EXPERTS AND SOLUTIONS IN SUSTAINABLE DEVELOPMENT
rdcenvironment.be - contact@rdcenvironment.be

CBA consumer packaging

Research on the impact of changes to consumer-portion packaging

Final report

Authors

Tom Huppertz (RDC Environment)

Simon Standaert (RDC Environment)

Anaïs Masson (RDC Environment)

Tjok Meuwissen (RDC Environment)

Mary Wilcockson (NSF)

Matthew Bown (NSF)

Contact

+32 2 420 28 23

contact@rdcenvironment.be

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Executive summary

The results of this study demonstrate that current single-use plastic packaging performs better than the alternative single-use and reusable packaging solutions tested in delivering a range of sauces, condiments and complementary foods from a societal perspective (aggregating environmental, economic and social impacts) to dine-in consumers in the European Union.

Objective of the study and methodology

The study evaluates the **environmental, economic, and social impacts** of different packaging and serving options in the HORECA (hotels, restaurants, canteens and cafés) sector. It has been carried out within the context of upcoming restrictions on use of single-use plastic packaging under Article 25 and Annex V (Row 4) of the EU Regulation on packaging and packaging waste (PPWR).

Life-cycle assessment (LCA) and cost-benefit analysis (CBA) methodologies were used to quantify and assign a monetary value to environmental, economic and social impacts across the full lifecycle.

A separate systematic analysis looked at the health, food safety, and food quality implications.

Scenarios tested

The study compares **single-use plastic packaging** - taken as the 'base case' - against two alternative packaging and serving options:

- a **single-use alternative** (like sealed paper or glass packaging, or dispensing into a single-use paper-based cup) and
- a **reusable serving solution** (dispensing into a reusable cup).

These packaging and serving options were evaluated in 16 scenarios covering:

- **four consumption locations** (canteen; restaurant; café; and hotel) and
- **four food types** (semi-viscous, specifically ketchup; creamer; preserve, specifically jam; and sugar).

In total, 47 different combinations of packaging / location / food type were modelled and assessed.

The key findings

1. **Across all scenarios modelled, single-use plastic packaging delivers the best overall outcome for society.**

   Single-use plastic packaging delivers the best overall outcome when looking at the total societal impact (combining economic, social and environmental impacts).

   In the figure below, the positive values show the additional societal cost of alternative packaging and serving options compared to single-use plastic packaging for the 31 comparisons tested.

Single-use plastic packaging therefore offers a better overall outcome for society compared to the alternative packaging options tested.

In economic terms, the estimated additional economic cost of using a reusable alternative for the four food types modelled in this study is €806m per year, while the single-use alternative would cost an additional €577m per year.

Serving from bulk packaging or dispensers needs more time and additional supporting operations (such as cleaning, training, and monitoring). While the study does not consider the coexistence of single-use and reusable systems, this could result in fewer economies of scale, less operational optimisation, and potentially higher costs.

The findings are robust across variations and uncertainties around labour costs and operation times, even when applying different labour cost assumptions (to reflect different costs in different countries) and taking account of uncertainty over service operation times relating to packaging and serving options that are not currently deployed at scale.

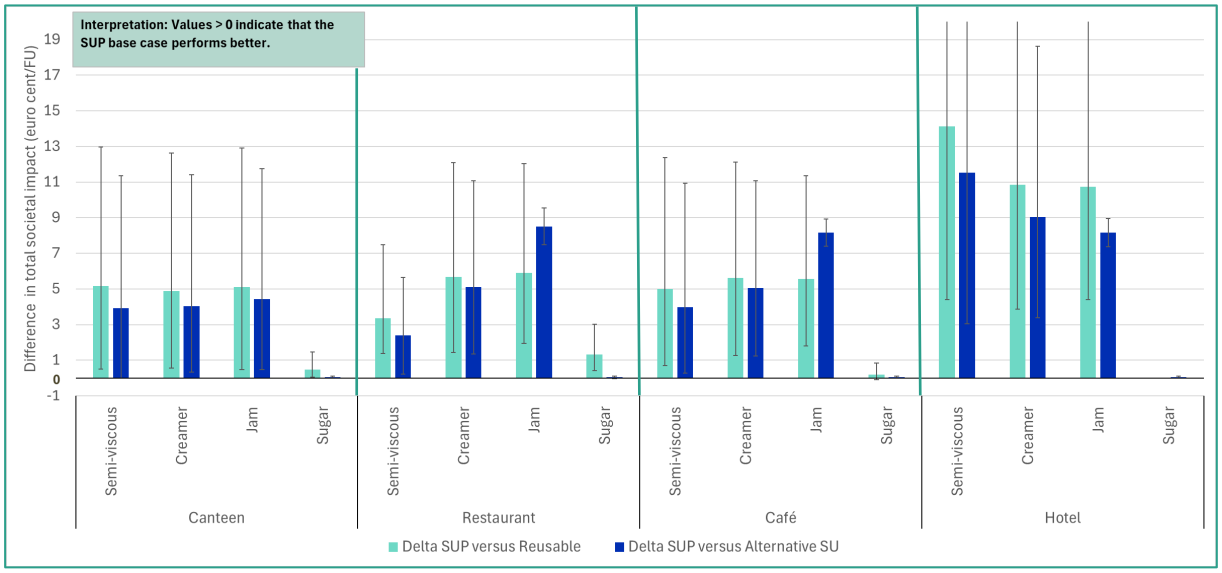


Figure 1 Difference in total societal impact between the single-use plastic base case and each of the alternatives: single-use and reusable alternative, in euro cents per functional unit *(the serving of one portion)*.[1]

Note for the figure above: Positive results indicate that the base case performs better than alternatives. Error bars represent the upper and lower bound results from sensitivity analysis.

[1] The upper bound values for delta SUP versus reusable and delta SUP versus alternative single-use are cut off for Scenarios Hotel- Semi viscous (Upper bound value Delta Reusable: 34 euro cents/FU; Upper bound value Alternative SU: 31 euro cents/FU), Hotel-Creamer (Upper bound value Reusable: 21 euro cents/FU), Hotel-Jam (Upper bound value Reusable: 20 euro cents/FU) for visibility of the graph.

2. **The alternatives perform better than the base case from an environmental perspective in 12 of the 31 modelled comparisons, but in another 12 comparisons, the base case performs better.**

   Alternative packaging and serving solutions outperform the base case from an environmental perspective in 12 of the 31 modelled comparisons. However, in another 12 out of 31 comparisons, single-use plastic packaging has a lower environmental impact than the alternatives.

   For a further seven cases, the difference is too small to make a definite statement.

   The environmental impact is mainly driven by the total weight of the packaging (including transport packaging) and the number of reuses (for the reusable alternative).

3. **Single-use plastic packaging is the best option to preserve product quality and presents the lowest risk to food safety.**

   Analysis of food quality implications shows that alternative options that involve serving from a dispenser introduce open storage risks like "skinning" on sauces, sugar clumping from moisture, and taste taints in reusable containers. These risks can potentially lead to products being discarded.

   Damage to reuseable containers, such as scratches and cracks, can trap food residues and present a microbiological and allergenic risk. Cleaning and storage operations also add risks.

   With regard to food safety, both the single-use plastic base case and alternatives packaging options within the assessment are comparatively low risk overall, but single-use plastic packaging presents the lowest risk as it is simple and efficient and requires fewer process steps for serving.

1. Introduction

1.1 Context

CPIC is the coalition of actors involved in the supply of consumer portions in the EU, from the packaging, food production and HoReCa sectors (Hotel, Restaurant, Café and Catering).

The Packaging and Packaging Waste Regulation (PPWR) entered into force on 11 February 2025. This regulation mandates a restriction of the use of single-use plastics from 2030 onwards for certain packaging formats. One such packaging format covered by this restriction is "single-use plastic packaging in the HORECA sector, containing individual portions or servings, used for condiments, preserves, sauces, coffee creamer, sugar and seasoning"[2].

The application of Article 25 of the PPWR would require a shift to alternatives to single use plastic consumer portion packaging, such as single-use sealed paper or glass individual formats or dispensing solutions with paper or reusable cups.

CPIC members wish to investigate the environmental, economic, and social impacts that might arise from this restriction, as well as the potential food safety, food quality and health issues associated.

1.2 Goal of the study

The objective is to compare the environmental, economic, and social impacts of single-use plastic consumer portion packaging with alternative packaging systems, used in dine-in HoReCa settings (Hotel, Restaurant, Café and Catering) in the European Union.

To achieve this goal, the study performs a comparative environmental, economic, and social cost-benefit analysis (CBA) of the single use plastic consumer portion packaging and alternative reusable or paper/glass-based solutions for four different food types (semi viscous (sauce), creamer, jam and sugar) across four consumption locations: canteens, restaurants, cafés and hotels. In addition, the study assesses the residual health and food safety risks as well as food quality implications associated with each packaging solution in each scenario tested.

The study models for each scenario, the differences in impact of two alternatives compared to the sealed, single use plastic (SUP) consumer portion packaging, hereafter referred to as the *SUP base case*. The two alternative serving systems modelled are:

- **An alternative single-use (SU) option,** that is paper-based or made of glass, which may be served from a dispenser/bulk packaging, or arrives in a sealed consumer-portion packaging.
- **A reusable serving option**, a reusable cup that is always served from a dispenser/ bulk packaging. For sugar, sugar cubes are served directly from a sugar bowl (no reusable cup required).

[2] Annex V of Regulation (EU) 2025/40 of the European Parliament and of the Council of 19 December 2024 on packaging and packaging waste.

Note: Restriction applied except when packaging is provided with a take-away food, or when required to ensure safety and hygiene such as in hospitals, clinics or nursing homes.

1.3 General approach: quantify environmental, economic and social differences, score the potential health, food quality and food safety risks

1.3.1 Cost-benefit analysis covering economic, environmental and social impacts

This study combines the **3 pillars of sustainability**:

- An **environmental Life Cycle Assessment** (LCA) following ISO 14040 and ISO 14044 guidelines. The results of the life cycle assessment have been monetised, valuing all environmental impacts in terms of costs and benefits for the society, in euros;
- An **economic assessment** of economic costs and benefits along the value chain, following the same scope as the LCA;
- A **social assessment** of the value of job creation for the society and the burden of client time (in euros), following the same scope as the LCA.

The sum of the three pillars forms a "cost-benefit analysis" taking economic costs as well as environmental and social externalities into account. The single score in monetary units, hereafter referred to as the "societal impact", facilitates the appropriation of results and enables multi-criteria decision-making.

