An environmental footprinting (EF) study, also referred to as a life cycle assessment (LCA), evaluates the environmental impact of a product or system throughout all the stages of its life cycle. 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 a black coffee beverage, ensuring the outcomes of the EF study are reproducible and use comparable principles.

For the entire life cycle of a serving of black coffee, 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 coffee-specific situations (e.g. cultivation types, 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 with the guidance developed by the European Commission for the development of Product Environmental Footprint (PEF) studies, which 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. Despite that, the aim was to stay as close as possible to current PEFCR guidelines in order 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:

- **Giovanni Lamberti: glamberti@ecf-coffee.org, and**
- **Samragi Chatim: samragi@blonksustainability.nl.**

2. General information

2.1 Development of the guidelines

This study was commissioned by the European Coffee Federation (ECF) 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; in practice also referred to as "the working group"). Table 1 below lists the members of the technical secretariat.

Table 1: Members of the technical secretariat.

Organization	Members
European Coffee Federation	Giovanni Lamberti
Lavazza	Angela Aiello
	Federica Princi
Illycaffé	Caterina Di Pascoli
Nestlé	Jorge Alava
	Namy Daniela Espinoza Orias
	Cilian Fitzgerald
	Jean-Claude Gumy
JDE Peet's	Wisse ten Bosch
	Simon Fox
Tchibo	Marjike Schöttmer
Delta Cafés Grupo Nabeiro	Carla Rodrigues
Neumann Kaffee Gruppe	Julius Wenzig Camilla Engel
Arvid Nordquist	Erica Bertilsson

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	Project management
Mariem Maaoui	Coffee LCA expert
Samragi Chatim	Coffee LCA expert
Jasper Scholten	LCA guidelines expert
Davide Lucherini	Carbon, soil and land expert

2.2 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.

Furthermore, FoodDrinkEurope's PEFCR guidance (FoodDrinkEurope, 2022) has been followed. Where above guidelines did not apply or were not specific for the coffee sector, distinct rules were defined based on inputs from the TS.

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 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.

These guidelines aim to establish key methodological rules for measuring the environmental impact of coffee without providing exact quantifications for benchmarks. Coffee encompasses multiple product categories, necessitating several benchmarks, complicating guidance development. Comparisons to a single benchmark could lead to confusion. While not the main focus, the guidelines recommend certain background datasets, subject to their specific terms and conditions. It is important to clarify that the intention was not to develop multiple benchmarks, as coffee is a family of product categories, and the guidelines are not intended to support cross-category comparisons, only intra-category comparisons.

2.3 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 in order 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.*

2.4 Geographical validity

These guidelines are focused on coffee products 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 coffee products.

2.5 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

A cup of coffee can be defined as a beverage made from the roasted and ground seeds (coffee beans) of the tropical coffee shrub and/or their extracts (instant coffee). The product in scope for these guidelines is “a serving of black coffee”, wherein a black coffee would be defined as a beverage that is prepared by brewing roasted and ground coffee in water, or by dissolving coffee extract into water (instant coffee). The scope of these guidelines excludes any additions, such as milk or sugar.

Classification of Products by Activity (CPA) codes of classification that may be relevant to coffee include 01.27.11 “Coffee beans, not roasted”, 10.83.11 “Coffee, decaffeinated or roasted” and 10.83.12 “Coffee substitutes; extracts, essences and concentrated of coffee or coffee substitutes; coffee husks and skins”.

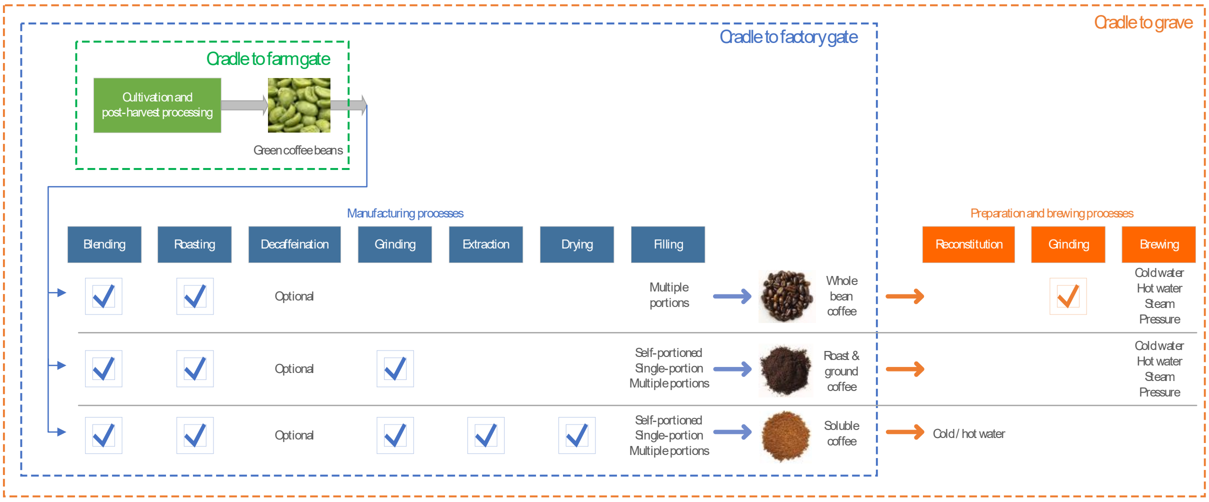

Figure 1 : Black Coffee Pathways and Scopes

Figure 1 illustrates the different coffee products and preparation methods for a serving of black coffee, as well as the three scopes covered in this document.

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, three different functional units are supported to accommodate varying system boundaries:

1) At the farm gate, the focus is on green coffee beans, which represent the unprocessed agricultural output from coffee farms.

2) At the factory gate, the analysis includes the main processed coffee products—whole bean coffee, roast and ground coffee, and soluble coffee as they leave the manufacturing facility.

3) Finally, under the cradle-to-grave boundary, the scope extends to the final consumption stage, represented by a cup of black coffee prepared by consumers using a range of preparation methods and brewing technologies.

In cradle-to-farm gate or cradle-to-factory gate studies, the functional unit will always pertain to the mass of the end product of the corresponding life cycle stage (e.g., 1 kg of green coffee at post-harvest processing, or 1 kg of roasted coffee beans at the end of manufacturing).

The functional unit that shall be used in cradle-to-grave studies for coffee is defined in Table 3.

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

Dimension	Definition for a serving of black coffee
What? **The function/service provided**	Providing 1 serving of black coffee
How much? **The extent of the function or service**	The characteristics and volume of the black coffee beverage will adhere to package recommendations and technology used.
How well? **The expected level of quality**	The coffee product should be in saleable condition as defined by the market.
How long? **The duration/lifetime of the product**	The shelf life would be defined by expiration date provided on the packaging

In this context, the reference flow is identical to the defined functional unit. In addition to this, it may occur that the objective of a coffee EF does not focus on the coffee itself, but on the specific technology used to brew one or more types of coffee (e.g. single serve/cup systems). In that case, the functional unit is defined differently; the functional unit then includes all possible types of black coffee which can be created by the specific technology. In such studies, the reference flow is defined as the weighted sum of all different types of coffee which could be made by that specific technology, including market volumes as weighing factors. The functional unit shall then describe clearly what types of coffee are included in the analysis and how they are numerically included in the whole life cycle of the machine or technology assessed.

To ensure consistency in obtaining market volumes, data should be collected from various sources, including industry sales data, consumer behaviour studies, retail sales information, and manufacturer disclosures. If direct data are unavailable, consumer surveys or assumptions based on regional preferences should be used, provided they are clearly documented and justified.

Table 4 provides an example of aspects related to a brewing technology-specific functional unit.

Table 4: Brewing technology-specific LCA functional unit aspects

Dimension	Definition for a serving of black coffee
What? **The function/service provided**	Providing 1 serving of black coffee brewed with a specific machine.
How much? **The extent of the function or service**	The beverage volume and coffee strength are determined by the machine settings.
How well? **The expected level of quality**	The coffee should meet the brand quality standards for taste, aroma, and temperature.
How long? **The duration/lifetime of the product**	The specific machine has an estimated lifetime of approximately 5,000 brewing cycles, which corresponds to about 7 years of operation under a typical usage scenario of two servings per day.

Table 5 below provides a list of various coffee beverages and a brief description of their preparation methods and technologies used. This list is non-exhaustive but helps in understanding the differences in the beverage preparation methods for EF studies that are focused on brewing technologies.

Table 5: List of coffee beverages and their preparation methods.

Type of beverages	Description of preparation	Technology used
Instant	Dissolves pre-brewed, dried coffee granules	Self- or pre-portioned & prepared by dissolving in hot/cold water
Drip (Filter) coffee	Water drips through grounds in a filter	Drip filter machine (electronic)

Type of beverages	Description of preparation	Technology used
Pour Over (Filter) coffee	Hot water poured over grounds in a filter	Similar principle to drip filter but prepared in a non-electronic filter coffee pot
Moka coffee	Steam pressure pushes water through grounds	Moka pot (stovetop)
Espresso	Pressurized water forced through fine grounds with home machine (with or without portioned pods)	Espresso home machine requiring an input of ground coffee; machines equipped for pre-portioned pods/capsules; stovetop espresso makers
Espresso traditional	Pressurized water forced through fine grounds with professional machine	Professional espresso machine meant for use in cafés, restaurants, etc.
French press coffee	Grounds steeped in hot water, then pressed	French press
Turkish coffee	Finely ground coffee simmered unfiltered	Self-portioned and prepared in a Turkish coffee pot (*cezve*) over a stovetop
Cold Brew	Grounds steeped in cold water for hours	Special cold brew pots or any other coffee preparation technology that allows for grounds to brew in cold water for 12-24 hours
Siphon coffee	Vacuum pressure brews coffee in chambers	Vacuum coffee maker (stovetop)
AeroPress coffee	Steeped grounds forced through a filter	AeroPress
Percolator coffee	Water cycles through grounds repeatedly	Percolator (stovetop)
Nitro coffee	Cold brew infused with nitrogen gas	Nitro coffee home kits; Professional keg with tap system for cafés, restaurants etc.
Vending	Various types of coffee beverages are automatically prepared and dispensed	Vending machines available in public or office spaces
Single serve	Water passes through pre-portioned ground coffee in capsules, pads or pods to produce coffee	Single-serve machines compatible with coffee capsules, pads or pods
Fully automated coffee machine	Automatic grinding of beans, brewing, and dispensing the coffee	Automatic coffee machines available in public or office spaces

If the EF study concerns self-portioned black coffee beverages where the serving size is defined by the technology used to prepare the beverage rather than the packaging, the serving size should be determined using primary data based on the specific equipment and its technical specifications. In cases where no specific equipment is evaluated or such primary data are unavailable, default serving sizes provided by the ECF (as presented in Appendix III) should be used.

3.3 System boundaries

The system boundaries define which processes should be included or excluded from the study. The life cycle stages that shall be included within the system boundary for black coffee are summarized below in Figure 2 and Table 6. EF studies following these guidelines shall include a system boundary diagram with a flow chart showing the coffee variety under study (arabica and robusta) and explicitly mention the applicable post-harvest processing method(s).

Carbon credits of products which are not in scope of the EF study, shall not be included. For more guidance on how to deal with carbon credits, section 4.6.1 of the generic PEF shall be followed.