The methodology proposed by RDC Environment is based on proven principles:

- Principles of cost-benefit analysis and monetary valuation of impacts are those of the OECD guidelines[3] and ISO 14007 and ISO 14008 standards;
- Life cycle analysis (see section 3.3) is based on ISO 14040/44 standards and the ILCD Handbook;
- Monetary valuation of social and environmental impacts is based on scientific publications and technical reports (explained further in section 3 – Methodology of the three pillars).

1.3.2 Impact quantification in an optimised setting

In this study, we quantify the impact of different packaging solutions, focusing on their technical characteristics in an optimised setting. We model situations where compared packaging solutions are mature, established and optimised. This means that value chains are optimised and investments can be amortised over their entire lifespan, marginal modifications in labour requirements translate directly into variations in labour costs, the same applies to capital use (machines) and space use.

This approach allows to focus on intrinsic differences in a comparable set-up, as the alternatives are not always deployed at scale, and the base case is the existing optimised solution. This approach allows for a fair and robust comparison between packaging solutions.

In order to tackle parameters that are uncertain because certain operations do not exist at scale today, we define ranges using best available information and assess the influence of the variation of these parameters on the conclusions.

[3] https://www.oecd.org/en/publications/cost-benefit-analysis-and-the-environment_9789264085169-en.html

For reusable serving options, this study assumes washing and drying occurs on-site. An alternative would be off-site washing at a dedicated facility, typically more resource-efficient due to optimised water and electricity use, but requiring additional transport logistics. The net societal impact of this alternative depends on parameters such as transport distance, fuel type, and facility scale, and falls outside the scope of this study.

1.3.3 Assessment based on an average EU setting and tested for variation in key parameters

The study is designed to reflect general conditions within the EU. As such, the results are based on average input data and harmonised assumptions. However, the following considerations were incorporated into the study design in order to account for a variety of situations:

- 16 different scenarios are modelled, representing different HoReCa locations and food types and alternative packaging solutions (each scenario consists of three packaging options).
- Ranges are defined for heterogenous parameters, and sensitivity analysis is performed to determine whether the conclusions remain valid across the range of parameters values.

1.3.4 Systematic assessment of food safety, quality, operational and health risks

1.3.4.1 Scope

The predominant focus of the assessment is the food safety and health impacts within the HORECA setting for the retail, serving and consumption of the 4 product types.

1.3.4.2 Food Safety

The food safety and associated assessments were completed by NSF food safety/risk consultants based on their training, qualification and experience of practical work in a number of food operation settings globally, including catering/restaurant, and food manufacturing. This is a standard approach within the food industry, that food safety risk assessment is a manual process, carried out by individuals with appropriate training and expertise.

Food safety impacts were considered using a HACCP (Hazard Analysis and Critical Controls Points) risk assessment and management approach. This is an internationally recognised methodology for food safety management and is a legal requirement for food businesses in many countries of the world. (see Food and Agriculture Organization of the United Nations, World Health Organisation - Codex Alimentarius International Food Standards – General Principles of Food Hygiene (CXC 1-1969) 2023).

The HACCP methodology includes construction of a process flow diagram, assessing the hazards at each step (microbiological, chemical, physical and allergenic hazards), assessing the risk level of the hazards and the controls required to reduce them to an acceptable level. Example HACCP assessments for some key scenarios can be found in the appendices.

Food safety management should also consider the risks of food fraud and food threat, as well as the prevalence of management commitment and food safety culture.

1.3.4.3 Operational

Operational impacts were considered including complexity of processes for each scenario, number of process steps and controls required to manage the risks at each step, required procedures and monitoring, as well as training and record-keeping (which are all key requirements of a HACCP plan). This in turn impacts on requirement for staff numbers, time and level of training and supervision. Requirements for equipment and space were also considered, for example to implement cleaning of reusable containers.

1.3.4.4 Health

Health & nutrition impacts were considered in terms of the inherent salt, fat, and sugar content of the product – e.g. jam is high in sugar, around 60% sugar – and the packaging / serving format – for example if this gives an actual limited portion size, or a visual indication of expected portion size - and whether access is self-service on-demand, or served on request by staff. The resulting likelihood of the scenario to result in excessive consumption of salt, fat, and sugar compared to national guidelines was considered.

1.3.4.5 Quality

Whilst focus of the assessment was food safety and health, quality is very important characteristic, and this has also been briefly considered. Quality impacts related to packaging / serving format were considered such as drying out or breaking up of the product, which may lead to additional wastage, and customer dissatisfaction/complaints.

See attached appendices for HACCP process flow diagrams for each of the scenarios.

2. Scope of the study

2.1 Scope of the scenarios tested

The study compares the **SUP base case (consumer portion single-use plastic packaging**) with the two alternatives serving systems:

- **An alternative single-use serving option:** that is paper-based or made of glass, which may be served from a dispenser/bulk packaging, or arrive in a sealed consumer-portion packaging.
- **A reusable serving option**: a reusable cup that is always served from a dispenser/ bulk packaging. For sugar, sugar cubes are served directly from a sugar bowl (no reusable cup required).

Each scenario is defined by three characteristics: consumption location, food type and serving option. The options for these characteristics are presented in the table below. Each combination of the options presented in the table is assessed (e.g. "strawberry jam served in a plastic SUP, in a Restaurant"). **A total of 47 packaging solutions modelled: 3 packaging types**[4] **across 16 food type – consumption location configurations** (hereafter referred to as *Scenarios)*.

An additional single-use, sealed max. 20% plastic alternative for semi viscous sauce is also tested in the sensitivity analysis in a restaurant setting (see section 7.4).

Table 1: Characteristics to define a scenario

Characteristic	Option
Consumption location	▪ Canteen ▪ Hotel ▪ Café ▪ Restaurant
Food type	▪ Semi-viscous (ketchup) ▪ Creamer (cow's milk) ▪ Jam (strawberry jam) ▪ Sugar (finely refined white sugar)
Serving option	▪ SUP base case - *sealed* ▪ Alternative SU packaging (max 20% plastic) – *sealed or dispensed* ▪ Reusable serving option – *dispensed*

[4] With the exception of Hotel-Sugar: only the single-use plastic sachet (base case) and a paper-based sachet (single-use alternative) are considered for this scenario.

2.2 Functional unit

The functional unit (FU) defines the qualitative and quantitative aspects of the function(s) and/or service(s) being provided. In accordance with the goal of this study, the function of the studied systems is defined per food type as follows:

- Semi-viscous: *"to serve one portion with a volume of 25ml while maintaining food safety requirements"*
- Creamer: *"to serve one portion with a volume of 12ml while maintaining food safety requirements"*
- Jam: *"to serve one portion with a weight of 30g while maintaining food safety requirements"*
- Sugar: *"to serve one portion with a weight of 4g while maintaining food safety requirements"*

The general approach for defining the functional unit across the different food types is based on the same principle: serving one portion. However, the volume or weight corresponding to a single portion varies depending on the specific food type. The value defined in the functional unit reflects typical consumption practices in Europe.

2.3 Scenario overview

This section covers the specific scenarios that are investigated in the study.

2.3.1.1 Canteen

The different configurations of packaging and serving options for the different food types and in the canteen consumption location are presented in the table below.

Table 2: Different serving configurations for the canteen consumption location

Consumption location	Packaging	Food type											
		Semi-viscous			Creamer			Jam			Sugar		
		Bulk packaging	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*
Canteen	Single-use packaging			 Single use dip cup			 Single use dip cup			 Single use dip cup			 Single use plastic sachet
	Reusable packaging	 Plastic pouch	 Manual dispenser	 Reusable plastic cup	 Plastic pouch	 Manual dispenser	Reusable plastic cup	 Plastic pouch	 Manual dispenser	 Reusable plastic cup	 Sugar cube box	 Stainless steel sugar pot	
	Alternative single-use packaging	 Plastic pouch	 Manual dispenser	 Single use paper cup	 Plastic pouch	 Manual dispenser	 Single use paper cup	 Plastic pouch	 Manual dispenser	 Single use paper cup			 Single use paper sachet

2.3.1.2 Restaurant

The different configurations of packaging and serving options for the different food types and in the restaurant consumption location are presented in the table below.

Table 3: Different serving configurations for the restaurant consumption location

Consumption location	Packaging	Food type											
		Semi-viscous			Creamer			Jam			Sugar		
		Bulk packaging	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*
Restaurant	Single-use packaging			 Single use dip cup			 Single use dip cup			 Single use dip cup			 Single use plastic sachet
	Reusable packaging	 Plastic squeeze bottle		 Reusable plastic cup	Plastic bottle		Reusable plastic cup	 Plastic tub		 Reusable plastic cup	 Sugar cube box	 Stainless steel sugar pot	
	Alternative single-use packaging	 Plastic squeeze bottle		 Single use paper cup	Plastic bottle		 Single use paper cup			 Single use glass jar			 Single use paper sachet

2.3.1.3 Hotel

The different configurations of packaging and serving options for the different food types and in the hotel consumption location are presented in the table below.

Table 4: Different serving configurations for the hotel consumption location

Consumption location	Packaging	Food type											
		Semi-viscous			Creamer			Jam			Sugar		
		Bulk packaging	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*
Hotel	Single-use packaging			 Single use dip cup			 Single use dip cup			 Single use dip cup			 Single use plastic sachet
	Reusable packaging	 Plastic pouch	 Manual dispenser	 Reusable plastic cup	Plastic bottle		Reusable plastic cup	 Plastic tub		 Reusable plastic cup			
	Alternative single-use packaging	 Plastic pouch	 Manual dispenser	 Single use paper cup	Plastic bottle		 Single use paper cup			 Single use glass jar			 Single use paper sachet

2.3.1.4 Café

The different configurations of packaging and serving options for the different food types and in the café consumption location are presented in the table below.

Table 5: Different serving configurations for the café consumption location

Consumption location	Packaging	Food type											
		Semi-viscous			Creamer			Jam			Sugar		
		Bulk packaging	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*	*Bulk packaging*	*Dispenser*	*Individual serving system*
Café	Single-use packaging			 Single use dip cup			 Single use dip cup			 Single use dip cup			 Single use plastic sachet
	Reusable packaging	 Plastic pouch	 Manual dispenser	 Reusable plastic cup	Plastic bottle		Reusable plastic cup	 Plastic tub		 Reusable plastic cup	 Sugar cube box	 Stainless steel sugar pot	
	Alternative single-use packaging	 Plastic pouch	 Manual dispenser	 Single use paper cup	Plastic bottle		 Single use paper cup			 Single use glass jar			 Single use paper sachet

2.4 System boundaries

The system boundaries define which life cycle phases and impacts are assessed within each scenario, a schematic presentation is presented below for the single-use serving option and the reusable serving option. These representations are high-level and help to visualise the system boundaries, as well as understand the results which are presented per life cycle phase.

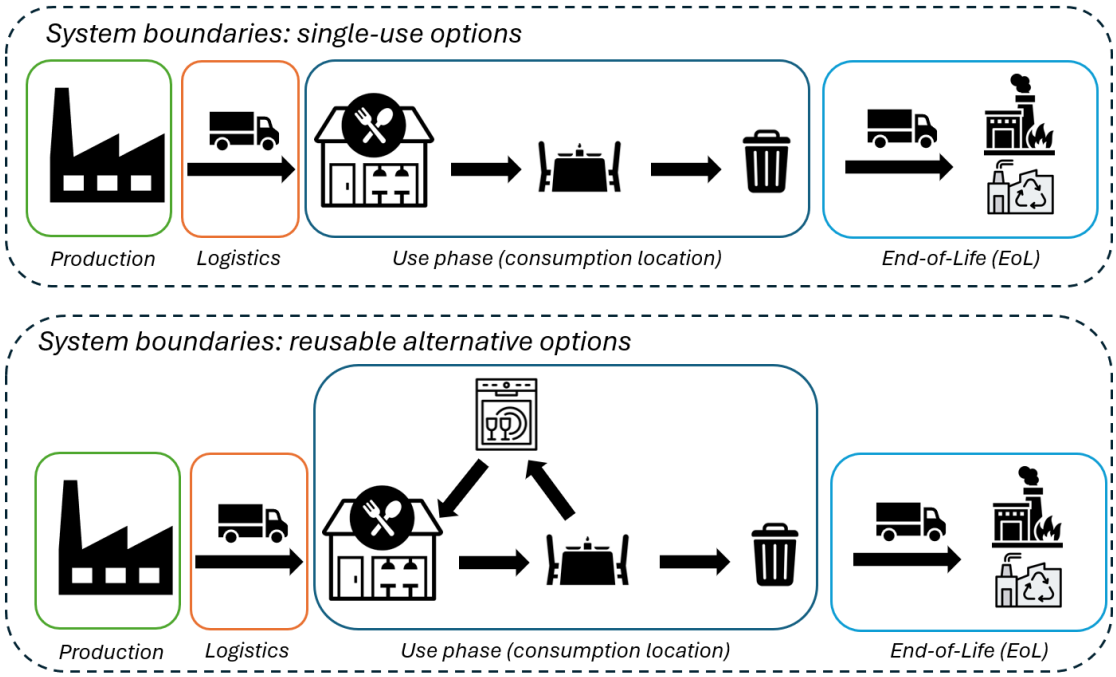


Figure 2: System boundaries of the single use options (plastic and alternative material) and reusable option

The system boundaries cover four main life-cycle phases: Production, Logistics, Use and End-of-Life. Each phase includes several sub-phases and associated impacts assessed across the economic, environmental, and social pillars of the CBA. The assessed impacts are presented in the table below.

Table 6: Summary of economic, environmental, and social impacts covered in scope of the study

Life cycle phase	Impacts		
	Economic	**Environmental**	**Social**
Production	▪ Production of primary and secondary packaging ▪ Food production losses associated with differences in food waste across scenarios	▪ Extraction raw material ▪ Production of primary packaging ▪ Production of secondary packaging (cardboard boxes) for all primary packaging ▪ Food production losses associated with food waste	*No specific modelling as the impact is limited compared to the other phases.*
Logistics	▪ Transport from production site to wholesaler/distributor (including palletisation and depalletization) ▪ Transport from the wholesaler/distributor to consumption location ▪ Time for loading and offloading ▪ Labour time for packing into back storeroom	▪ Transport from production site to wholesaler/distributor ▪ Transport from the wholesaler/distributor to consumption location	▪ Value of job creation associated with labour time of the lorry driver and consumption location staff packing supplies into back storeroom
Use phase	▪ Investment in dispensers and reusable cups ▪ Investment a washing machine for reusable cups <u>If serving or clearing is performed by staff:</u>	▪ Washing reusable cups (electricity, water & detergent consumption) ▪ Electricity consumption automated dispenser	<u>If serving or clearing is performed by staff:</u> ▪ Value of job creation associated with the labour time for serving

	▪ Labour time for serving ▪ Labour time for clearing after consumption <u>Supporting operations:</u> ▪ Training costs associated with performing more complex[5] operations [6] ▪ Monitoring costs associated with performing more complex operations[7] ▪ Labour time for refilling front stock ▪ Labour time for washing dispensers and loading and offloading reusable cups ▪ Backroom and front-end storage of bulk packaging, individual serving system and dispensers		▪ Value of job creation associated with labour time for clearing after consumption <u>If serving and clearing is performed by the client:</u> ▪ Burden of the client's time for serving ▪ Burden of the client's time for clearing after consumption <u>In addition, for all scenarios:</u> ▪ Value of job creation associated with labour time for supporting operations (refilling, washing etc.)
End-of-Life	▪ Pre-collection (emptying bins) ▪ Collection transport ▪ Sorting (for recycling)	▪ Collection transport ▪ Waste treatment: incineration & recycling ▪ Avoided impacts due to waste treatment:	*No specific modelling as the impact is limited compared to the other phases.*

[5] The term 'complex' refers to operations that are more sensitive to food safety risks.

[6] This cost is included for scenarios where the alternative involves serving from a bulk packaging or dispenser.

[7] This cost is included for scenarios where the alternative involves serving from a bulk packaging or dispenser.

	▪ Treatment (incineration or recycling, including associated revenues)	○ Fossil fuel mix due to energy production incineration ○ Virgin production due to recycled material	

2.5 Describing the product – safety controls & product characteristics

The HACCP methodology includes describing the product and identifying intended use. For each individual food product, the manufacturer must provide storage and usage instructions and advise the maximum safe shelf life under those prescribed storage and usage conditions. This shelf life should be determined by the manufacturer based on studies involving microbiological testing and sensory analysis.

All product examples in the study are considered to be comparatively low risk products and would typically carry a best before date rather than a use by date.

Table 7: Description of the assessed food product types

Food type	Description
Ketchup	This food type – ketchups and condiment sauces - is potentially the most variable of the 4 types selected for the study, based on ingredients and manufacturing process. Safety control may be the following – or combinations of the following – low pH, high sugar/ low water activity, high salt content. They may be heat processed or cold mixed during manufacturing. Shelf life may typically be 6 - 12 months stored unopened at ambient temperatures but may require refrigerated storage once opened. Ketchup/condiment sauces will have varying quality and safety properties based on their individual recipe/composition formulation. Generic tomato ketchup was the main product for consideration, however this should not be considered in isolation, as various types of product may be offered in addition to ketchup which contain different ingredients and allergens – e.g. barbecue sauce, mustard, mayonnaise, curry sauce, vinegar.
Milk	In this assessment, the assumption has been made that it is standard pasteurised cows' milk. Safety control is the pasteurisation temperature processing and refrigeration and limiting shelf life once opened. Once opened and served at ambient temperature milk would typically deteriorate from a quality perspective – e.g. development of "off"/sour flavours – any therefore would not be consumed, before deterioration would have an impact on food safety. Generic cows' milk was the main product for consideration, however various alternative 'milks' may be offered in addition to this, particularly for customers with allergies/ intolerances to cows' milk, or as a lifestyle dietary choice – soya, almond, oat, coconut - which may all contain different allergens.
Jam	Safety control is high sugar/ low water activity.

	Shelf life may typically be 6 - 12 months stored unopened at ambient temperatures but may require refrigerated storage once opened from a quality perspective to prevent mould and spoilage organism growth. In this assessment, the assumption has been made that it is standard quality fruit jam for example strawberry. There may be varying compositions – fruit content, sugar content, added pectin or not, whole fruit pieces or not, but these variations would typically not significantly affect the safety. Generic fruit jam was the main product for consideration, however this should not be considered in isolation, as various types of product may be offered in addition to jams as a breakfast item for serving on bakery items or in porridge, which contain different ingredients and allergens and have different safety controls –e.g. honey, syrup, peanut butter, soft cheese.
Sugar	Safety control is high sugar/ low water activity. Shelf life may typically be 12-18 months stored at ambient temperatures in dry conditions. In this assessment, the assumption has been made that it is generic white granulated sugar or cubes made from white sugar.

3. Impact assessment methodology for the three pillars

3.1 Economic impacts

The economic impacts assessed in this study are the economic costs and benefits associated with the functional unit along the life cycle.

The result of the economic cost assessment is expressed in **euro exclusive VAT**. The cost modelling reflects the average situation in the EU. Ranges were defined for heterogenous or uncertain parameters. The reference year for the value of one Euro is 2026.

Hence, all cost parameters are expressed in average European price levels for 2026, using Eurostat's purchasing power parities data where relevant, as well as European inflation data to adjust across countries where relevant.

The following table summarises the types of costs and the general principles to estimate them. The technical parameters are common to all pillars.

Table 8 Overview of types of costs and principles for cost estimation for each type

Type of cost and benefits	Methodology to calculate
Labour cost	The labour cost is calculated as a function of: ▪ The time needed to perform an action ▪ The labour cost (super gross wage) per hour
Cost of capital	The annual capital cost is calculated as function of: ▪ The investment cost ▪ The lifetime of the equipment ▪ The real interest rate
Cost of resources/production	The production cost of packaging and food is calculated as a function of: ▪ The estimated production cost per unit of material[8] ▪ The weight of material needed The storage space per functional unit is calculated as a function of: ▪ The square metres of space needed ▪ The annual rental cost per square metre.

[8] For the production cost of packaging, several approaches are used to define an appropriate range (raw commodity prices, sold production value from the EU ProdCom dataset as well as industry turnover from federation reports, etc.). This is detailed in Table 20 Key economic parameters for the production phase.

Economic benefits	Just as the costs, all possible benefits along the chain are considered such as recycled material value, energy from waste etc.

The labour cost used in this study is calculated based on Eurostat Labour cost levels for accommodation and food service activities[9].
The hourly wage is converted to a full-time equivalent considering full-time employment, a 42h work week, and 230 working days per year. To account for the variation of labour cost in the European Union, a range of labour cost is defined and tested in sensitivity analysis.

Table 9 Labour costs used in this study

Parameter	Lower bound	Upper bound	Source
Labour cost (€/hour)	6.4 €/hour	41.1 €/hour	Eurostat Dataset : Labour cost levels by NACE Rev. 2 activity (lc_lci_lev) 2024 costs adjusted for inflation.
Labour cost (€/full-time equivalent)	12 191 €/FTE	78 454 €/FTE	
Country of the source value	Bulgaria	Iceland	

Values of parameters for costs of capital and costs of production/resources are described per phase in section 4.2.1.

3.2 Social impacts

The social impacts assessed in this study are:

- Job creation,
- The burden of client time.

3.2.1 Job creation

The social value of job creation, associated with the labour time required in the consumption location, is valued in euros.