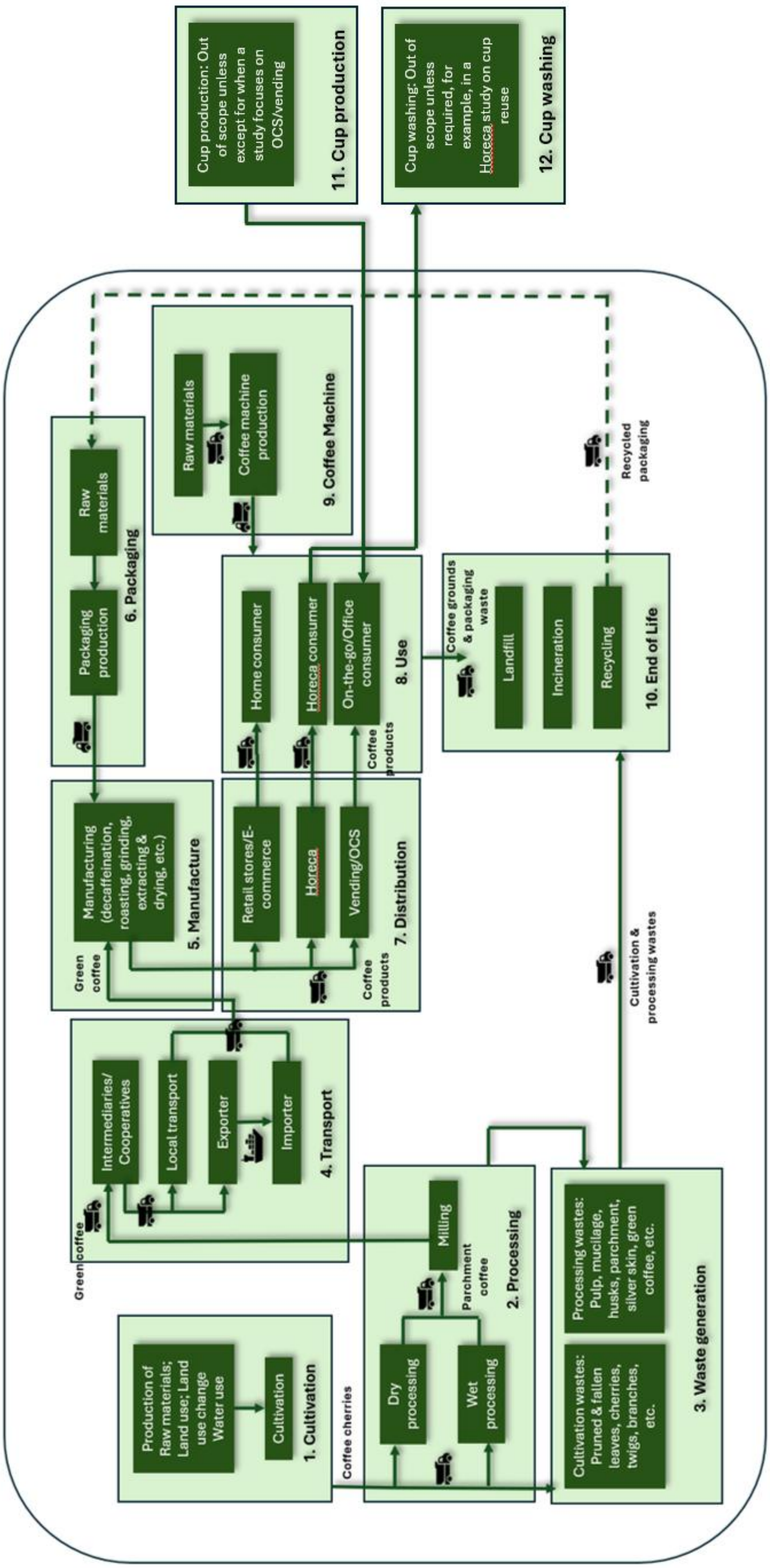

Figure 2: System boundary diagram of the coffee life cycle.\

Table 6: Life cycle stages for coffee.

Main life cycle stage (generic PEF)	Specific life cycle stage (these guidelines)	Section (these guidelines)	Relevant activities
Agricultural inputs acquisition and pre-processing	**1. Cultivation**	5.1	• Production and inbound transport of cultivation inputs; application of the cultivation inputs (synthetic and organic fertilizers, pesticides, water, etc.); • Pruning, shade tree planting, intercropping, harvesting the yield of coffee cherries; • Waste & residue generation resulting from cultivation and harvest activities and its management.
	2. Processing	5.2	• Post-harvest processing of coffee cherries to green coffee; • Wet processing or drying of coffee cherries and generation & management of associated wastes and wastewater; • Milling and associated waste generation & management; • Packaging materials used to parcel the green coffee
Production of the main product	**3. Transport**	5.3	• Transport of packed green coffee to the point of manufacturing; • All local and international transportation steps; • Transport by road, rail, ship and/or plane from point of processing to the point of manufacturing.
	4. Manufacturing	5.4.1	• Manufacturing of coffee products such as roasted beans, ground coffee, decaffeinated variants, instant coffee, single serve variants and such others, that can be used to make a serving of black coffee (as per instructions on the product packaging); • Use of raw materials (such as green coffee) & ancillary materials (water, steam, etc.), energy use and, if relevant, transportation in between manufacturing locations; • This life cycle stage ends when the finished product is ready to be packaged.
	5. Consumer packaging	5.5	• All activities related to primary, secondary and tertiary packaging of coffee products; • Manufacturing of packaging of coffee products; • Production of their raw materials, processing of recycled materials, transport of packaging materials to manufacturing facility and the packaging process itself.
Product distribution and storage	**6. Distribution**	5.4.2	• Transport of packaged coffee products to distribution centres • Transport of packaged coffee products from distribution centres to points of sale; • The sale of coffee products via retail stores, e-commerce, direct to consumer, hotels, restaurants, and cafés (HoReCa) and vending/office coffee services (OCS) should be included under the different avenues of distribution if relevant for the coffee product in scope.
Use	**7. Use**	5.6.1	• Brewing and consumption of the coffee product by the end user; • Energy, water and ancillary materials (filter paper) used to prepare the beverage; • The beverage may be prepared and consumed via food services/HoReCa, vending/OCS or at home.
	8. Coffee machine	5.6.2	• Manufacturing of coffee machines • Transport of coffee machines to the point of use.
End-of-Life	**9. End-of-Life**	5.7	• End-of-life (EoL) of packaging waste, coffee wastes, coffee machines and ancillary materials (e.g. filters). • Transport from point of disposal to point of final waste management.

3.4 Most relevant impact categories, life cycle stages and processes

A life cycle impact assessment (LCIA) method converts the life cycle inventory data into contributions to each of the environmental impact categories in scope. 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.

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). The most relevant life cycle stages are those that together contribute to at least 80% to any of the most relevant impact categories identified. The most relevant processes are those that together contribute to at least 80% of the single overall impact 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 aligns with the PEF methodology. The list in Table 7 serves as the baseline set of relevant impact categories to 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 7:EF impact categories relevant to these guidelines.

EF Impact category	Impact category indicator	Unit
Climate change, total	Radiative forcing as global warming potential (GWP100)	kg CO_2 eq.
Particulate matter	Impact on human health	disease incidence
Acidification	Accumulated Exceedance (AE)	mol H^+ eq.
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq.
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTUe)	CTUe
Land use	Soil quality index	Dimensionless (Pt)
Water use	User deprivation potential (deprivation-weighted water consumption)	m^3 world eq.
Resource use, fossils	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ

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. Guidance on how to deal with this is given in section 5.1.1.
- **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. There is a limitation with this impact category 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. The limitations and recommendations for pesticide modelling are further discussed in section 5.1 of these guidelines.
- **Eutrophication (terrestrial):** This impact category is related to nutrients (mainly nitrogen and phosphorus) from sewage outfalls and fertilized farmland that accelerate the growth of algae and other vegetation in water. The degradation of organic material consumes oxygen, resulting in oxygen deficiency and, in some cases, fish death. Eutrophication calculation translates the quantity of substances emitted into a common measure, expressed as the oxygen required for the degradation of dead biomass.
- **Land use:** This impact category refers to the impact on soil quality related to the use of the land compared to its natural state. To calculate impacts from land use, the generic PEF currently recommends using LANCA® method (Horn and Maier, 2018). However, this method can be complicated to interpret as it involves the aggregation of five indicators into one dimensionless unit; in essence, this can lead to a lack of transparency during interpretation of EF results. LCA practitioners should report on land occupation (e.g., m^2 used per kg product) or, if primary data are available, to re-calculate LANCA by using primary data (see note box).
- **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).
- **Resource use, fossils:** This impact category addresses the use of non-renewable fossil natural resources (e.g. natural gas, coal, oil).
- **Water use:** This impact category represents the water remaining per area in a watershed once the demand from aquatic ecosystems and humans has been fulfilled. It examines the potential of water deprivation to human and/or ecosystems. The data requirements for water use have been further elaborated upon in section 5.1 of these guidelines.

Below are the life cycle stages and processes that are generally most significant for the coffee supply chain, based on input from LCA experts within the coffee industry. How to model these, is further explained in chapters 4 and 5.

Note: LANCA® is an LCA indicator that evaluates the environmental impact of land use on the quality of soil. Its five key indicators are **erosion resistance potential** (assessing soil's ability to resist erosion), **mechanical filtration potential** (measuring soil's ability to filter water and trap particles), **physicochemical filtration potential** (evaluating soil's capacity to filter chemical substances), **groundwater regeneration potential** (indicating the ability of soil to recharge groundwater), and **biotic production potential** (reflecting the soil's capacity to support vegetation growth). Together, these indicators provide a comprehensive understanding of land use impacts, helping guide sustainable practices. While the LANCA characterization factors are included in the PEF method on a country level, it is possible and recommended to apply the LANCA indicator in its most refined version, that is, by using farm primary data (e.g., slope, clay content, rainfall, soil organic matter). This recommendation is based on the indicator's ability to indicate not only the soil quality status of the farm under analysis, but to identify the most relevant impact reduction measures.

Most relevant life cycle stages:

- Cultivation
- Use stage
- Production of packaging

Most relevant processes:

- Application of pesticides (insecticides) and related emissions
- Application of synthetic and organic fertilizers and related N_2O emissions
- Energy consumed by a coffee machine during beverage preparation
- Production of packaging material
- In the case of instant coffee – manufacturing process

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. All recommendations in these guidelines are based on LCA studies that are publicly available or commissioned by the coffee industry, without supporting studies to enforce the validity of the guidelines. Whenever these guidelines are to be further developed (for example into an official PEFCR), the execution of supporting studies would be an essential addition.

3.6 Claims

These guidelines **are intended** to be used for supporting single product claims and **not intended** to support the comparison of different coffee beverages to each other. These guidelines shall only be used in the following comparative cases:

- Comparison of functionally identical black coffee types, without any additions, from cradle-to-grave. For example: comparing cups of coffee made by a drip filter system, using two different coffee beans; packaging materials with different recycling rate etc.;
- Comparison of green coffee at a cradle-to-farm gate level;
- Comparison of roasted coffee beans or other coffee products that can be used to prepare a serving of plain black coffee at a cradle-to-factory gate level.

For clarification, these guidelines shall NOT be used in the following comparative cases:

- Comparison of coffee beverages with differing preparation parameters (e.g., comparison of one lungo versus one espresso), accounting for variations in input quantities and extraction methods;

- Comparison of green coffees at cradle to manufacturing gate level (i.e., including more life cycle stages than relevant for the green coffee);
- Comparison of roasted coffee beans at cradle to farm gate level (i.e., without the roasting).

Reporting organizations adhering to these guidelines may make claims, provided they comply with the following rules:

- If a non-comparative claim is to be made, an external reviewer shall verify the study to ensure it complies with these guidelines.
- 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 beverage.
- 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. Special attention shall be paid to cases where variation is possible (e.g., in consumer behaviour, different beverage preparation methods, etc.).
- Any EF study adhering to these guidelines shall be a multi-impact study in order 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 (LCI)

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 chapter defines generic principles related to the life cycle inventory, whereas the next chapter 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 recyclable accessories (cups), coffee machine washing and maintenance. However, if data is 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 Sampling of farms

Users of these guidelines may apply a sampling approach to reduce the number of representative coffee farms from which data should be collected.

The generic PEF generally recommends a stratified sampling approach; however, this may be difficult to achieve in practice as stratification/segmentation of coffee farms based on different farming practices is often not obvious. There are no known fixed number or combinations of farming practices that are applied at plantations, and thus, it is difficult to determine a “list” of coffee farm categories. In addition, the number of farms supplying to a coffee company may easily exceed hundreds (or even thousands), and without clear categorization, stratification on farming practises becomes virtually impossible.