The rationale is as follows:

- When the unemployment rate lies above the frictional (minimal) level, a more labour-intensive system is generally considered preferable to a less labour-intensive system, *ceteris paribus*, because the more labour-intensive system is likely to create jobs.
- Job creation is positively valued for several reasons including the decrease in societal costs to pay for unemployment benefits and social security.

[9] Using the Eurostat Dataset lc_lci_lev. Labour costs are adjusted for inflation in the Eurozone from 2024 – 2026 using an inflation factor of 1.03.

The societal value of job creation is calculated using the following formula:

$$Value\ of\ job\ creation = Labour\ cost - Shadow\ wage$$

The shadow wage is determined by following the prescriptions of EU's Guide to Cost-Benefit Analysis of Investment projects[10]. The guide proposes a set of coefficients corresponding to four typical job market situations existing in the EU to use to compute the social value of job creation, i.e. the difference between labour cost and shadow wage.

Using an average of the proposed coefficients, we value one Full Time equivalent between 3 200 €/FTE and 20 594 €/FTE (depending on the labour cost used).

3.2.2 Burden of client time

The burden of client time is expressed as opportunity cost of labour. We value client time at between 6.4 and 41.1 €/hour, equivalent to the EU hourly wage for labour used in the economic impact modelling.

3.3 Environmental impacts

The environmental impact is assessed through a **Life Cycle Assessment (LCA)**, which is a comprehensive, multi-criteria method for assessing the environmental impacts of products or services. It quantifies potential impacts across the entire life cycle to provide a global view of their environmental footprint.

More information on the general methodology of an LCA can be found in Annexe 2.

The key parameters defining the LCA conducted in this study are presented below:

- LCA software: RangeLCA, see Annexe 1
- Standards followed:
  - ISO 1440/44: general guidelines LCA
  - PEF methodology[11]: LCA methodology, developed by the European Commission
- System boundaries: cradle-to-grave (all life cycle phases are included, from raw material extraction to final waste treatment)
- LCIA method: EF3.1, complete set of 16 impact categories covered in the LCA (see Annexe 3 for the full list of impact categories)

Monetary valuation of environmental impacts

Monetary valuation of environmental impacts is used to express environmental impacts in terms of welfare loss. The marginal cost of pollution for society is expressed in euros per kilogram pollutant or unit of impact metric, for example. Monetary valuation of the environmental impacts is determined through revealed or state-preference methodologies, in accordance with ISO 14008. This is the ISO

[10] Source: EU. (2015). Guide to Cost-Benefit Analysis of Investment projects - Economic appraisal tool for Cohesion Policy 2014-2020.

[11] https://eplca.jrc.ec.europa.eu/EnvironmentalFootprint.html

norm which provides a methodological framework for the monetary valuation of environmental impacts and related environmental aspects.

A table with information on monetary valuation of LCIA results for each single impact category, covered in the multi-criteria LCA, is presented in Annexe 10.

Note that the monetary values considered cover the "external" part of the environmental cost only, in order to avoid double counting environmental taxes which are considered in the economic impacts. These taxes are the internalised share of the total environmental costs.

The figure below shows how the environmental impacts are integrated in an CBA, with focus on greenhouse gas emissions and their impact on the environmental indicator climate change.

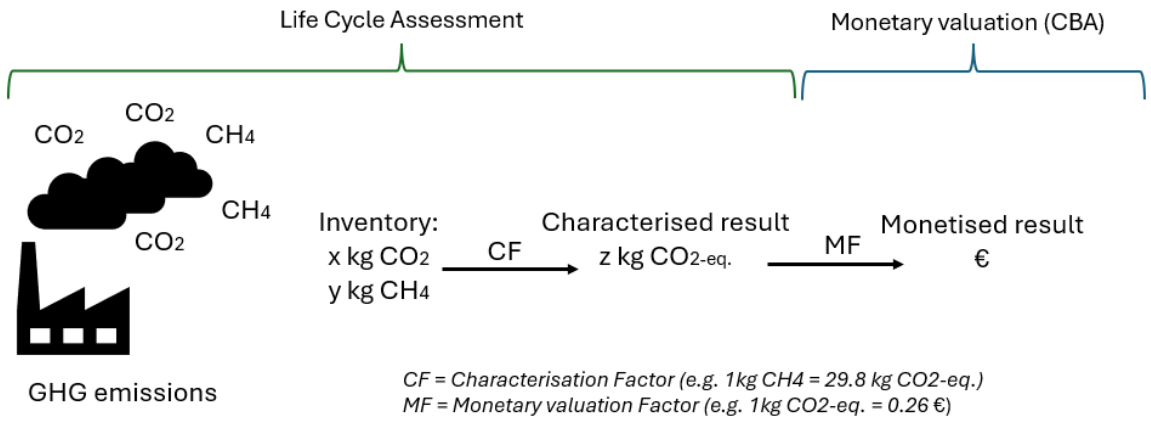


Figure 3: Schematic presentation of the integration of environmental impacts in a CBA

4. Data inventory

4.1 Scenario data

This section presents the data used to define the scenarios and are common to all three pillars of the CBA (economic, social and environmental impacts). These are presented by life cycle phase.

4.1.1 Production

The tables below present the data used to characterise the different packaging and dispensing types across all scenarios. More information is given on the main sources and assumptions used related to the data below the tables.

Table 10: Inventory data used production of individual serving system

Packaging type		Life cycle phase	Parameter	Value	Unit	Present in scenarios
Dip cup		Primary packaging	weight PP	1.13	g	canteen - semi-viscous hotel - semi-viscous café - semi-viscous restaurant - semi-viscous
			recycled content PP	0	%	
			volume	25	ml	
		Secondary packaging	#dip cups per cardboard box	125	#	
			weight cardboard box	120	g	
Dip cup		Primary packaging	weight PP	0.54	g	canteen - creamer hotel - creamer café - creamer restaurant - creamer
			recycled content PP	0	%	
			volume	12	ml	
		Secondary packaging	#dip cups per cardboard box	120	#	
			weight cardboard box	125	g	
Dip cup		Primary packaging	weight PP	1	g	canteen - jam hotel - jam café - jam restaurant - jam
			recycled content PP	0	%	
			volume	23	ml	
		Secondary packaging	#dip cups per cardboard box	120	#	
			weight cardboard box	154	g	
Plastic sachet		Primary packaging	weight PP	0.2	g	canteen - sugar hotel - sugar café - sugar restaurant - sugar
			recycled content PP	0	%	
			weight sugar content	4	g	
		Secondary packaging	#sachets per cardboard box	1000	#	
			weight cardboard box	292	g	

Paper sachet		Primary packaging	weight paper	0.36	g	canteen - sugar hotel - sugar café - sugar restaurant - sugar
			recycled content paper	0	%	
			weight LDPE	0.07	g	
			recycled content LDPE	0	%	
			weight sugar content	4	g	
		Secondary packaging	#sachets per cardboard box	1000	#	
			weight cardboard box	292	g	
Paper cup - thin		Primary packaging	weight paper	0.6	g	canteen - semi-viscous hotel - semi-viscous café - semi-viscous restaurant - semi-viscous
			recycled content paper	0	%	
			volume	25	ml	
		Secondary packaging	#cups per cardboard box	5000	#	
			weight cardboard box	358	g	
Paper cup - rigid[12]		Primary packaging	weight paper	1.85	g	canteen - jam hotel - jam café - jam restaurant - jam
			recycled content paper	0	%	
			volume	23	ml	
		Secondary packaging	#cups per cardboard box	6480	#	
			weight cardboard box	678	g	
Glass jar		Primary packaging	weight glass	41	g	hotel - jam café - jam restaurant - jam
			recycled content glass	40	%	
			weight tinplated steel (lid)	6	g	
			recycled content tinplated steel	58	%	
			volume	23	ml	
		Secondary packaging	#glass jars per cardboard box	60	#	
			weight cardboard box	162	g	
Reusable plastic cup [13]		Primary packaging	weight PP	7	g	canteen - semi-viscous hotel - semi-viscous café - semi-viscous restaurant - semi-viscous
			recycled content PP	0	%	
			volume	25	ml	

[12] The specification given here are for the rigid paper cup used to serve a portion of jam (30g). Packaging weights are extrapolated for serving a portion of creamer (12ml).

[13] The specification given here are for the reusable PP cup used to serve a portion of semi viscous (sauce) (25 ml). Packaging weights are extrapolated for serving a portion of creamer (12ml) and jam (30g).

		Secondary packaging	#reusable cups per cardboard box	96	#	
			weight cardboard box	97	g	

The table below presents the data used to model the bulk packaging formats for the single-use and reusable alternatives for certain scenarios (listed in far-right column).

Table 11 Inventory data used production of bulk packaging

Packaging type		Life cycle phase	Parameter	Value	Unit	Present in scenarios
Plastic squeeze bottle		Primary packaging	weight PP (bottle + cap)	40	g	Restaurant - semi-viscous
			recycled content PP	0	%	
			volume	0.5	l	
		Secondary packaging	#bottles per cardboard box	12	#	
			weight cardboard box	150	g	
Plastic bottle		Primary packaging	weight HDPE (bottle)	26	g	hotel - creamer café - creamer restaurant - creamer
			recycled content HDPE	0	%	
			weight PP (cap)	1.5	g	
			recycled content PP	0	%	
			volume	1	l	
		Secondary packaging	#bottles per cardboard box	12	#	
			weight cardboard box	403	g	
Plastic tub		Primary packaging	weight PP (tub + cap)	113.5	g	hotel - jam café - jam restaurant - jam
			recycled content PP	0	%	
			volume	2.26	l	
		Secondary packaging	Weight cardboard	114	g	
Plastic pouch		Primary packaging	Weight LDPE	44	g	canteen - semi-viscous hotel - semi-viscous café - semi-viscous

			Recycled content LDPE	0	%	canteen - jam canteen- creamer
			Volume	5	l	
		Secondary packaging	# pouches per carton	2	#	
			Weight cardboard	154	g	
			Recycled content cardboard	0	%	

The table below presents the data used to model the dispensers used for single-use and reusable alternatives for certain scenarios (listed in far right column).

Table 12 Inventory data used production of dispensers

Packaging type		Life cycle phase	Parameter	Value	Unit	Present in scenarios
Manual dispenser		Primary packaging	weight stainless steel	5.3	kg	canteen - semi-viscous canteen - creamer canteen - jam hotel - semi-viscous café - semi-viscous restaurant - semi-viscous
			recycled content stainless steel	58	%	
			Lifetime	5	y	
			volume	5	l	
		Secondary packaging	Cut-off: not included	/	/	
Steel sugar pot		Primary packaging	weight stainless steel	270	g	canteen - sugar café - sugar restaurant - sugar
			recycled content stainless steel	58	%	
			Lifetime	5	y	
			volume	0.6	l	
		Secondary packaging	Cut-off: not included	/	/	

The sources used to define these packaging and dispensing types are:

- Weight and volume primary/secondary packaging:

- Data received from CPIC members
- Online desk research; data taken from technical fiches by wholesalers/distributors of these products

- Recycled content material: EU average values for recycled content of different packaging materials, as defined in the Annex C of the PEFCR guidance document[14]

The main remarks related to the data in this table are:

- The weight of the paper sachet is estimated by RDC Environment using industry data on the dimensions of the SUP sachet and a representative grammage for paper packaging.
- For the paper cup and reusable PP cup, only one volume (25ml) is presented with its corresponding weight. The weight of the paper/reusable cups with volume of 12 and 23 ml is based on extrapolation of the weight of the 25ml cup.
- For some packaging/dispensing options, the impact of the secondary impact is not included because it is assumed that the impact of this packaging, allocated to the FU, will be negligible. Therefore, using the cut-off rule, it is excluded from the model.[15]
- The same type of secondary packaging (cardboard box) is modelled across all scenarios.[16] However, its weight and volume are adjusted to reflect real-life configurations corresponding to each primary packaging option. In other words, the environmental impact per kilogram of cardboard remains identical in all scenarios, while the box dimensions are adapted to the specific primary packaging.
  - The recycled content of the cardboard box is based on the ecoinvent dataset for a cardboard box and equals ~80% (this dataset represents 73% of the total annual production of corrugated board products in Europe).
- The lifetime of the dispensing options needs to be estimated to be able to allocate part of the total impact of this product over its entire lifetime, to the FU assessed in this study.

4.1.2 Transport

4.1.2.1 Upstream transport

The upstream transport represents the transport of raw material to the factory where the different packaging and serving options are made (E.g. transport of PP pellets to the factory where these pellets are converted into a dip cup). Default transport modes and distances are based on the PEFCR guidance document[17], and are assumed to be the same for all materials:

[14] Commission recommendation on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations v2.1, 16.12.2021 (Annex C)

[15] Taking the manual dispenser as an example: The estimated weight of the cardboard for one dispenser is 250 g. If we consider the economic cost to be 1.16 €/kg and the monetised environmental impact to be 0.96 €/kg, then the estimated impact of the cardboard is €0.53 per dispenser. Assuming 70,000 portions are served over its lifetime (approximately 60 portions per day), the impact of the cardboard per portion becomes negligible.

[16] C-flute single-wall standard shipping cardboard is modelled for all packaging formats (cardboard thickness of ~4 mm).

[17] Default distances based on assumption of having all suppliers of raw material within Europe

- Road (lorry >32 metric ton): 280 km
- Train (average EU fleet): 280 km
- Sea (container ship, heavy fuel oil): 360 km

The impact of this upstream transport is included in the results of the production phase.

4.1.2.2 Logistics of packaging and serving options

Two logistics steps are modelled in this study:

- Transportation by pallet from production site to wholesale/distribution centre
- Transportation from wholesale/distribution centre to the consumption location

The key parameters are given in the table below.

Table 13 Key parameters for the logistics phase

Parameter	Production site to wholesale/distributor	Wholesaler to consumption location
Lorry model	Long distance - semi trailer	7.5T carrier
Carrying payload (tonnes)	28	3.2
Distance (km)	200 - 300	150 – 250
Speed (km/h)	60 - 80	60
Loading rate	100%	70-90%
Empty outbound (%)	50%	20%
Lorry interior length (m)	13.6	6.2
Lorry interior width (m)	2.45	2.45
Lorry interior height (m)	2	2.4

These lorry parameters are used to calculate the number of cartons of each packaging type would fit into a lorry. This is used to allocate a transport impact to a functional unit.

The number of cartons of each packaging type are given in Annexe 8.

4.1.3 Use phase

The use phase consists of different impacts, related to the serving and clearing of the condiment serving option, and the washing impact of the reusable cups.

4.1.3.1 Serving and clearing configuration

The assumptions made on who (either staff or client) serves and clears the different serving options in the different scenarios, is presented in the table below. This distinction is important as the time spent will either be considered an economic cost (labour time of staff) or a social cost (burden of client time).

Table 14: Serving and clearing configuration in the different scenarios

Consumption location	Food type							
	Semi-viscous		Creamer		Jam		Sugar	
	Serving	*Clearing & sorting*	*Serving*	*Clearing & sorting*	*Serving*	*Clearing & sorting*	*Serving*	*Clearing & sorting*

Canteen	Client	Client	Client	Client	Client	Client	Client	Client
Restaurant	Staff/Client [18]	Staff	Staff	Staff	Staff	Staff	Client	Staff
Hotel	Staff	Staff	Staff	Staff	Staff	Staff	Client	Staff
Café	Staff	Client	Staff	Client	Staff	Client	Client	Client

4.1.3.2 Lifetime of reusable serving options

The reusable cups will serve many single portions during their lifetime. Since the FU is defined for the serving of one portion, only part of their total impact of these serving options and dispensers over their entire life cycle must be allocated to the FU. This is done through the allocation factor '1 / total servings of single portions over lifetime'. Since a natural variability can be expected on the amount of times the reusable cups are used (accidental throw away), a large range is used for this parameter. **For all scenarios, we consider that the reusable serving cups are used between 5 – 100 times.**

4.1.3.3 Serving rates and opening times of consumption locations

The table below presents the serving rate and opening times defined for each consumption location. Where possible, the serving rates were validated through industry interviews.

Table 15 Serving rate and opening times of each consumption location.

Consumption location	Food type				Location features		
	Semi-viscous	Creamer	Jam	Sugar	*Hours open per day*	*Days open per week*	*Weeks open per year*
	Serving rate						
Canteen	High				5	5	49
Restaurant	Medium				6	6	49
Hotel	Very low				18 – 24[18]	7	52
Café	Low	Medium – Low	Low	High	9	6	49

[18] In this scenario, the SUP base case is served by the staff (brought to table), whereas the two alternative options are served from a squeeze bottle on the table.

The serving rate and the opening hours per day are used to define a range of the number of portions served per day for each scenario, which are presented in the table below. This parameter is used to calculate the average number of portions served per year, which influences how certain fixed economic costs (e.g. rental cost of storage, capital costs and labour costs related to daily dispenser cleaning and training) and environmental impacts (e.g. dispenser production impacts) are allocated to the FU.

Table 16 Portions served per day for each scenario modelled.

Consumption location	Food type							
	Semi-viscous		Creamer		Jam		Sugar	
	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
Canteen	300	600	300	600	300	600	300	600
Restaurant	144	216	144	216	144	216	144	216
Hotel	11	29	11	29	11	29	11	29
Café	108	162	108	324	108	162	540	1,080

Note that this range is intended to represent the flow of consumption over the entire daily opening period of the consumption location.

4.1.3.4 Washing impacts

The table below presents the input to model the washing impacts of the reusable cups; the unit is expressed per litre of volume of serving option. The actual impact in each scenario is thus based on the volume defined in the functional unit.

For example, the detergent consumption in any scenario with jam; 0.88 g/l x 0.023 l = 0.019 g

Table 17: data for washing impact reusable cups

Parameter	Unit	Consumption location			
		Canteen	Hotel	Restaurant	Café
Electricity washing	kWh/l	0.048 – 0.1			
Water consumption	l/l	0.4 – 0.5			
Detergent consumption	g/l	0.88			

The washing impacts are based on a professional washing machine which is assumed to be used in all consumption locations.

Dispensers are washed by hand once a day. The water consumption to wash dispensers is calculated using a water consumption rate of a standard tap for washing up of 7 l/minute.

4.1.4 Food waste

Food waste vs. food loss:

According to the European Commission, "food waste" is discarded food and its associated inedible parts (such as bones or fruit cores)[19]. Food waste occurs at all stages of the food supply chain, from farm to fork. However, the largest share is generated at consumption, which is a key area of focus for food waste prevention programmes.

There is no official legal definition of "food loss" at the EU level. However, the United Nations[20] defines it as "the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retail, food service providers, and consumers." Another possible definition is "the edible portions of food that remain on the farm, whether they are returned to the soil or used for on-site composting."

This study includes the potential impacts associated with food waste. Three main mechanisms that may cause food waste rates to differ across the scenarios are considered:

- Food waste linked to packaging design: certain packaging types may be less effective than others at allowing consumers to fully use the food content, particularly for products with high viscosity or other properties that cause adherence to the packaging surface. **This study assumes that this represents up to 1% of additional food waste.**
- Food waste linked to serving configuration: when the consumer is asked to dispense the portions themselves, food waste may occur due to spillage or mishandling. **This study assumes that this represents up to 1% of additional food waste.**
- Food waste linked to consumption flow: for quality or safety reasons, staff may throw out unfinished bulk packaging containers or product that have been pre-served into cups. **This study assumes that this represents up to 5% of additional food waste.**

For each scenario we set a range of food waste for the alternative packaging option between 0% and the sum the abovementioned additional food waste rates relevant to the specific scenario (maximum 7%).[21] This is food waste rate is applied to the environmental and economic cost of food production and other relevant lifecycle phases (transport of food, waste collection and treatment).

The possibility for the consumer to serve himself more (or less) than the foreseen quantity is not taken into account. This is justified by the following reasons:

- Where the consumer controls the amount of food taken, food waste is largely driven by consumer behaviour, which is inherently variable and difficult to quantify with certainty.
- Consumer behaviour-driven differences are considered less relevant as a basis for policy recommendations, as such behaviour is subject to change through awareness campaigns, financial incentives, or other interventions, and should therefore not in itself determine the preferred packaging policy direction.

[19] https://food.ec.europa.eu/food-safety/food-waste/frequently-asked-questions-reducing-food-waste-eu_en#:~:text=Food%20waste%20is%20discarded%20food,chain%2C%20from%20farm%20to%20fork.

[20] https://www.folou.eu/wp-content/uploads/2024/03/FOLOU_presentation_webinar_meeting1.pdf

[21] The food waste rate ranges used in this study are consistent with results of industry tests, which show that alternative packaging solutions result in 4 – 8.5% more food waste than SUP base-case packaging, depending on product viscosity.

4.1.4.1 Cost of food production

The economic costs are calculated using average food prices per kilo or litre from European datasets, summarised in the table below.

Table 18 Economic costs of food production in euro cents per functional unit.