In view of this, it is recommended to apply a random sampling approach, only distinguishing stratification at a country-level. In this, the total number of coffee farms in a country shall be determined, and the square root of this number will determine the number of farms that are to be sampled for a given study (as shown in equation 1).

$$N = \sqrt{n} \tag{1}$$

Where:

- N is the size of the sample
- n is the total number of coffee farms in a given country supplying the coffee product being assessed.

It is important to note that taking the square root shall only be valid when $n \geq 25$; if $n < 25$, then a higher sample rate shall be required for the sample to be representative.

However, if the reporting organization is in possession of high quality (primary), up-to-date (≤ 5 years) farm data that allows for stratification by farm type, the following formula may be used to determine the sample size for any identified number of strata (as shown in equation 2):

$$N_i = \frac{\sqrt{n_i}}{\sum_{j=1}^{a} \sqrt{n_j}} \times \sqrt{n} \quad (2)$$

Then the total sample size can be calculated as shown in equation 3,

$$N = \sum_{i=1}^{a} N_i \quad (3)$$

Where:

- N_i is the sample size of stratum *i*
- n_i or n_j is the size of stratum *i* or *j*
- *n* is the total number of units
- *N is* the total size of the sample
- *a* is the total number of strata

4.2 Allocation

Allocation at the different life cycle stages will be dealt with in the following manner:

- Cultivation – 100% of the impacts allocated to coffee cherries (see section 5.1.2).
- Post-harvest processing – 100% of the impacts allocated to green coffee (see section 5.2.1).
- Manufacturing – if a manufacturing plant is a multi-output location (e.g., producing both instant coffee as well as ground coffee) without information on the individual processing steps which would enable subdivision of the inputs and outputs, the impacts shall be allocated based on the decision hierarchy as defined by PEF. This should be, in order of preference:

  1. Allocation based on a relevant underlying physical relationship: Physical relationships to consider may be embedded energy, production volume or any other relationship which justifies allocation of multiple products.

  2 Allocation based on other relationship: In case of instant coffee (which requires more energy inputs per kg of end product than only ground coffee), economic allocation may cause a bias in the impact assessment, and should be avoided whenever possible, or shall be explicitly mentioned as a limitation in the study.

  Please note that for manufacturing sites that produce both instant coffee and roasted coffee grounds, allocation shall be based on embedded energy.

4.3 List of primary & secondary data

Table 8 lists the requirements with respect to primary data and secondary data for LCAs of coffee 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 4.4 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**

Activities such as 'loading green coffee onto a truck' are typically considered out of scope and may be excluded in most studies. However, if high-quality primary data are readily available, they may be included; future guidance should clarify whether and how to include these steps. In the absence of primary data, these can be disregarded, as sourcing secondary data for such minor contributions is generally not justified.

As for pesticide active ingredients, data quality relying on secondary data would compromise the robustness of results and therefore it shall not be used, given the sensitivity of ecotoxicity impact assessments

Table 8: List of mandatory primary data and allowed secondary data.

Life cycle stage	Process	Mandatory primary data	Allowed secondary data
1. Cultivation	**Fertilizers**	Type and amount of synthetic and/or organic fertilizer & soil amendments[1] used	Impacts from the production of fertilizers (synthetic & organic) & soil amendments
	Pesticides	Type and amount of pesticides used and their active ingredients	Impacts from the production of pesticides
	Energy	Amount and type of energy (fuel/electricity mix) used by agricultural equipment	Impacts from energy use
	Irrigation		Amount and source of irrigation water **if primary data are unavailable**
			Impacts from water sourcing (pumping, treatment etc.)
	Transport		Transport distances and modes for cultivation inputs
			Impacts from transport
	Yield		Yield of coffee cherries can be derived from Table 11 **only if primary data are unavailable**. Planting density is recommended to validate farmer-reported data provided per hectare.
	Land use	Area of land used for cultivation activities	

[1] While current LCA methodologies (including PEF) do not systematically account for changes in soil organic carbon (SOC), it is advisable to start considering related activities, especially in light of future methodological developments. This includes the use of soil amendments and circularly managed inputs—such as biochar, on-farm produced compost, and other organic matter recycled locally—which can have significant environmental relevance, particularly for small-scale or regenerative farming systems.

Life cycle stage	Process	Mandatory primary data	Allowed secondary data
	Land use change		Land use change equally discounted impacts compliant with the PEF[2] guidance (i.e., following the PAS 2050;1)
	Waste	Amount & type of waste/residues generated and type of waste management strategy	Impacts from waste treatment
	Carbon removals	Carbon removals by shade trees[3]	
	Packaging	Recycled content in packaging material	The amount of packaging material used **if primary data are unavailable**
			Impacts from packaging production
2. Processing[4]	**Wet processing**	Type of waste/residues generated and type of waste management strategy	Amount of waste (coffee cherry pulp, mucilage, etc.) can be derived from Table 11 **if primary data are unavailable**
			Impacts from waste treatment
		The volume of wastewater generated and information on the type of wastewater treatment system	Impacts from wastewater treatment
		Amount and type of energy (fuel/electricity mix) used by the wet processing equipment	Impacts from energy use
		Volume of water used	Impacts from water sourcing (pumping, treatment etc.)
	Dry processing	Amount & type of waste/residues generated and type of waste management strategy	Impacts from waste treatment
		Amount & type of energy (fuel/electricity mix) used (in case drying is mechanically carried out)	Impacts from energy use
	Milling	Type of waste/residues generated and type of waste management strategy	Amount of waste (parchment) can be derived from Table 11 **if primary data are unavailable**
			Impacts from waste treatment
		Amount & type of energy (fuel/electricity mix) used in milling equipment	Impacts from energy use
			Yield of green coffee beans (the saleable product) can be derived from Table 11 **only if primary data are unavailable**
	Packaging		Amount of packaging material used **if primary data are unavailable**
			Impacts from packaging production
	Loading	Loading of green coffee into	

[2]Cool Farm Tool uses linear amortisation to align with the SBTi, and these guidelines recommend using equal amortisation to align with the PEF.
[3] As these guidelines do not allow inclusion of carbon removals, it shall be only reported separately from the carbon footprint results.
[4] Table 11 provides conversion factors.

Life cycle stage	Process	Mandatory primary data	Allowed secondary data
		vehicles **only if primary data are available (not mandatory to include in scope)**	
	Transport		Transport distances and modes from plantation to processing & between processing facilities, **if primary data are unavailable**
			Impacts from transport
3. Transport	**Domestic coffee supply**		Distance and mode of transport of green coffee domestically by road/rail from processing facility to manufacturing facility **if primary data are unavailable**
			Impact from transport
	International coffee supply		Distance and mode of transport of green coffee domestically by road/rail from processing facility to port of exporting country, **if primary data are unavailable**
			Distance and mode of transport of green coffee by sea from port of exporting country to port of importing country, **if primary data are unavailable**
			Distance and mode of transport of green coffee by road/rail from port of importing country to manufacturing facility, **if primary data are unavailable**
			Impact from transport
4. Manufacturing	**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, etc.)	
	Emissions	Volatile organic carbon (VOC) emissions from the roasting and grinding processes **only if primary data are available (not mandatory to include in scope)**	
	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
5. Consumer 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) **if primary data are unavailable**

Life cycle stage	Process	Mandatory primary data	Allowed secondary data
6. Retail	Transport		Transport mode & distance from factory to distribution centre/retail **if primary data are unavailable**
			Transport mode & distance from retail to consumer
			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
			Impacts from energy use
	Losses		Loss rates during distribution and at consumer stage
7. Use	Brewing	Amount of water used	Impacts from water use
		Amount of energy used for brewing	Impacts from energy use
	Cup production (for vending machines only)		Cup manufacturing and EoL
	Coffee machine		Coffee machine lifespan **if primary data are unavailable**
			Transport mode & distance to assembly location **if primary data are unavailable**
			Impacts from transport
			Raw material used for coffee machine production **if primary data are unavailable**
8. End-of-Life	Wastewater		Volume of wastewater at the use stage from beverage preparation and beverage wasted/not consumed **if primary data are unavailable**
	Transport		Transport mode & distance to end-of-life
			Impacts from transport
	Coffee machine		Coffee machine weight **if primary data are unavailable**
	Waste		Amount of spent coffee grounds **if primary data are unavailable**

4.4 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 (as being data suppliers to the generic PEF);
- 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 9 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 6.3 (Blonk et al., 2022) and Ecoinvent 3.11 (Ecoinvent, 2024).

Table 9: Summary of background databases.

Data type	Recommended database
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
Raw materials and materials forming (e.g. coffee machine production, packaging, etc.)	Ecoinvent, cut-off
Fertilizers	Agri-footprint
Other chemicals	Ecoinvent, cut-off
Solid waste treatment	Ecoinvent, cut-off
Wastewater treatment	See section 5.2.1

4.5 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:

- Pesticides: While retrieving primary data on the amount of pesticide applied is possible, these guidelines acknowledge that information on the exact number and amount of active ingredients of a pesticide are difficult to retrieve. Section 5.1.1 discusses how to tackle these data gaps.

- Irrigation water: Retrieving accurate data on irrigation water can be difficult. Modelling of water use has been elaborated upon in section 5.1.1.

- 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. Land-use-change-free certificates are not per se reliable proof that no land use change emissions have occurred. It must be demonstrated that the certificate covers the minimum 20-year timeframe and applies specifically to the cropland under assessment, with physical traceability of the certified volume. If reliable primary data are unavailable, a sensitivity analysis of the land use change calculation should be considered (see section 5.1.1).

4.6 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.[5] 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.

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

5. Life cycle stages

5.1 Cultivation

This life cycle stage encompasses the cultivation and harvest of coffee cherries. The cultivation stage is often the most relevant life cycle stage in a coffee EF and shall be investigated appropriately.

5.1.1 Cultivation inputs

Cultivation requires 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
- Pruning & waste management
- 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 can 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.

As shown previously in Table 8, the applied quantities of all these inputs shall be farm-specific data. For pesticides, the amount as well as type (active ingredients) should be primary data. If this information is not available, then pesticides shall be excluded from the scope altogether, and shall be explicitly mentioned as a limitation in the EF study report. It is important to model pesticides with the correct active ingredients as this is sensitive to ecotoxicity impact calculations (Paeezi, et al., 2025).

Impacts from the application of fertilizers, lime and pesticides shall be modelled following the generic PEF. Table 10 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 10: Generic PEF recommended models to quantify emissions from fertilizers, lime & urea application.[6]

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

[6] 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. Since coffee is primarily cultivated in tropical regions, it is recommended to include the corresponding tropical zone EFs in the table to enhance accuracy and contextual relevance.

Emission	PEF recommended model	Compartment	Relevant impact category
N_2O direct	((synthetic N+ organic N) *0.01) *44/28	Air	Climate change
N_2O indirect	($NH_{3volatilization}$*Frac $_{volatilisation}$[7]*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 as described in Table 8.