Food type	Value (€/k)	Source
Ketchup	1.91 €/kg	Eurostat ProdCom database.[22] Average calculated using sold production quantity and production value of tomato ketchup [10841230] for 2024.
Milk, whole, pasteurised	0.72 €/L	Milk Market Observatory of the European Commission.[23] EU Average price for 2024 – 2025 was taken.
Jam, strawberry	2.66 €/kg	Eurostat ProdCom database.[24] Average calculated using sold production quantity and production value of jam [10392290] for 2024.
Sugar, white	0.67 €/kg	EU Sugar Price Monitor. [25] Average price for 2024 – 2025 was taken.

Environmental cost data is calculated using the french Agribalyse database (version 3.2), a comprehensive database on environmental indicators for agricultural and food products based on Life Cycle Assessment.[26]

[22] https://ec.europa.eu/eurostat/databrowser/view/ds-059358__custom_19998496/default/table

[23] https://agriculture.ec.europa.eu/data-and-analysis/markets/price-data/price-monitoring-sector/milk-and-dairy-products_en

[24] https://ec.europa.eu/eurostat/databrowser/view/ds-059358__custom_19998037/default/table

[25] https://agriculture.ec.europa.eu/data-and-analysis/markets/price-data/price-monitoring-sector/sugar_en

[26] https://doc.agribalyse.fr/documentation-en/agribalyse-program/agribalyse-supporting-ecological-transition

4.1.5 End-of-Life

The different waste treatment rates for the different packaging and serving options are presented in the table below. Below the table, more information is given on the main sources and assumptions used related to the data in this table.

Table 19 Waste treatment rates for the different packaging and serving options

Packaging type		Parameter	Value (%)
Individual serving system			
Dip cup		Collection rate	47%
		Sorting efficiency	91%
		Recycling efficiency	96%
		Recycling rate	41%
		Incineration rate	59%
Plastic sachet		Collection rate	47%
		Sorting efficiency	91%
		Recycling efficiency	96%
		Recycling rate	41%
		Incincineration rate	59%
Paper sachet		Collection rate	84%
		Sorting efficiency	99%
		Recycling efficiency	90%
		Recycling rate	75%
		Incineration rate	25%
Paper cup		Collection rate	84%

		Sorting efficiency	99%
		Recycling efficiency	90%
		Recycling rate	75%
		Incineration rate	25%
Glass jar		Collection rate	77%
		Sorting efficiency	93%
		Recycling efficiency	93%
		Recycling rate	66%
		Landfill rate	34%
Reusable plastic dip cup and plastic pouring cup		Collection rate	47%
		Sorting efficiency	91%
		Recycling efficiency	96%
		Recycling rate	41%
		Incineration rate	59%
Bulk packaging			
Plastic squeeze bottle		Collection rate	47%
		Sorting efficiency	91%
		Recycling efficiency	96%
		Recycling rate	41%
		Incineration rate	59%
Plastic bottle		Collection rate	47%
		Sorting efficiency	91%

		Recycling efficiency	96%
		Recycling rate	41%
		Incineration rate	59%
Plastic tub		Collection rate	47%
		Sorting efficiency	91%
		Recycling efficiency	96%
		Recycling rate	41%
		Incineration rate	59%
Plastic pouch		Collection rate	47%
		Sorting efficiency	91%
		Recycling efficiency	96%
		Recycling rate	41%
		Incineration rate	59%
Dispensing solutions			
Manual dispenser		Collection rate	100%
		Sorting efficiency	100%
		Recycling efficiency	89%
		Recycling rate	89%
		Incineration rate	11%
Steel sugar pot		Collection rate	100%
		Sorting efficiency	100%
		Recycling efficiency	89%
		Recycling rate	89%

		Incineration rate	11%

The sources used to define these treatment rates are:

- Collection rates are calculated backwards starting from the recycling rate and the recycling and sorting efficiencies, as follows:
  - Collection rate = recycling rate x (1/recycling efficiency) x (1/sorting efficiency)
- Plastic packaging recycling rate: EU average recycling rate according to the European Parliament[27].
  - Recycling rate defined in 2024, and based on 2022 data
- Recycling rate other materials: EU average values for recycling rates of different packaging materials, as defined in the Annex C of the PEFCR guidance document[28]
- Sorting and recycling efficiency rates are derived from the relevant ecoinvent datasets on sorting and recycling for these specific materials, except for:
  - Recycling efficiency paper: based on scientific study[29]
  - Recycling efficiency glass: based on online article by ACRplus[30]

The main remarks related to the data in this table are:

- The treatment rates of the different packaging and serving options are assumed to be independent of the consumption location.
- Because of the prohibition of landfilling this type of packaging material in the Landfill directive[31], the only treatment options are recycling and incineration.
  - An exception exists for glass: glass that is not recycled will be sent to landfill. This is the only material where landfilling is possible.
- The recycling rate represents the amount of material that ultimately is recycled compared to the amount of material put on the market, and as such is the result of the collection rate multiplied with the sorting and recycling efficiency.
  - The material lost during the sorting and recycling is sent to incineration to ensure 100% of the collected material is treated. This fraction of the material is calculated as: collection rate x (1 - sorting efficiency) x (1 - recycling efficiency).

[27] https://www.europarl.europa.eu/topics/en/article/20181212STO21610/plastic-waste-and-recycling-in-the-eu-facts-and-figures#:~:text=Plastic%20waste%20in%20Europe:%20key,EU%20exports%20to%20the%20country.

[28] Commission recommendation on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations v2.1, 16.12.2021 (Annex C)

[29] National wood fibre balances for the pulp and paper sector: An approach to supplement international forest products statistics, Jochem et al, 2021, URL: https://www.sciencedirect.com/science/article/abs/pii/S1389934121001465

[30] https://www.acrplus.org/en/news/new-report-highlights-strong-performance-of-glass-recycling-in-europe-4729#:~:text=Close%20the%20Glass%20Loop%20has,Sustainable%20Food%20Systems

[31] https://circular-cities-and-regions.ec.europa.eu/support-materials/eu-regulations-legislation/landfill-directive-directive-eu-2018850

- The dispensing solutions are large items and assumed to be collected separately to be sent directly to recycling, thus the amount of recycled material only depends on the recycling efficiency and not the collection rate or sorting efficiency (both assumed to be 100%).

4.2 Pillar specific data

4.2.1 Economic and social pillars data

The economic impacts considered are listed in section 2.4. The following section highlights key data used to calculate the economic impacts. The social impacts are calculated using the labour or client time calculated in the economic impact modelling.

4.2.1.1 Production phase

The table below presents the key data used in the Production phase.

Table 20 Key economic parameters for the production phase

Parameter	Value	Used in model	Source
Cost of PP production	1300 – 4815 €/t	To calculate the production price of PP packaging and reusable PP cups	Lower bound: Estimated using commodity prices from Plastics Portal - Copolymer PP market price - W4/2026; 30% production margin applied. Upper bound: Estimated turnover per tonne of European plastic converters[32]
Cost of HDPE production	1235 – 4815 €/t	To calculate the production price of HDPE milk cartons	Lower bound: Estimated using commodity prices from Plastics Portal - blow moulding HDPE market price - W4/2026; 30% production margin applied. Upper bound: Estimated turnover per tonne of European plastic converters[33]
Cost of LDPE production	1413 - 4815 €/t	To calculate the production price of LDPE film pouch bags	Lower bound: Estimated using commodity prices from Plastics Portal - LDPE film market price - W4/2026; 30% production margin applied. Upper bound: Estimated turnover per tonne of European plastic converters[34]
Inox 304 - virgin price	3900 €/t	To calculate the production price of dispensers	Société Ardéchoise de Récupération - *Quel est le prix de l'inox au kilo en 2026 ?* 30% production margin applied.
Production cost of glass	424 – 626 €/t	To calculate the production costs of glass jars	Lower bound: Estimated using 2024 sold production quantity and sold production value[35] from the Eurostat Prod Com dataset Upper bound: Estimated using turnover and production of glass production in Germany[36]

[32] https://www.plasticsconverters.eu/

[33] https://www.plasticsconverters.eu/

[34] https://www.plasticsconverters.eu/

[35] Product category: Glass containers for beverages and foodstuffs of a nominal capacity < 2,5 litres [23131160]

[36] https://www.bvglas.de/media/BV_Glas/Jahresbericht_24_pdfs/Ueberblick_Behaelterglaswaren.pdf

Production cost of cardboard	1134 - 1188 €/t	To calculate the production costs of cardboard	Lower bound: Estimated using turnover and production of corrugated packaging industry in the EU[37] Upper bound: Estimated using 2024 sold production quantity and sold production value[38] from the Eurostat Prod Com dataset
Production cost of paper packaging	1615 – 3088 €/t	To calculate the production costs of paper packaging	Lower bound: Estimated using turnover and production of the paper industry in the EU[39] Upper bound: Estimated using 2024 sold production quantity and sold production value[40] from the Eurostat Prod Com dataset
Investment cost of manual dispenser	200 - 300 €	To calculate the equivalent annual cost of the dispenser	Range defined by RDC based on web research.
Investment cost of sugar bowl	12 - 18 €	To calculate the equivalent annual cost of the sugar bowl	Range defined by RDC based on web research.
Investment cost of dishwasher – Large	10 000 – 15 000 €[41]	To calculate the equivalent annual cost of the dishwasher Canteen scenarios	Industry interviews
Investment cost of dishwasher – Small	2 000 – 3 000 €	To calculate the equivalent annual cost of the dishwasher in Restaurant, Hotel and Café scenarios	Range defined by RDC based on web research.

4.2.1.2 Logistics

The table below presents the key data for the logistics phase.

Table 21 Key economic parameters for the logistics phase

Parameter	value	unit	Source

[37] https://www.fefco.org/about-fefco/industry-statistics

[38] Product category: Cartons, boxes and cases, of corrugated paper or paperboard [17211300]

[39] https://www.fefco.org/about-fefco/industry-statistics

[40] Product category: Trays, dishes, plates, cups and the like of paper or paperboard [17221300]

[41] We consider that the cost of the dishwasher would be allocated to multiple food products served in reusable cups. Therefore, we divide by estimated total number of portions served in reusable cups in a consumption location to attain a cost of the machine per FU that can be used in the model.

Average transport cost per trip for 28T semi-trailer	1.35 – 1.44[42]	€/km	RDC model based on data from the French "Comité national routier" of transport costs for long distance transport. [43] The model separates the costs proportional to the distance, to the working hours of the driver and to the duration of unavailability of the lorry due to its use. Values are adjusted to EU level prices.
Average transport cost per trip for 7.2T regional lorry	0.77	€/km	RDC model based on data from the French "Comité national routier" of transport costs for long distance transport. [44] The model separates the costs proportional to the distance, to the working hours of the driver and to the duration of unavailability of the lorry due to its use. Values are adjusted to EU level prices.
Offloading time per delivery of 1m³ of produce	5.7	min/ delivery	RDC model based on the following assumptions: ▪ 1 m³ of goods are delivered per delivery ▪ Arrival and departure of the lorry takes 1 minute in total ▪ Offloading is performed by trolley and takes 30 seconds per trolley trip The time allocated to a functional unit depends on the carton's volume and the number of units it contains.
Packing time per trip	20 - 30	seconds /trip to back storage	RDC model based on the following assumption: We consider that an employee can carry a maximum of 14kg at a time. The time allocated to a functional unit depends on the carton's weight and the number of units it contains.

[42] Total trip cost ranges from 405.44 – 647.8 €/trip for a distance ranging from 200 – 300 km and a 50% empty outbound distance.

[43] https://cnr.fr/prix-revient/12

[44] Référentiel prix de revient Régional EA – Gazole - Régional ensemble articulé: https://cnr.fr/prix-revient/10

4.2.1.3 Service

The table below presents the key parameters for the Service phase, presented as ranges. The following factors were considered when defining ranges:

- Is the item sealed, or does it need to be dispensed or served in a container?
- Client or staff served: clients may take longer to serve than staff.
- Attention needed while serving: for example, serving milk from a bulk carton would require attention to avoid spillage.

The representativeness of the ranges was verified through industry interviews.

Table 22 Key parameters for the Service phase

Parameter	Relevant scenario	Range used
Time to place a sealed consumer portion packaging on tray/plate (*Sealed)*	All scenarios	1 – 3 s
Time to place a sugar cube on tray/plate *(Dispensed)*	All Sugar scenarios	1 – 3 s
Time to pump one portion into dip cup from manual dispenser *(Dispensed)*	Canteen (Semi viscous (sauce), Creamer, Jam)	5 – 10 s
	Café/Hotel – Semi viscous (sauce)	2 – 10 s
Time to scoop/pour one portion into dip cup from bulk packaging *(Dispensed)*	Restaurant/Café/Hotel – Creamer	7 - 12 s
	Restaurant/Hotel – Jam	5 – 10 s
Time to place packaging in bin after use *(Sealed or dispensed)*	All scenarios	1 – 2 s
Time to place reusable PP cup in dirty tray *(Dispensed)*	All scenarios except Sugar	0.5 - 3 s
Time to take the full tray of dirty reusable PP cups to the back for cleaning *(Dispensed)*	Hotel/Restaurant/Café (Semi viscous (sauce), Jam, Creamer)	0 - 60 s[45]

Time parameters are presented for the different serving modes (placing on tray, dispensing from dispenser, serving from carton etc.). Section 4.1.3.1 presents the serving mode for each alternative in each scenario.

[45] This parameter is set from 0 as it may also be the case that reusable PP cups are cleared with plates directly to the kitchen and not placed in an intermediary container.

4.2.1.4 Supporting operations

The table below presents the key parameters for the 'supporting operations' phase. The representativeness of the ranges was verified through industry interviews.

Table 23 Key parameters for the support operations phase

Action	Parameter	Average value	Description
Refilling	Time to replace front stock (i.e. one carton of SU dip cups/sachets)	15 – 60 s/carton	Time needed to replace the stock in the preparation area, which involves: - throwing out empty cardboard box - getting a new carton from the storeroom and placing it on/under the service counter
	Time to replace bulk packaging	15 – 60 s/unit	Time needed to replace the stock at the preparation area, which involves: - throwing out empty packaging container - getting a new container from the storeroom and placing it on/under the service counter
	Time to fit a new pouch to the manual dispenser	1 – 3 min	Time needed to replace the stock in the preparation area, which involves: - getting a new container from the storeroom - attaching pouch in the dispenser - throwing out the empty packaging or returning to the storeroom if not yet empty
	Time to refill sugar bowl	1 - 3 min	Time needed to replace the stock in the preparation area, which involves: - getting a new container from the storeroom - pouring into the dispenser until filled - throwing out the empty packaging or returning to the storeroom if not yet empty
Washing	Time to load and unload dishwasher	1 – 3 minutes	Time needed to load PP cups into the dishwasher (50 cm x 50 cm tray) and unload into storage containers when cycle is finished
	Time to clean dispensers by hand	5 - 10 min/wash	Time needed to wash down with water and soap and reassemble. Frequency of washing is set between 2 – 5 days.
	Time to clean sugar bowl by hand	5 - 10 minutes/wash	Time needed to wash down with water and soap. Frequency of washing is set between 2 – 5 days.
Storage	Annual rental cost	80 - 115 €/m²/year	A range of possible rental costs is considered, where the minimum corresponds to an EU average of indoor industrial storage rent.[46] Used to calculate the cost of front and back storage.
Training	Cost of health and safety	500€/h	RDC assumption of the cost of a two-hour training session for site staff on health and food

[46] Source: *Logistics & Industrial Rents in Europe,* Cushman & Wakefield, 2023.

	expert for bi-annual training		safety practices associated with the management of food in bulk formats.
Monitoring	Maximum time per day spent monitoring	20 min/day	RDC assumption of the time spent each day monitoring operations related to bulk products, such as checking expiry dates, cleaning up spills, and ensuring the cleanliness of dispensers and cups, in a setting with a very high order throughput.

The total training cost comprises the cost of the expert trainer and the labour cost of employee attendance for a 2-hour session, assumed to cover 10 products. This cost is allocated to each product's functional unit by dividing by the number of portions served over a 6-month period.

Monitoring time is scaled to daily portion volume, on the basis that higher daily consumption flow implies proportionally greater risk. The required time is therefore adjusted according to the consumption rate in each scenario, and is assumed to be performed by a manager, reflected by a 50% uplift on the standard labour cost.

4.2.2 Environmental pillar data

The environmental impacts are modelled using the *ecoinvent* (https://ecoinvent.org/) database, which is globally the largest and most transparent life cycle inventory (LCI) inventory.

The specific database used is:

- Version: *3.11*
- System model: *Allocation, cut-off by classification*

All specific datasets used in the model for this study are presented in Annexe 4.

The data used to model the environmental impact is mostly the data presented in the section 4.1. Additional information to model the environmental impact can be found in the appendix:

- Annexe 6: explanation of the CFF formula (PEF methodology) and the associated material-specific values.
- Annexe 7: all transport in the model is assumed to occur through lorry, the explanation of the methodology to model this transport is presented in this appendix.
- Annexe 9: description of the transformation processes modelled during the production phase of the different packaging and serving options.

5. Results of the impact analysis (cost-benefit analysis)

The following section presents the results of the difference in societal impact (aggregated environmental, economic and social impacts) between the single-use plastic base case and the reusable/single-use alternatives for all the scenarios modelled.

5.1 Key messages

- **From societal perspective, the single-use plastic base case performs on average better than both the reusable and the single-use alternative for all the scenarios.**
- **The difference is mainly impacted by economic cost.** This is driven by the additional labour time required during service and supporting operations.
- **From an environmental perspective, the difference between the base case and alternative is significant for most scenarios.** Only for a limited number of scenarios (7 out of 31), is the difference in total impact below the threshold of 20%. The difference can be either negative or positive, the main trends are:
  - Alternative options with pouch packaging (for manual dispenser), as well as a bowl for sugar instead of a plastic sachet, result in a lower environmental impact.
  - The SUP base case outperforms the glass-based single-use alternative and the tabletop squeeze bottle for semi viscous (sauce).
- **From a social perspective, the reusable and the single-use alternatives perform better than the base case except in self-service settings.** This is driven by the benefit of job creation associated with the additional labour required for the alternatives.

5.2 Guidelines for the interpretation of the results

The following should be noted when interpreting the graphs:

- The bars in the graphs represent the **difference in total societal impact** between an alternative and the single-use plastic base case for each scenario. The sign (+/-) of the bar represents the following:
  - A positive value (+) indicates that the base case is considered better for society than the alternative.
  - A negative value (-) indicates the alternative performs better than the base case for society.
- The results are presented in euro cents per functional unit (in absolute terms) and not as percentages (in relative terms). This is because the model **includes only the lifecycle steps where a difference between the single-use base case and the alternatives occurs**. Lifecycle phases where there is no difference between the base case and the alternatives (for example, insurance costs for the consumption location) do not appear as they are null. Consequently, relative results would be overestimated and are thus not presented.
  - This is however not the case for the environmental impacts, because the LCA is sufficiently complete to compare the total impact of the different packaging options within a scenario. The relative results are presented in section 5.3.1.

- The main results are calculated using the average value of each parameter range presented in section 4. For example, the range defined for labour cost is between 6.4 €/h and 41.1€/h and so for the base results, a labour cost of 23.75€/h is taken.

The graphs represent either the three pillars (aggregated environmental, economic and social impacts) combined in an aggregated value, or the results per pillar.

5.3 Baseline results

5.3.1 Societal impact results for all scenarios

Total societal impact

The figure below presents the difference in total societal impact for the reusable and alternative single-use packaging options compared to the single-use plastic base case, aggregating all three pillars. Monetised impacts are presented in cents per functional unit (FU). The error bars indicate minimum and maximum values of these differences resulting from the sensitivity analysis where the full range for all parameters with a range are assessed (see section 7.2).