[7] Fraction volatilisation into NH_3 0.11 for Synthetic fertilizers and 0.21 for organic fertilizers

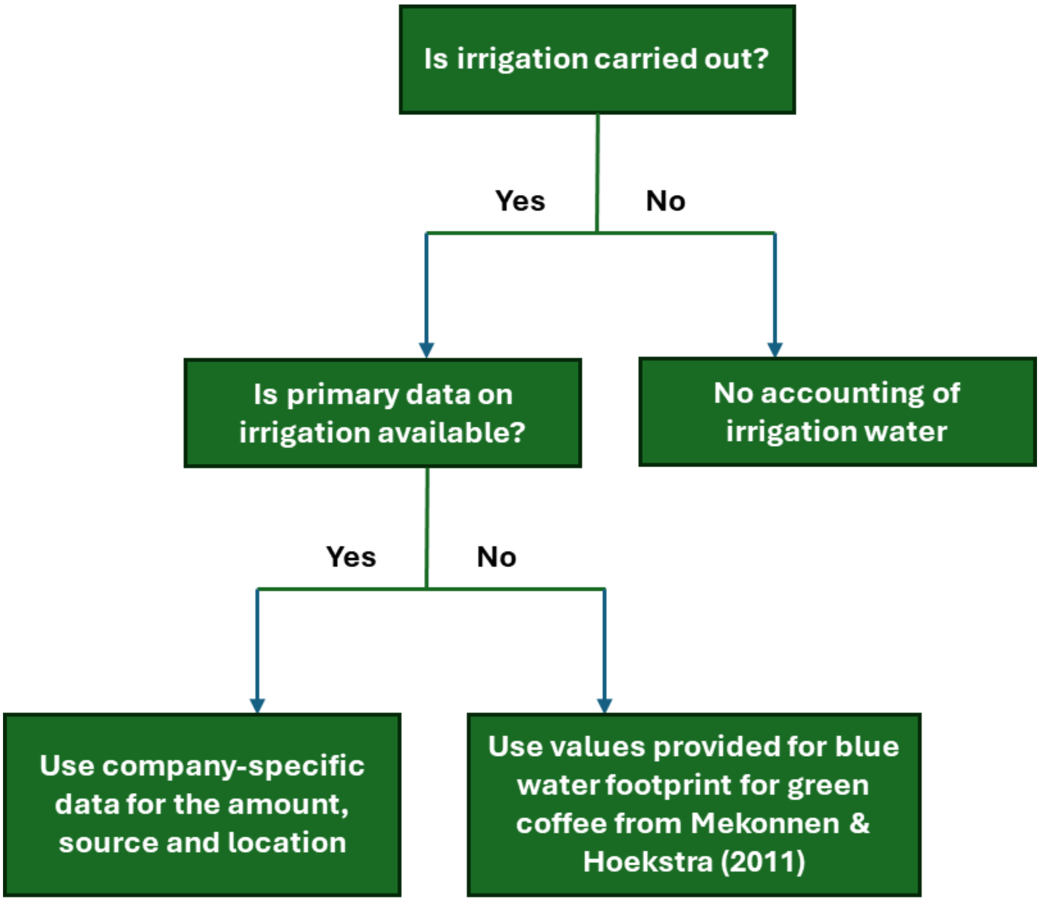

Figure 3: Decision tree for modelling irrigation water.

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 entire area of the coffee farm shall be reported in hectares, and this shall be primary data; the yield of coffee cherries shall be reported per hectare of farmland. The yield should ideally be primary data, however, in case this is not possible to retrieve, then the conversion factors provided in Table 11 shall be used to derive this value; a reasonable explanation shall be provided for why it was not possible to collect primary data on yield.

Energy used in agricultural machinery

The amount of energy used in agricultural machinery (whether fuel/electricity) shall be primary data (as mentioned in Table 8) 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).

Packaging

Typically, coffee cherries are packed in durable fabric bags, often made of jute or other sturdy materials. These fabric bags are placed within secondary packaging solutions such as crates or bins during transport.

For jute bags, the following dataset from Ecoinvent may be used: Textile, jute {GLO}| market for textile, jute | Cut-off. As mentioned in Table 8, quantity of packaging materials should be based on primary data. If unavailable, secondary data may be used.

If no primary data are available, a default quantity of 60 kg of coffee beans should be considered per jute bag, which itself has a default weight of 1 kg (B-Twill jute bag, Binola jute bag).

5.1.2 Nursery, shade trees & intercropping

The nursery stage and the cutting down of aged coffee trees shall not be modelled separately. It is understood that the full life cycle of a coffee tree can be represented through a loss in productivity, as at any given point, the farm will consist of some trees that are productive and some that are unproductive. It is to be noted that the application of cultivation inputs (and coffee cherry yields) shall be accounted for based on the land area of the entire farm, and not just the areas consisting of productive coffee trees.

The nursery stage, maintenance and cutting down of shade trees may also be excluded from the life cycle inventory. Shade trees are relatively much fewer in number than coffee trees and their maintenance demands are negligible over the course of their entire lifetime (15-50+ years as suggested by the TS).

In intercropping systems, 100% of the cultivation impacts shall be allocated to coffee and not to other crops. This is because cultivation inputs at farms are applied with the intention of nourishing coffee trees and not the shade trees/other crops. Additionally, coffee trees are usually the main source of income at coffee farms that carry out intercropping/agroforestry (Thi Duong Nga and Thuy, 2017). However, if in an intercropping system a crop other than coffee does cover a large share of the farm, then a sensitivity analysis using economic allocation, considering the value and yield of the other crop(s), is recommended.

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 coffee cultivation, carbon removals can refer to the storage of carbon in three main carbon pools: tree biomass, dead organic matter, and soil. 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.

Considering the expected publication of the final version of the GHG Protocol for Land Sector and Removals guidance as well as the updated PEF method, the next version of this coffee shadow PEFCR could include more guidance on how to include carbon removals.

In these guidelines, carbon removals related to the carbon stored in the biomass of shade trees is considered potentially relevant for communication purposes (there could however be more avenues for carbon removal). Thus, it is allowed to calculate and report carbon removals **only** as additional environmental information. However, carbon removals **shall not be reported as negative emissions** in the climate change impact category, following the guidance from the generic PEF. Independent of the accounting method chosen, the carbon removals estimate shall be supported with on-field direct measurements, as indicated in the GHG Protocol.

5.1.4 Waste management from cultivation

The coffee cultivation process can generate wastes such as pruned or fallen branches, trunks, leaves, twigs as well as cherries. The types and amounts of waste as well as the applied waste management strategy shall be collected as primary data while the environmental impact of the waste management practice shall be modelled using secondary datasets. Since most coffee plantations are smallholder operations, the waste management techniques usually involve piling of the waste, composting, mulching or burning the waste.

5.2 Processing

This life cycle stage covers the post-harvest processing steps such as wet or dry processing of coffee cherries into parchment coffee, followed by milling of parchment coffee into green coffee.

5.2.1 Inputs and outputs from processing

The amount of energy used in all processing steps (wet or dry processing, as well as milling) shall be collected as primary data. The total energy use of the wet or dry processing and milling activities shall be reported separately under the respective activities. The impacts from energy use shall be modelled using secondary databases; information on electricity mixes may be secondary information. Reporting of any form of renewable energy use shall follow the same rules as given in section 5.1.1. Datasets for most forms of renewable energy can be found in the secondary databases listed in section 4.4. However, for biofuels, there is a lack of reliable datasets. If no primary data are available, datasets from the UK DEFRA[8] (United Kingdom Department for Environment, Food & Rural Affairs) database should be used. The DEFRA databases focus solely on greenhouse gas emissions and thus climate change impacts; other impacts are overlooked, for example from the production of biofuels itself (cultivation of crops and manufacturing of the fuel). These activities should be modelled separately; however, if that is not feasible, they shall be clearly reported as a limitation in the EF study report.

Water consumption is typically only relevant for wet post-harvest processing and not for other processing activities. Wet post-harvest processing method uses water to transport coffee cherries, in pulping, fermentation and washing steps. The total amount of water used in this processing method shall therefore be reported as primary data.

The output at processing is green coffee along with generation of coffee pulp, mucilage, husk and parchment along all the processing steps (depending upon the fermentation methods chosen). The by-products generated during post-harvest processing are presently considered to have zero economic value and are classified as wastes, thus, prompting 100% allocation of impacts to the green coffee. Below are some examples of secondary datasets from the EEcoinvent database that may be used to model these wastes:

- *Biowaste {RoW}| treatment of biowaste, open dump | Cut-off*
- *Biowaste {RoW}| treatment of biowaste by anaerobic digestion | Cut-off*
- *Biowaste {RoW}| treatment of biowaste, industrial composting | Cut-off*
- *Biowaste {GLO}| treatment of biowaste, municipal incineration | Cut-off*

For wastewater, both the amount generated and the waste management strategy applied shall be collected as primary data. Water released directly on water bodies without treatment shall be reported as emission to the specific compartment (e.g. river, sea, etc.), including the geographical specification which should be at least country-level, but may be more specific (e.g. state level). Impacts of wastewater treatment at the wastewater treatment plant (if applicable), should be secondary data and shall be modelled based on the chemical oxygen demand (COD)-level as is proposed in Chapter 5 of the IPCC 2019 guidance.

Transport of wastes to the waste management/treatment facility (if any), shall be included in the scope and should be reported as primary data. If this is unavailable, a default distance of 100 km (from the generic PEF) by road shall be used.

[8] https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs

For the transport from the farm to the processing facility, as well as in between processing facilities, the same rules as given in section 5.1.1 shall apply. Loading green coffee into transport vehicles may be excluded from the scope, unless the energy consumption for this activity is known; then it shall be included for completeness. Storage at the processing facilities may be excluded from the scope as its impact is expected to be minor when no cooling, heating or heavy mechanical operations are occurring.

5.2.2 Conversion factors for yield

The coffee cherry undergoes several processing stages in order to be transformed into a green bean, with the mass of end product changing at every stage. The cherries will first undergo either dry or wet processing steps to produce parchment coffee, which is in turn milled to produce green coffee (Rotta et al., 2021). In these processes, the coffee cherries lose a part of their initial mass; thus, the yield of green coffee at the end of milling is not the same as that of the cherries at harvest.

The yield of green coffee at the end of the milling step should ideally be primary data. If primary data on yield of the green coffee is unavailable, then a default conversion factor shall be used to determine how much green coffee is produced from a given quantity of coffee cherries. Table 11 provides default conversion factors for each stage that coffee undergoes, which shall be used to determine the product yields and amount of waste generated in each processing step, unless primary data are available.

Table 11: Conversion factors for the different coffee products during processing (Source: Federación Nacional de Cafeteros de Colombia, 2008).

Coffee product	Description	Ratio	Conversion factor
Coffee cherry	End product of cultivation at harvest	Coffee cherry: fresh pulp[9]	2.3
		Coffee cherry: coffee in slime	1.81
		Coffee cherry: washed coffee	2.56
		Coffee cherry: parchment coffee	4.94
		Coffee cherry: green coffee	6.23
Coffee in slime	End product of fermentation in wet processing	Coffee in slime: washed coffee	1.41
		Coffee in slime: parchment coffee	2.74
		Coffee in slime: green coffee	3.43
Washed coffee	End product of washing after fermentation in wet processing	Washed coffee: parchment coffee	1.93
		Washed coffee: green coffee	2.42
Parchment coffee	End product after drying of washed coffee	Parchment coffee: green coffee	1.25
Green coffee	End product after milling of parchment coffee	-	-

5.2.3 Post-processing packaging

In many cases, the primary packaging involves the use of jute or polypropylene bags to contain the green coffee beans. For secondary packaging, these primary bags may be placed into larger bags, which are often made of polypropylene or woven plastic. To facilitate storage and transport, wood pallets are often used to stack these bags. Finally, for tertiary packaging, pallets are typically secured with shrink wrap.

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[9] Byproduct of pulping in wet processing

Table 12 below gives an overview of background datasets which should be used for modelling post-processing packaging, unless primary data are available.

Table 12: Background datasets to use from Ecoinvent for modelling packaging.

Packaging type	Background dataset Ecoinvent	Material forming
Jute bag	Textile, jute {GLO}| market for textile, jute | Cut-off	Not applicable
Polypropylene bag	Polypropylene, granulate {RoW}| polypropylene production, granulate | Cut-off	Extrusion, plastic film {RoW}| extrusion, plastic film | Cut-off
Woven plastic bag	Polypropylene, granulate {RoW}| polypropylene production, granulate | Cut-off	Extrusion, plastic film {RoW}| extrusion, plastic film | Cut-off + Weaving, synthetic fibre {GLO}| market for weaving, synthetic fibre | Cut-off
Wood pallet	EUR-flat pallet {GLO}| market for EUR-flat pallet | Cut-off	Not applicable
Shrink wrap	Packaging film, low density polyethylene {GLO}| market for packaging film, low density polyethylene | Cut-off	Not applicable

5.3 Post-processing transport

This life cycle stage covers all the transportation steps that take place to transport packaged green coffee from point of processing to point of manufacturing (both domestic and international). It is expected that before green coffee reaches manufacturers, it is stored at a number of intermediary organisations; however, any transport to, from and between intermediaries and also all storage shall be excluded from the scope.

For coffee manufacturers present in the country of cultivation, the transport life cycle stage will encompass local transport from the processing facility directly to the domestic manufacturing facility. This also applies to international transportation that occurs via road/rail. For overseas transport, the transportation steps will cover the distance travelled by road/rail to the port of export; this will be followed by the distance covered via ship/air to the port of import at the receiving country. Lastly, the distance traversed via road/rail from the port of import to the manufacturing facility (domestic or international), will be covered. All these distances travelled and the modes of transport shall be included within the scope and should be collected as primary data. Any type of storage occurring at each step shall be excluded from the scope, as this usually does not require any heating or cooling.

In case primary data on transport distances and modes is unavailable, the following generic PEF defaults for combination of transport modes shall be used:

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[10];*
- *In case the supplier's location is unknown, transport to be modelled as if supplier is located outside Europe.*

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

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 in the in the PEFCR Feed for food producing animals (FEFAC, 2024) (Annex VI) shall be used.

5.4 Manufacturing & distribution

This life cycle stage encompasses the manufacturing of coffee products that can, at the end of this stage, be used to prepare a serving of black coffee, as well as their distribution to consumers via various distribution channels.

5.4.1 Manufacturing

Manufacturing shall include all relevant steps in the production of coffee products. Examples of manufactured coffee products include:

- Roasted coffee beans
- Ground coffee (also in single serve variants)
- Instant coffee
- Decaffeinated coffee if relevant (in either one of the three above-mentioned forms).

All products that can be used to prepare a single serving of black coffee (as defined in section 3.2) shall be included in the scope. Coffee products that contain milk and sugar are not supported by these guidelines.

The energy used to produce every type of product shall be collected as primary data and be reported separately for each product. Electricity use shall be modelled as per the generic PEF[11]. In cases where the manufacturing site produces multiple outputs (e.g., instant and ground coffee) and disaggregated energy data per product is not available, the allocation of energy use shall follow the decision hierarchy defined by PEF, as detailed in section 4.2. If energy used in manufacturing (either for roasting or drying) comes from burning of spent coffee grounds (energy recovery), guidance given in section 5.7 of these guidelines shall be followed.

The amounts of all raw materials (green coffee) and ancillary materials (e.g. water, steam, solvents, etc.) used in the manufacturing of coffee products shall be collected as primary data, whereas the impacts of their production shall be derived from secondary data. Any emissions identified at the roasting and grinding level (VOC emissions) shall be reported as primary data if the information is available; if not available, this may be excluded from the scope.

The energy used to fill coffee products into their packaging shall be included in this life cycle stage. Losses during the packaging process are estimated to be 1% in accordance with the generic PEF.

As for wastewater, impacts of wastewater treatment at the wastewater treatment plant (if appliable), should be based on secondary data and shall be modelled as is proposed in Chapter 5 of the IPCC 2019 guidance.

Lastly, any transport occurring between manufacturing facilities shall be collected as primary data; no default values are available.

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[11] See section 4.4.2. of Annexes 1 to 2 of the Generic PEF.

5.4.2 Distribution

This life cycle stage includes all transport activities required to deliver the packaged coffee and coffee machine to the end user.

5.4.2.1 Distribution channels

Distribution may happen through various channels, as shown in Figure 4. The main channels include HoReCa, vending, retail, and direct-to-consumer, as detailed below.

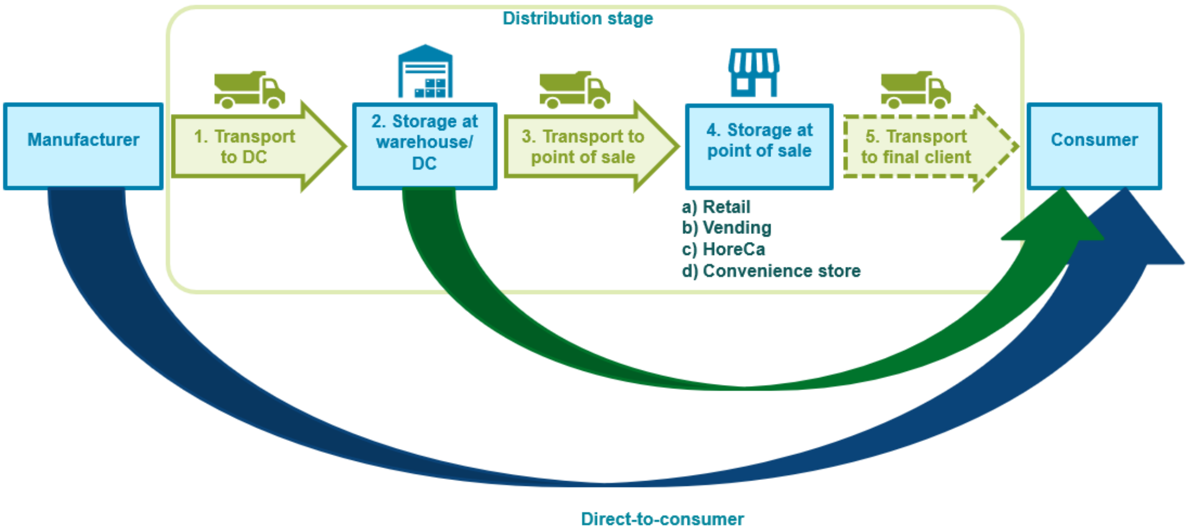

Figure 4 : Most common distribution channels for coffee.

- HoReCa
  - Hotels: Coffee is supplied for in-room services, restaurants, and hotel cafés.
  - Restaurants: Coffee is offered on menus, often as an after-meal beverage.
  - Cafés: Wholesale coffee is provided to independent or chain coffee shops for brewing and resale. Coffee may also be roasted at cafés before brewing, and roasted coffee may also be sold directly to consumers.
- Vending
  - Hot Coffee Vending Machines: Serve fresh brewed coffee in locations like offices and public spaces, offering quick, convenient access to various coffee drinks.
  - Coffee Bean/Pod Vending: Distribute packaged coffee beans or pods in vending machines for retail or office environments, allowing consumers to purchase coffee for home use.
- Retail
  - E-commerce: coffee products are sold and distributed through online platforms.
  - Grocery and Supermarkets: Coffee is sold on store shelves, ranging from local grocers to big-box retailers
  - Specialty Stores: Often organic or artisanal coffee, sold in health food stores, boutique shops or other places.
- Direct-to-Consumer: roasters sell coffee directly to consumers, often through online platforms or subscription services.

5.4.2.2 Distribution data

For a comprehensive coffee 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 PEFCR Feed Annex VI. 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 Comission, 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 Comission, 2021):

- Energy consumption at warehouses: 30 kWh/m²·year for ambient storage and 40 kWh/m³·year for chilled storage.
- Energy consumption at retail: 400 kWh/m² per year for general building energy consumption, with additional requirements of 1,900 kWh/m² per year for chilled storage and 2,700 kWh/m² per year for frozen storage.

Loss rates during distribution

Losses should be based on secondary data from generic PEF (European Comission, 2021):

- 1% loss during distribution

5.5 Consumer packaging

If the scope of the EF study is comparative on the product level, then the amount of packaging material used shall be primary data. In all other cases, the amount of packaging material should be based on primary data but if unavailable, literature data or well-justified estimates should be used. In case of literature data/estimates, the selected packaging shall be appropriate for the analysed coffee type.

When considering recycled material in packaging, only post-consumer recycled material shall be considered and not pre-consumer recycled material or materials resulting from process inefficiencies. When modelling packaging, recycled content shall only be included when applicable (e.g. glass and aluminium for direct food contact; paper and cardboard for secondary or tertiary packaging if permitted).

The following packaging types are commonly used:

- **Primary coffee packaging types** typically include pouches, glass jars, tin cans and capsules. Pouches, for example, can be crafted from diverse materials such as PET (Polyethylene Terephthalate), LDPE (Low-Density Polyethylene), PP (Polypropylene), and aluminium and paper. Similarly, coffee capsules can be produced from a variety of materials, including aluminium and bioplastics.

- In primary coffee packaging, **lamination** is typically used for a combination of materials. The lamination process often involves combining more than two layers of materials and may use either water-based or solvent-based adhesives. Lamination can occur in a single operation or as a sequential process—such as adding an additional layer to a pre-existing two-layered material. Given the complexity and variety of lamination techniques, primary data from suppliers should be searched for, as available secondary datasets are currently limited.

- **Secondary packaging** typically includes cardboard boxes, while **tertiary packaging** comprises wood pallets and shrink wrap.

Appendix I provides a (non-exhaustive) list of recommended datasets for modelling consumer packaging. These may be used, unless more appropriate region-specific datasets are available.

The following requirements are applicable specifically for bioplastics/biomaterials:

- In the production/life cycle of bioplastics no mass allocation shall be applied.

Losses/inefficiencies/waste from production shall not be substituted as energy credit somewhere in the life cycle).

The transport from packaging materials to the filler location shall be included. The distance and transport mode should be based on primary data. When primary data are not available, generic PEF defaults shall be used:

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

The preparation and consumption of coffee involve a variety of methods, equipment, and consumables, each contributing to the environmental impact across its lifecycle. This section addresses the use phase of coffee preparation, focusing on defining the scope, identifying critical inputs and outputs, and addressing energy consumption, water use, and brewing equipment. It also extends to the production phase of coffee machines, providing insights into raw materials, transport, and their role in environmental assessments.

5.6.1 Beverage preparation

5.6.1.1 Inputs and outputs for the use stage

The data required to model coffee preparation includes several key aspects:

- Energy used for brewing by various methods[12]
- Quantity of water required
- Amount of coffee grounds used
- Type of coffee brewing equipment, material quantities and its lifespan
- Quantities of consumables such as filters and coffee pods.

[12] In many brewing processes, bean grinding and mixing are often carried out using separate machines. It is important to note that the energy consumption of these machines should also be accounted for when evaluating overall energy usage.

Additional ingredients such as milk and sugar shall not be included in the scope of the coffee EF study adhering to these guidelines. If the LCA practitioner wants to assess the impact of milk and/or sugar, the practitioner may only include it as a sensitivity assessment.

Additionally, manufacture of spoons, reusable cups, and dishwasher are excluded. Washing of cups may be included but only in specific cases and depending upon the goal & scope of the study (also see Figure 2).

When it comes to data sources, if the goal and scope do not specifically focus on nor depend heavily on the brewing phase, default values for brewing should be included. For instance, if the goal is to make a cradle-to-grave claim, incorporating generalized brewing data are appropriate. When using data from external sources, such as literature, a transparent explanation detailing how the data was measured and validated shall be given. This ensures clarity and credibility in the assessment process.

The next sections describe how the brewing phase should be modelled. In addition, appendix IV presents default preparation methods for Moka, Espresso and traditional Espresso in case a more specific modelling is in scope of the study.

Energy consumption for coffee brewing

As detailed in Table 13, primary data should be used for energy consumption in brewing. If no primary data are available, secondary data may be used. Default data which should be used for energy consumption in brewing when no primary data are available, is provided in Table 13. Please ensure that the assessment includes not only the coffee-making process but also the baseload and standby modes.

For vending machines EVA EMP protocol, and DIN 18873-2 may be used to define the energy consumption.

Table 13: Default values for energy consumption for coffee brewing in case no primary data are available.

Coffee Machine Type	Electrical energy use per 100ml (kWh)
Drip (pre ground)	0.022
Mocha Pot	0.01224
Bean To Cup	0.0174

Energy use can be modelled based on Ecoinvent dataset: Electricity, low voltage {country}| market for electricity, low voltage | Cut-off, S. Ecoinvent provides electricity datasets for a total of 139 countries listed in Table 14 below.

Table 14: List of countries available for the Ecoinvent electricity datasets.

Africa	Asia	Europe	Americas	Oceania
Angola, Benin, Botswana, Democratic Republic of the Congo, Republic of the Congo, Cote d'Ivoire, Cameroon, Algeria, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Libya, Morocco, Mozambique, Namibia, Niger,	United Arab Emirates, Armenia, Azerbaijan, Bangladesh, Bahrain, Brunei, China, Cyprus, Georgia, Hong Kong, Indonesia, India, Iraq, Iran, Japan, Jordan, Kyrgyzstan, Cambodia, North Korea, South Korea, Kuwait, Kazakhstan, Lebanon, Sri Lanka, Myanmar, Mongolia, Malaysia, Nepal, Oman,	Albania, Austria, Bosnia and Herzegovina, Belgium, Bulgaria, Belarus, Switzerland, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, United Kingdom, Gibraltar, Greece, Croatia, Hungary, Ireland, Iceland, Italy, Lithuania, Luxembourg,	Canada, Costa Rica, Cuba, Curacao, Dominican Republic, Guatemala, Honduras, Haiti, Jamaica, Mexico, Nicaragua, Panama, Puerto Rico, El Salvador, United States,	Australia, New Zealand

Nigeria, Sudan, Senegal, South Sudan, Togo, Tanzania, Tunisia, South Africa, Zambia, Zimbabwe	Philippines, Pakistan, Qatar, Saudi Arabia, Singapore, Syria, Thailand, Tajikistan, Turkmenistan, Turkey, Taiwan, Uzbekistan, Vietnam, Yemen	Latvia, Moldova, Montenegro, North Macedonia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Russia, Sweden, Slovenia, Slovakia, Ukraine, Kosovo	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Peru, Paraguay, Uruguay, Venezuela	

Coffee grounds
As detailed in Table 8 primary data shall be utilized to determine the quantity of coffee grounds based on the serving size specified on the packaging.

Water use
As detailed in Table 8, primary data shall be used for water consumption based on serving size specified on the packaging.

It is important to define the minimum amount of water required for coffee preparation, while accounting for potential losses, such as heating more water than necessary. A distinction should be made between vending machines & portioned systems, which generally experience no water losses, and home use, where consumer behaviour significantly impacts water usage. Factors such as the number of cups prepared at a time can also influence water consumption and should be addressed in the functional unit to ensure accurate assessments and comparisons.

Loss rates during use

Losses should be based on secondary data from generic PEF (European Comission, 2021): 5% at the consumer stage.

To accurately reflect post-preparation losses in the life cycle assessment (LCA), it is important to include not only the coffee product itself but also the water and energy used for heating. This approach is based on a conservative assumption that some losses occur after the beverage has been prepared, ensuring a more comprehensive and realistic evaluation of the environmental impacts associated with coffee consumption.

For multi-serve systems, losses shall be accounted. For single-serve systems, losses may be omitted but shall be considered if known.

Brewing equipment

As mentioned in Table 8, a default value may be used for the lifespan of the brewing equipment (coffee machine): 5 years. This would depend on the maintenance of the machine, the number of uses etc.

Significant maintenance activities, such as monthly descaling, and frequent replacement of equipment parts should be considered if their impact is anticipated to exceed the cut-off boundary over the equipment's lifetime. This can be evaluated or verified through mass or energy balance analysis.

Consumables
Default quantities of consumables, which may be used when no primary data are available, are presented in below in Table 15.

Please note, if allocation is needed, the default number of coffee cups prepared per filter use is two. If primary data are available, it should preferably be used.

Table 15: Default quantities of consumables.

Material	Number of uses	Quantity (g)	Source
Unbleached paper	1	1.6	https://www.biopak.com/en-de/

Material	Number of uses	Quantity (g)	Source
Bleached paper	1	2	https://www.biopak.com/en-de/
Metal (round filter)	1000	10	https://www.amazon.com/Coffee-Filter-Stainless-Reusable-AeroPress/dp/B07D7NYMS9
Metal (cone filter)	1000	264	https://www.amazon.com/Cafe-Crush-Club-Stainless-Measuring/dp/B09CMTH8JW?th=1
Cloth (cotton)	100-300	9	Cotton coffee filter
Cloth (mesh)	100-300	20	Mesh coffee filter

5.6.2 Coffee machine production

5.6.2.1 Coffee machine data

Modelling the production of coffee machines involves considerations related to raw materials, including their types, quantities (bill of materials), and sources. Transportation of these materials to the assembly location is also a key aspect. However, the assembly process and packaging may be ignored in EF studies as they often have insignificant impact on the overall life cycle of the product.

Raw materials

As mentioned in Table 8, raw materials quantities may be used as default values (detailed in Table 16), unless primary data are available.

At least the basic forming and shaping processes of raw materials shall be included, such as plastic blowing or steel rolling.

Table 16 below provides data on the quantities of raw materials required to produce various coffee machines. This is not an exhaustive table, and it only focuses on equipment available for home consumption. Data for vending machines or equipment used in HoReCa are not included here.

Table 16: Quantities of raw materials for various coffee machine types (Source: Material provided by the ECF).

Material	Kettle	Drip Filter	Coffee Capsules	Espresso Machine
ABS (Acrylonitrile Butadiene Styrene)			55.0%	26.0%
Aluminium		5.7%	10.0%	
Brass	3.0%			
Copper	1.0%	1.2%	11.0%	
Electric components			2.4%	
Electronic		3.0%		3.1%

Material	Kettle	Drip Filter	Coffee Capsules	Espresso Machine
Ferrous		4.3%		
Glass fibre		11.4%		
Misc. (cables+motors)		0.1%		17.8%
Natural Rubber	5.0%			
Nickel-chromium alloys	2.0%			
Nonferrous		0.4%		0.2%
PA66 (Polyamide 66 (Nylon)				0.4%
PBT (Polybutylene Terephthalate)				1.1%
PC (Polycarbonate)		0.4%		
PEI (Polyetherimide)				0.2%
Phenolic	3.0%			
Plastic misc.				6.5%
PP (Polypropylene)	77.0%	51.8%		17.1%
POM (Polyoxymethylene (Acetal))				8.0%
PPE+PS (Polyphenylene Ether + Polystyrene)				0.8%
PPS (Polyphenylene Sulphide)		1.6%		
PVC (Polyvinyl Chloride)		1.2%		
Rubber		0.8%	0.8%	1.0%
SAN (Styrene Acrylonitrile)				2.6%
SEBS (Styrene-Ethylene-Butylene-Styrene)				1.8%
Silicone				0.2%
Stainless steel	8.0%	18.0%		1.4%
Steel			12.0%	11.7%
Zamak			6.9%	

Cup production

Cups are out of scope for most coffee EF studies because they are product independent, except for studies focusing on coffee from vending machines; in that case, they shall be included. Table 17 below provides suggestions for material amounts which may be used to model cup production if no primary data are known, presuming one-way cups are most occurring. However, primary data shall aways be preferred over these default values, since they are very generic.

Table 17: Cup production data (Source: Material provided by the ECF).

Cup type	Quantity
Cardboard cup	• 5 g carton/cup • 0.5 g LDPE/cup • Cup lid (must be included for the on-the-go option): 4 g PS/cup
Plastic cup	• 3 g PS/cup • Cup lid (must be included for the on-the-go option): 4 g PS/cup

Coffee machine maintenance

When conducting technology-specific LCAs focused on individual coffee machine models or types, descaling shall be included as part of the system boundary if it is determined to be a significant contributor to environmental impacts over the product's life span. Descaling involves the use of cleaning agents and water, and depending on the frequency and method used, it may influence energy use, chemical consumption, and waste generation.

However, in the context of general LCAs on coffee production and consumption systems—where the primary focus lies on the coffee value chain (e.g., cultivation, processing, packaging, brewing, and waste)—the impact of descaling may be relatively negligible. Therefore, it is typically considered non-essential and may be excluded from the analysis unless evidence suggests it has a meaningful influence on the overall results.

To give an example, in Switzerland, the commonly used descaling product is from the Durgol brand, containing a 15% sulfamic acid solution. Descaling is recommended after every 500 cups of coffee prepared.

5.7 End-of-Life (EoL)

This section examines the destination and treatment of various elements leaving the coffee lifecycle after the use phase, being primarily consumer packaging, coffee machines, and spent coffee grounds.

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, generic PEF defaults should be used:

(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

(Based on generic PEF)

This section provides a definition of the factors used in the circular footprint formula. Sections 5.7.3.1 & 5.7.3.2 below describe in more detail how to apply the formula, breaking it down into tangible pieces, and explaining what data can be used.

Table 18: The equations of the circular footprint formula (CFF).

Element	Formula
Material	$(1-R_1)\,E_v + R_1 \times (AE_{recycled} + (1-A)E_v \times Q_{sin}/Q_p) + (1-A)R_2 \times (E_{recyclingEoL} - E^*_v \times Q_{sout}/Q_p)$
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	$(1-R_2-R_3) \times E_D$

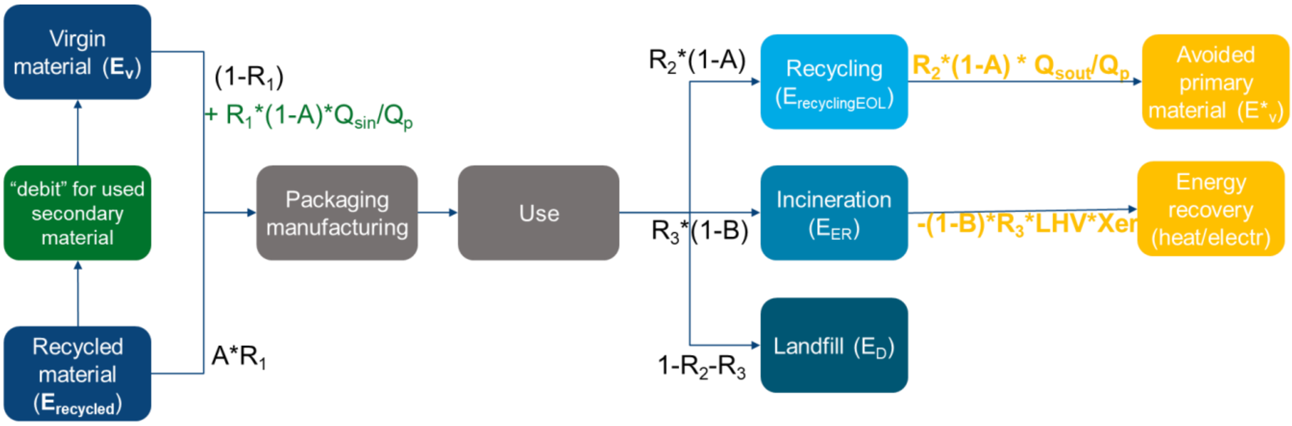

Figure 5 schematic overview of the circular footprint formula (CFF). Please note that packaging manufacturing (e.g. blow moulding, metal sheet rolling, can making) is not part of the CFF and has to be added separately.

Table 19: 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 6. 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.

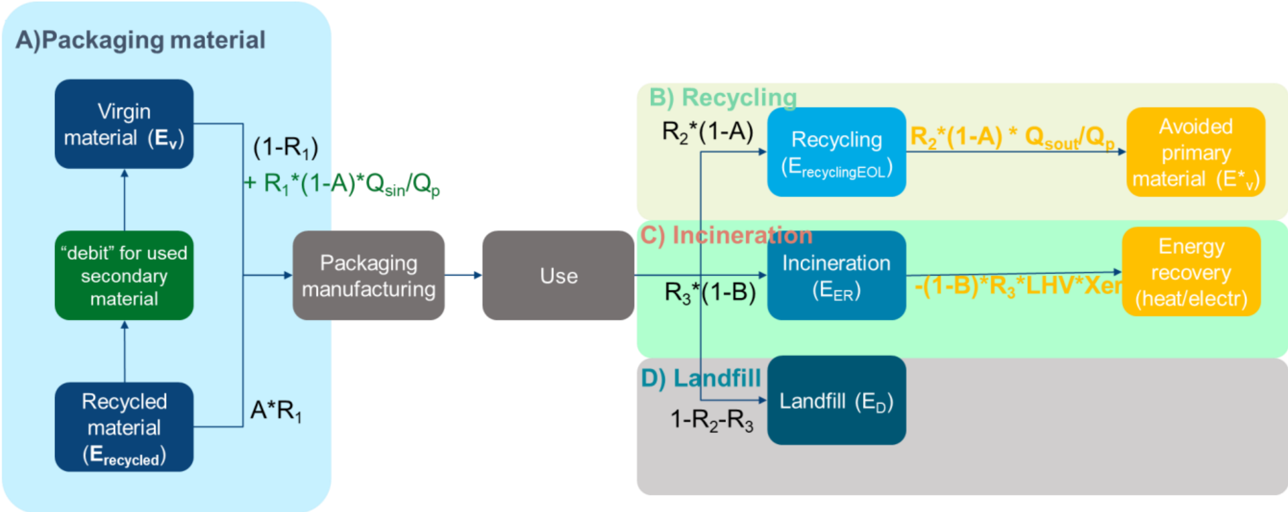

Figure 6 schematic overview of the CFF, indicating the 4 different components: A) packaging materials, B) recycling, C) incineration and D) landfill

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*[13]

$X_{er,heat}$ *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:

E_D *Specific emissions and resources consumed arising from disposal of waste material at the EoL of the analysed product, without energy recovery (landfill)*

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

Table 20: 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

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

5.7.4 Coffee machine end-of-life

For the purpose of assessing the end-of-life phase, coffee machines are treated as part of the general waste stream in compliance with Waste Electrical and Electronic Equipment (WEEE) regulations. The EoL coffee machines may be modelled via two approaches:

1) Default approach using secondary data. As the end-of-life treatment of the machine often has relatively small contribution to the total impact of coffee's life cycle, a rough estimate of the end-of-life impacts are justified.

2) A more detailed evaluation, using primary data, may be used as well. This approach is particularly relevant, and therefore should be considered, for technology-specific coffee EF studies, where the unique characteristics and end-of-life scenarios of each component can be effectively considered. This approach is further explained in Appendix II.

In the default approach, no recycling benefits are assumed; the machine's components should be directed to either landfill or incineration, utilizing a cut-off approach. This simplification aims to reduce the modelling burdens for the end-of-life phase.

Some form of disassembly should be considered. The following dataset from Ecoinvent may be used as a proxy:

- *Waste electric and electronic equipment {GLO}| treatment of waste electric and electronic equipment, shredding | Cut-off.*

Once the machine is disassembled, the resulting waste should be assigned to one or a mix of the following disposal pathways. Country specific datasets may be used if justified (e.g. an EF analysis with a specific national scope). Disposal pathways include:

- Municipal solid waste: landfill for example,
    - *Municipal solid waste {RoW}| treatment of municipal solid waste, sanitary landfill | Cut-off*
    - *Municipal solid waste (waste scenario) {Europe without Switzerland} | Treatment of municipal solid waste, landfill | Cut-off*
- Municipal solid waste: incineration for example,
    - *Municipal solid waste {RoW}| treatment of municipal solid waste, incineration | Cut-off*
    - *Municipal solid waste (waste scenario) {Europe without Switzerland}| Treatment of municipal solid waste, incineration | Cut-off*

5.7.5 Spent coffee ground end-of-life

Spent coffee grounds (SCG) are a significant by-product of the coffee consumption process, generated in large volumes globally by both industrial operations and everyday consumer use. Given their rich organic composition, SCG present valuable opportunities for resource recovery at their end-of-life, rather than being disposed of as waste.

A variety of end-of-life treatment options are available for SCG, including landfilling, incineration (with or without energy recovery), composting, and anaerobic digestion. Each of these pathways has distinct environmental implications, depending on the extent to which energy or material value is recovered from the SCG, and what conventional products or processes are displaced as a result.

To accurately assess and compare these impacts, the CFF will be applied for SCG.

The table below provides the CFF parameters to apply to SCG. For all regions a composting rate of 5% is assumed. The split of the remaining 95% into energy recovery and landfill is based on the average distribution of municipal solid waste destinations in that region. For Europe this is based on

2021 Eurostat data (Eurostat, 2021), for other regions on the 2024 UNEP (UNEP, 2024). Global Waste Management Outlook.

Table 21: Default CFF parameters to use for spent coffee grounds, at manufacturing stage.

Region	A	R1	R2	R3	1-R2-R3	(Qsin/Qp)	(Qsout/Qp)
Europe	0.2	0	0	0.05	0.48	0.47	N.A.
South America	0.2	0	0	0.05	0	0.95	N.A.
East and South-East Asia	0.2	0	0	0.05	0.31	0.64	N.A.
North America	0.2	0	0	0.05	0.15	0.80	N.A.
Rest of the world	0.2	0	0	0.05	0.03	0.92	N.A.

Table 22: Default CFF parameters to use for spent coffee grounds, at postconsumer stage.

Region	A	R1	R2	R3	1-R2-R3	(Qsin/Qp)	(Qsout/Qp)
Europe	0.2	0	0	0.45	0.55	N.A.	1
South America	0.2	0	0	0	1	N.A.	1

For the landfilled SCG the split of (unmanaged/unsanitary) landfill and sanitary landfill are defined in Table 23. Different background datasets should be used for each landfill scenario.

Table 23: Default rates for sanitary and unsanitary landfill per region.

Region	Sanitary landfill	Unsanitary landfill
Europe	0.47	0
South America	0.33	0.62
East and South-East Asia	0.26	0.38
North America	0.78	0.02
Rest of the world	0.35	0.57

Composting

When SCG is composted, it is important to determine what product or material is being displaced by the resulting compost. The substituted material could be:

- Compost made from other organic materials
- A synthetic fertilizer
- An organic fertilizer

It is essential to account for the nutrient content of compost when determining its substitution potential for inorganic fertilizer. Due to the significantly lower nutrient concentration in compost, a mass-to-mass substitution (e.g., 1 kg compost = 1 kg fertilizer) is not appropriate. According to the default Ecoinvent dataset, compost contains 13.63 g of nitrogen per kg, which corresponds to a substitution of approximately 0.1363 kg of “inorganic fertilizer, as N”. When assessed per unit of biowaste input, this equates to 3.59 g N per kg of biowaste. Table 24 contains an overview of the nutrient content of compost.

Table 24: Nutrient content of compost (Ecoinvent, 2024).

Nutrient	g per kg DM compost	g per kg FM compost	g per kg FM biogenic waste
Calcium (total)	50.41	26.57	13.28
Magnesium (total)	5.25	2.77	1.38
Nitrogen (total)	13.63	7.18	3.59
Phosphate (total)	6.32	3.33	1.67
Potassium (total)	12	6.32	3.16
Sulphur (total)	1.91	1.01	0.5

This assumption directly influences the material component of the CFF. In this context:

- There is **no recycled content** of SCG in the coffee itself (i.e., the original product). Therefore, **R_1 = 0** in the CFF formula.
- A distinction must be made between **Ev** (the environmental impact of SCG as a material) and **E*v** (the environmental impact of the fertilizer or compost being replaced).

As a result, the material section of the CFF is simplified significantly and reduces to the following expression:

SCG CFF material formula	$E_v+(0.5 \times R_2)(E_{composting}-E^*_v)$

Where:

- E_v = Environmental impact of SCG
- $E_{composting}$ = Environmental impact of the composting process
- E^*_v = Environmental impact of the substituted fertilizer

Anaerobic Digestion

In cases where **anaerobic digestion** is selected as the end-of-life option, the environmental impact term associated with recycling at end-of-life $E_{recycling}$ is replaced by $E_{anaerobic\ digestion}$.

Energy and Disposal

The **energy recovery** and **final disposal** components of the CFF are handled in the same manner as for packaging materials. No changes are needed to the methodology except for the inclusion of parameters specific to SCG, such as the **Lower Heating Value (LHV)**, to estimate the energy recovery potential accurately.

Table 25 provides an overview of datasets that should be used to model end-of-life of SCG, unless more specific datasets are applicable.

Table 25: Background datasets for modelling End-of-life of spent coffee grounds (Ecoinvent 3.10).

Waste destination	Background datasets

Landfill	Waste paperboard {RoW}| treatment of waste paperboard, sanitary landfill[14]
Incineration	Biowaste {GLO}| treatment of biowaste, municipal incineration
Unsanitary landfill	Waste paperboard {GLO}| treatment of waste paperboard, unsanitary landfill, moist infiltration class (300mm)[12]
Composting	Biowaste {RoW}| treatment of biowaste, industrial composting
Fertilizer substituted by compost	Inorganic nitrogen fertiliser, as N {RoW}| nutrient supply from NPK (15-15-15) fertiliser

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.

[14] No dataset available for biowaste, assuming paper has similar impact as SCGs because of similar carbon content (~50%)

6. Recommendations for improvement

During the development of these guidelines, multiple topics were identified as relevant in the next phase of development. The main recommendations for improvement are to:

- Execute supporting studies in order to substantiate the most relevant impact categories, life cycle stages and elementary flows as identified in this document.
- Develop more default values and recommendations for default datasets for the cultivation phase, especially with regards to pesticide use, water use and land use change (as limited primary information is available on these parameters).
- Ensure alignment among carbon footprint experts on the methodology for land use change accounting (equal or linear amortization).
- Include more (specific) guidance on the inclusion of carbon removals, not necessarily only limited to shade trees (but also including removal by soils, for example), based on the publication of the updated PEF guidance and the GHG Protocol for Land Sector and Removals guidance.
- Develop default energy consumption values in the use phase (beverage preparation for HoReCa and other preparation methods).
- Develop more specific and up-to-date data for end-of-life scenarios (R1, R2, R3 of PEFCR Annex C), in consultation with the European Commission for packaging materials (plastic).

For additional recommendations and feedback please contact:

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Appendix I – Background datasets for consumer packaging

Table 26: Background datasets which should be used in modelling consumer packaging.

Packaging type		Background dataset (Ecoinvent)[15]	Material converting process
Primary packaging	Pouch (plastic, aluminium, paper)	• Polyethylene terephthalate, granulate, amorphous {RoW}| polyethylene terephthalate production, granulate, amorphous | Cut-off • Polyethylene, low density, granulate {RoW}| polyethylene production, low density, granulate | Cut-off • Polypropylene, granulate {RoW}| polypropylene production, granulate | Cut-off • Aluminium, primary, ingot {RoW}| market for aluminium, primary, ingot | Cut-off • Kraft paper {RoW}| market for kraft paper | Cut-off	• Extrusion, plastic film {RoW}| extrusion, plastic film | Cut-off • Sheet rolling, aluminium {RoW}| sheet rolling, aluminium | Cut-off
	Capsule	• Aluminium, primary, ingot {RoW}| market for aluminium, primary, ingot | Cut-off • Polypropylene, granulate {RoW}| polypropylene production, granulate | Cut-off • Polylactic acid, granulate {GLO}| polylactic acid production, granulate | Cut-off[16]	• Sheet rolling, aluminium {RoW}| sheet rolling, aluminium | Cut-off • Injection moulding {RoW}| injection moulding | Cut-off
	Glass jar	• Packaging glass, white {RoW}| packaging glass production, white | Cut-off (green and brown glass also available)	Not applicable
	Glass jar lid	• Polyethylene terephthalate, granulate, amorphous {RoW}| polyethylene terephthalate production, granulate, amorphous | Cut-off • Polypropylene, granulate {RoW}| polypropylene production, granulate | Cut-off	Injection moulding {RoW}| injection moulding | Cut-off
	Tin cans	• Tin plated chromium steel sheet, 2 mm {RoW}| tin plated chromium steel sheet production, 2 mm | Cut-off	Sheet rolling, steel {RoW}| sheet rolling, steel | Cut-off + Deep drawing, steel, 3500 kN press, automode {RoW}| deep drawing, steel, 3500 kN press, automode | Cut-off
	Plastic	• Polypropylene, granulate {RoW}| polypropylene production, granulate | Cut-off	• Extrusion, plastic film {RoW}| extrusion, plastic film | Cut-off

[15] Additional datasets, such as primary datasets or producers' LCAs, may be utilized provided they adhere to these guidelines, align with generic PEF requirements, and meet or exceed the quality standards of the default datasets from Ecoinvent.
[16] When evaluating bioplastic, ensure that comparisons with conventional materials are conducted on an equivalent basis.

- Carbon storage in the product/soil/waste shall not be included.
- A product only partly based on bioplastic

	Labelling	• Paper, woodcontaining, supercalendered {RoW}| paper production, woodcontaining, supercalendered | Cut-off • Kraft paper {RoW}| market for kraft paper | Cut-off • Polypropylene, granulate {RoW}| polypropylene production, granulate | Cut-off	• Plastic: Extrusion, plastic film {RoW}| extrusion, plastic film | Cut-off
	Lamination	• NA	• Laminating service, foil, with acrylic binder {RoW}| laminating service, foil, with acrylic binder | Cut-off
Secondary and tertiary packaging	Cardboard	• Corrugated board box {RoW}| corrugated board box production | Cut-off	Not applicable
	Wood pallets	• EUR-flat pallet {RoW}| EUR-flat pallet production | Cut-off (Default number of reuses: 5)	Not applicable
	Shrink wrap	• Packaging film, low density polyethylene {RER}| packaging film production, low density polyethylene | Cut-off, U	Not applicable

Appendix II - Modelling specific End-of-Life pathways of coffee machines

As explained in section 5.7.3.2, the end-of-life of coffee machines may be modelled by using secondary data. A more detailed evaluation, using primary data, may be used as well and is particularly relevant (and hence should be considered) for technology-specific coffee environmental footprint studies, where the unique characteristics and end-of-life scenarios of each component can be effectively considered. In this approach, the coffee machine should be defined by its individual material streams, such as plastics, metals, and electronic components, based on how it can be disassembled. Each material stream shall then be assessed for its potential recycling, incineration, or landfill disposal.

Table 27 below gives an overview of end-of-life scenarios for various material streams which may be in the coffee machine.

Table 27: Overview of potential materials and their most occurring waste treatment scenarios.

Type of material	Materials	Waste treatment	Is CFF relevant?
Plastic	ABS, PA66, PBT, PC, PEI, Phenolic, Plastic misc., Polypropylene (PP), POM, PP, PPE+PS, PPS, PVC, SAN, SEBS	Incineration (energy recovery), Landfill	Yes for PET, ABS, PE, PMMA, PP, PS, EPS, PVC, PA (polyamide), PVDF, PPSU, and Polycarbonate (PC).
Metal	Aluminium, Brass, Copper, Ferrous, Nickel-chromium alloys, Nonferrous, Stainless steel, Steel, Zamak, Titanium	Recycling, Landfill, Incineration	Yes for Steel, Aluminium, Copper, Copper alloys, Copper telluride, Lead, Antimony, Cadmium, and Ferrite.
Electronic Components	Circuit boards, sensors, electric wiring, control boards, LCD screens	E-waste recycling (specialized facilities), Landfill (as hazardous waste)	NO
Composite	Glass fibre, Carbon fibre	Landfill, Incineration	Yes for glass fibre
Rubber	Natural Rubber (NR), Rubber, Silicone	Landfill, Incineration	NO
Glass	Borosilicate glass (carafes, water reservoirs)	Recycling, Landfill, Incineration	Yes
Ceramic	Ceramic burrs (grinders), ceramic coatings	Landfill/Recycling	NO
Insulating Materials	Insulation foams, silicone rubber (gaskets, seals)	Incineration, Landfill	Yes (for stone wool)

Table 28 below gives an overview of secondary datasets which should be used in specific coffee machine end-of-life modelling, unless primary data of higher data quality or higher relevance (e.g. in case of a very specific plastic type) is available.

Table 28: Secondary datasets for modelling specific waste streams in coffee machine end-of-life.

Type of material	Recycling	Landfill	Incineration
Plastic	PET: Waste polyethylene, for recycling, sorted {Europe without Switzerland}| treatment of waste polyethylene, for recycling, unsorted, sorting | Cut-off	PET: Waste polyethylene terephthalate {CH}| treatment of waste polyethylene terephthalate, sanitary landfill | Cut-off PP: Waste polypropylene {RoW}| treatment of waste polypropylene, sanitary landfill | Cut-off PVC: Waste polyvinylchloride {Europe without Switzerland}| treatment of waste polyvinylchloride, sanitary landfill | Cut-off Mix: Waste plastic, mixture {RoW}| treatment of waste plastic, mixture, sanitary landfill | Cut-off	PET: Waste polyethylene terephthalate {Europe without Switzerland}| treatment of waste polyethylene terephthalate, municipal incineration | Cut-off PP: Waste polypropylene {CH}| treatment of waste polypropylene, municipal incineration | Cut-off PVC: Waste polyvinylchloride {CH}| treatment of waste polyvinylchloride, municipal incineration | Cut-off
Metal	Steel: Iron scrap, sorted, pressed {RoW}| market for iron scrap, sorted, pressed | Cut-off Alu: Aluminium, wrought alloy {RoW}| treatment of aluminium scrap, post-consumer, prepared for recycling, at remelter | Cut-off	Steel: Scrap steel {Europe without Switzerland}| treatment of scrap steel, inert material landfill | Cut-off Alu: Waste aluminium {RoW}| treatment of waste aluminium, sanitary landfill | Cut-off	Steel: Scrap steel {Europe without Switzerland}| treatment of scrap steel, municipal incineration | Cut-off Alu: Scrap aluminium {Europe without Switzerland}| treatment of scrap aluminium, municipal incineration | Cut-off
Electronic Components	Circuit boards, sensors, electric wiring, control boards, LCD screens	Waste electric and electronic equipment {GLO}| treatment of waste electric and electronic equipment, shredding | Cut-off + Municipal solid waste {RoW}| treatment of municipal solid waste, sanitary landfill | Cut-off	Waste electric and electronic equipment {GLO}| treatment of waste electric and electronic equipment, shredding | Cut-off + Municipal solid waste {RoW}| treatment of municipal solid waste, incineration | Cut-off
Composite	Not applicable	Municipal solid waste {Europe without Switzerland}| market group for municipal solid waste | Cut-off OR Waste glass {GLO}| treatment of waste glass, sanitary landfill | Cut-off	Waste glass {Europe without Switzerland}| treatment of waste glass, municipal incineration | Cut-off
Rubber	Not applicable	Municipal solid waste {Europe without Switzerland}| market group for municipal solid waste | Cut-off	Waste rubber, unspecified {Europe without Switzerland}| treatment of waste rubber, unspecified, municipal incineration | Cut-off

Type of material	Recycling	Landfill	Incineration
Glass	Glass cullet, sorted {RER}| treatment of waste glass from unsorted public collection, sorting | Cut-off	Waste glass {GLO}| treatment of waste glass, sanitary landfill | Cut-off	Waste glass {Europe without Switzerland}| treatment of waste glass, municipal incineration | Cut-off
Ceramic	Not applicable	Municipal solid waste {Europe without Switzerland}| market group for municipal solid waste | Cut-off	Municipal solid waste (waste scenario) {Europe without Switzerland}| Treatment of municipal solid waste, incineration | Cut-off

Appendix III - Default Coffee and Water Quantities per Beverage Serving

Table 29: Default quantities of coffee and water per beverage serving.

Type of beverage	Description	Small black coffee	Long black coffee	Large black coffee
Instant	Self-portioned instant coffee	-	• Coffee – 1.8 g • Water – 120 ml	• Coffee – 3.6 g • Water – 240 ml
Filter	Water drips through grounds in a filter	-	• Coffee – 7 g • Water – 120 ml	• Coffee – 14 g • Water – 240 ml
Moka	Steam pressure pushes water through grounds	• Coffee – 5.5 g • Water – 43 ml	-	• Coffee – 14 g[17] • Water – 240 ml
French press	Grounds steeped in hot water, then pressed	-	• Coffee – 7 g • Water – 120 ml	• Coffee – 14 g • Water – 240 g
Espresso	Pressurized water forced through fine grounds with home machine (with or without self-portioned pods)	• Coffee – 7.5 g[17] • Water – 32 ml	-	-
Espresso traditional	Pressurized water forced through fine grounds with professional machine	• Coffee 8 g[17] • Water 20 ml	-	-
Turkish coffee	Self-portioned roast & ground Turkish coffee	• Coffee – 6 g • Water – 40 ml	-	-

[17] More details are provided in appendix IV

Appendix IV - Default data for specific coffee brewing methods

This appendix presents default preparation methods for Moka, Espresso and traditional Espresso in case a more specific modelling is in scope of the study than the more generic use cases which were defined in section 5.6.1. The basis for these tables are the currently expired PCRs for Moka coffee and espresso coffee, which were created by small working groups not representing the complete coffee sector and hence not validated by a representative group of stakeholders. Nevertheless, these values may be used as default values since no other significant reference is known by the developers of these guidelines and the presented defaults are deemed of sufficient quality as they are developed by experts.

Table 30 presents default values for Moka coffee preparation.

Table 30: Moka coffee specifications and preparation methods (The international EPD system, 2019).

Criteria/parameter	Unit	Lower limit value	Upper limit value	Parameter stage	Parameter type
Extraction pressure	[bar]	0.2	2.5	Extraction	Analytical
Extraction temperature, in cup	[°C]	70	85	Extraction	
Weight of coffee grounds	[g]	14	19	Extraction	
Extraction flow	[g/s]	1	2.5	Extraction	
Strength (soluble concentration)	[%]	2.3	4.5	Brewing chart	
Extraction (soluble yields)	[%]	22	32	Brewing chart	
Dose in one cup	[g]	35	50	Characterisation of the cup	
Persistence of the cream	[s]	N.A.	N.A.	Characterisation of the cup	Visual
Lipids	[g/100g]	0.05	0.2	Characterisation of the cup	Analytical

Table 31 below presents default values for espresso coffee preparation.

Table 31: Espresso coffee specifications and preparation methods (The international EPD system, 2018).

Criteria/parameter	Unit	Lower limit value	Upper limit value	Parameter type
Extraction pressure	bar	> 5	n.a.	Physical
Extraction flow	ml/s	0.5	3.0	
Extraction temperature, in cup	˚C	70	85	
Weight of coffee grounds	g	5	10	
Strength (soluble	%	> 3.5	n.a.	Chemical

Criteria/parameter	Unit	Lower limit value	Upper limit value	Parameter type
concentration)				
Dose in one cup	g	13	50	Physical
Persistence of the crema	s	Visual assessment of the uniformity and persistency of the crema within 120 seconds.		
Qualitative criteria	n.a.	Only beverages prepared with roast and ground coffee are suitable, excluding soluble products		

Table 32 presents default values for traditional espresso coffee preparation.

Table 32: Traditional espresso coffee specifications and preparation methods (Comitato Italiano del Caffè, (unknown)).

Criteria/parameter	Unit	Lower limit value	Upper limit value	Parameter type
Extraction pressure	bar	> 8	n.a.	Physical
Extraction flow	g/s	0.48	1.3	
Extraction temperature, in cup	˚C	90	96	
Weight of coffee grounds	g	7	9	
Dry residue (with oven-drying method) for filtered beverage	[% of TDS – total dissolved solid]	> 5	n.a.	Chemical
Dry residue (with oven-drying method) for unfiltered beverage	[% of TDS – total dissolved solid]	> 5	n.a.	
Dose in one cup	g	13	26	Physical
Cream persistence	s	Coverage must be complete and persist for at least 120 sec		
Extraction time	s	20	27	

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