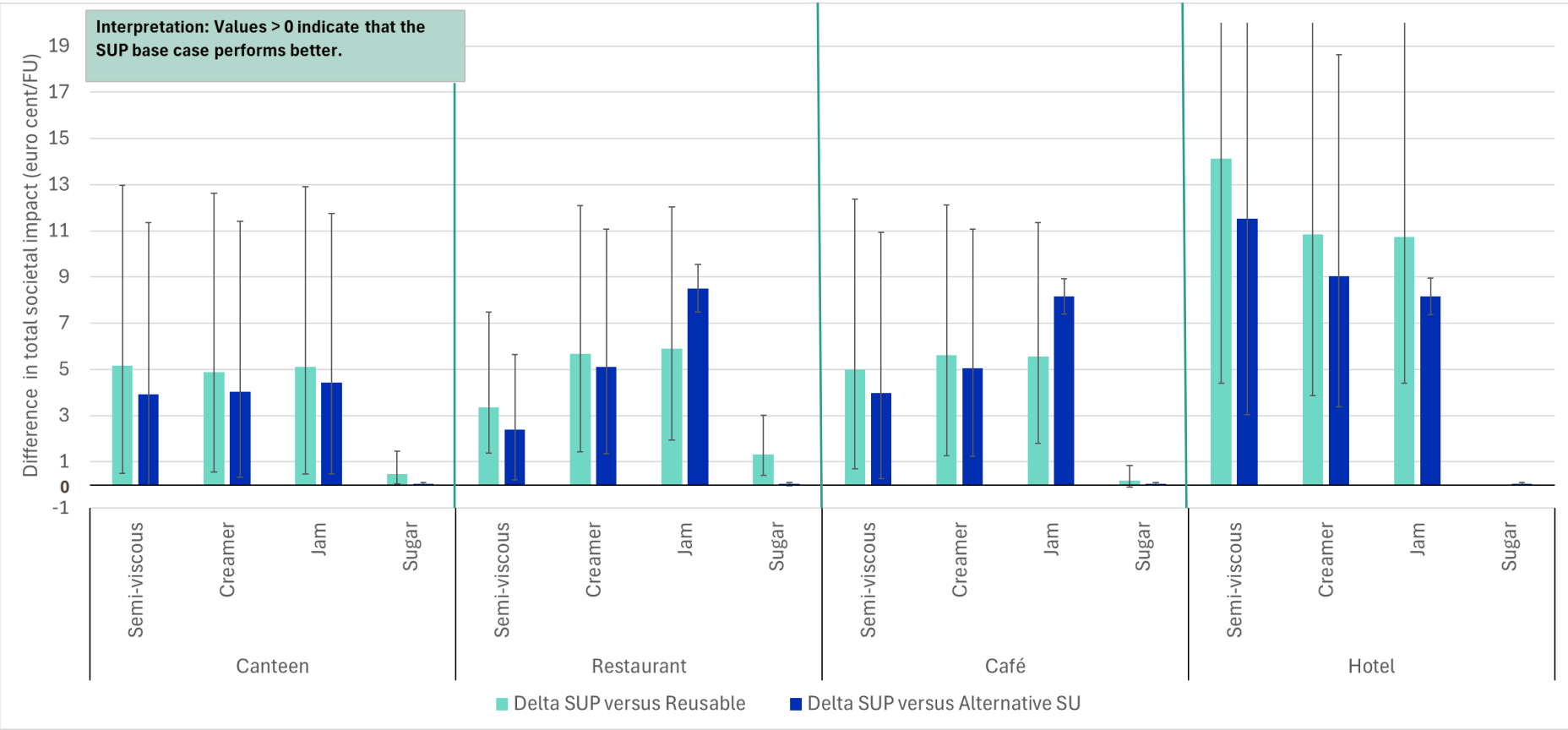


Figure 4 Difference in total societal impact between the single-use plastic base case and each of the alternatives: single-use and reusable alternative, in euro cents per functional unit.[47]

[47] The upper bound values for delta SUP versus reusable and delta SUP versus alternative single-use are cut off for Scenarios Hotel- Semi viscous (Upper bound value Delta Reusable: 34 euro cents/FU; Upper bound value Alternative SU: 31 euro cents/FU), Hotel-Creamer (Upper bound value Reusable: 21 euro cents/FU), Hotel-Jam (Upper bound value Reusable: 20 euro cents/FU) for visibility of the graph.

To illustrate how the results from this graph can be interpreted, consider the bar on the far-left (scenario Canteen-semi-viscous, comparing the reusable alternative with the single-use base case):

> *"In a Canteen setting, serving a semi-viscous portion (ketchup) into a reusable dip cup from a manual dispenser is estimated to cost **5 euro cents (or 0.05 euros)** more to society, aggregating economic, environmental and social perspectives, compared to the single-use plastic consumer portion packaging."*

In all scenarios, the single-use plastic base case performs better on average than the other two options. The alternative single-use performs better than the reusable option, except in scenarios involving the single-use glass alternative for jam (Restaurant-Jam, Café-Jam and Hotel-Jam).

The error bars in the graph indicate that this result holds for most scenarios when the full range of parameter values defined in sections 3 and 4 are tested. Sensitivity analysis results are discussed further in section 7.

Total impact per pillar (economic, social and environmental)

The same results are presented in the figure below, separated into environmental, economic, and social monetised impacts. Each bar in the figure below represents the difference in impact between the alternative and the single-use plastic base case in a specific scenario.

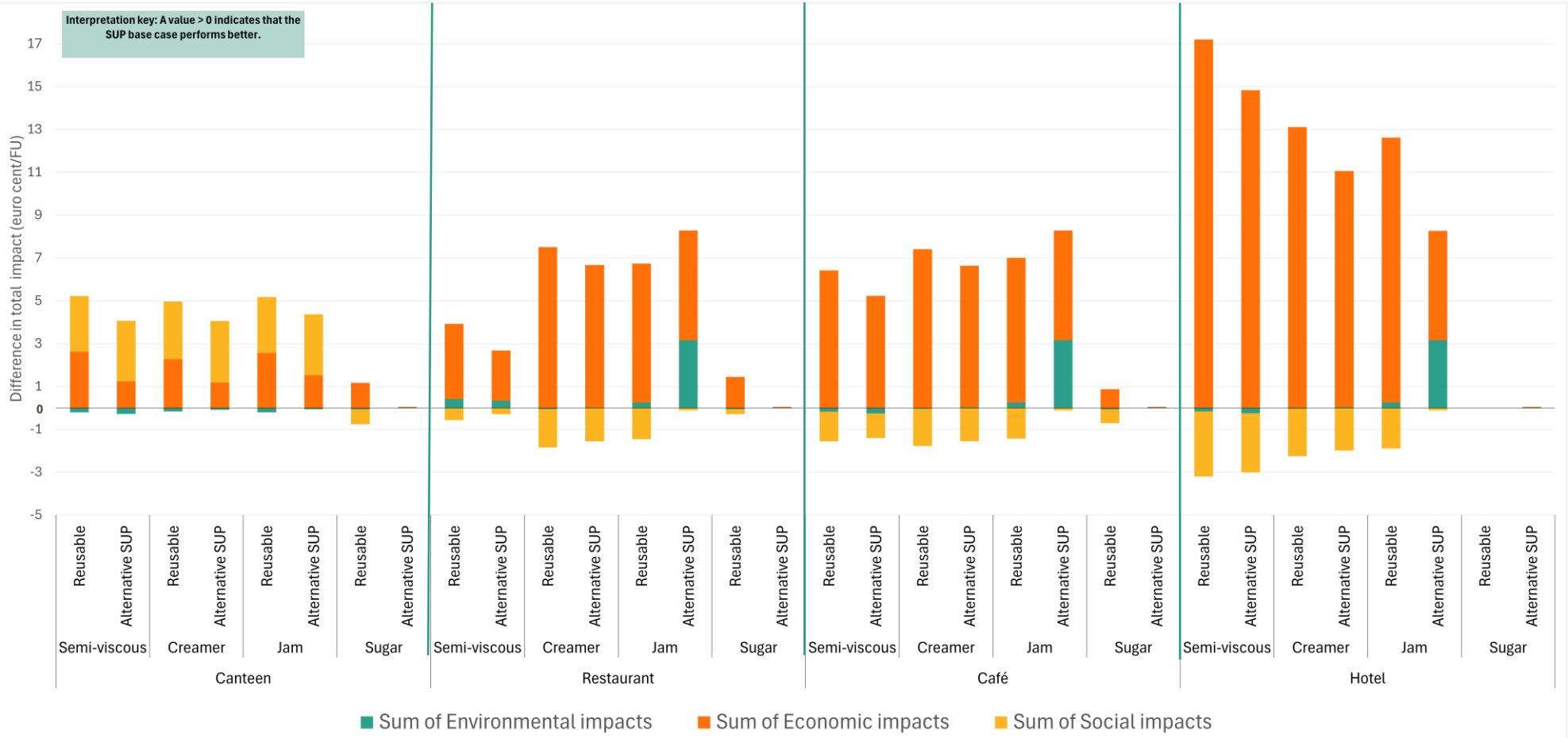


Figure 5 Difference in impact per pillar between the single-use plastic base case and each of the alternatives: single-use and reusable alternative, in euro cents per functional unit.

The graph shows that the **economic pillar contributes the most to explaining the difference in societal impact**; the differences in economic costs between the single-use plastic base case and the alternatives weigh much more than differences in environmental and social impacts. Only in the canteen scenario, is the difference in the social pillar as big or bigger than the difference in the economic pillar.

Economic impacts

From an economic perspective, the single-use plastic base case is, on average, the least costly option in all scenarios. This is mainly due to the additional labour time required for servicing and supporting operations (e.g. cleaning dispensers and loading dip cups into washing machines), and to a lesser extent, the additional CAPEX investment required (e.g. a dishwasher for reusable cups for Semi viscous (sauce), cream and jam scenarios). Even when the alternative allows for a more optimised transport, this does not compensate the extra service costs (see detailed results in Annexe 12).

Several points should be noted when interpreting these results:

- The additional service time required for the dispensing solution is due to the careful handling of the product and cup required when serving from a dispenser or bulk packaging compared to a sealed solution. However, this parameter is technology-sensitive, and dispensing technologies and service operations may become more efficient with wide-scale deployment in the future (see section 9 that describes how this limitation was tackled in this study)
- The higher economic costs of the alternatives to the base case in the hotel scenarios can be explained by the low consumption flow defined for these scenarios. Fixed economic costs, particularly training costs for employees to handle more complex operations, weight more per functional unit than in other consumption locations where more portions are served in a year. The assumptions made to model these training costs are detailed in Section 4.2.1.4.

Social impacts

From a social perspective, the alternative options generate a greater positive social impact than the base-case in most scenarios. This result is driven by the positive value of job creation associated with the higher labour required to provide alternative options.

- As mentioned for economic costs, additional labour time required for the dispensing solution is a technology-sensitive parameter. Dispensing technologies and service operations may become more efficient with wide-scale deployment in the future, requiring less additional labour and therefore generating a smaller positive social impact associated with job creation.

However, for the scenarios where semi-viscous sauce, jam and sugar served in a canteen (for both alternative SU and reusable comparison), the base case has a greater positive social impact:

- This can be explained by the fact that clients serve themselves and the time spent serving is considered a cost (burden of client's time). As the alternative options, served from manual dispensers, require a longer service time than the SUP base case, the latter is the cheaper option from a social perspective.

Environmental impacts

Due to the small share of the environmental pillar to the difference in total societal impact, the figure above causes the difference in environmental impact to be negligible compared to the difference in economic impact. Nevertheless, we cannot conclude that the difference in environmental impact is negligeable.

The LCA (environmental impacts) allows us to express the total results of the different packaging options in relative terms: the table below presents the difference in impact between the SUP base case, and either the reusable or single-use alternative as a percentage of the absolute environmental impact of the base case.

Like the figures presented above:

- A positive percentage (+) indicates that the SUP base case performs better (lower environmental impact) than the alternative.
- A negative result (-) indicates that the SUP base case performs worse (higher environmental impact) than the alternative.

Table 24 Difference in environmental impact between the alternative compared to the SUP base case option, relative to the absolute environmental impact of the SUP base case.

Scenario		Difference in environmental impact (%)	
Location	**Food type**	**Reusable alternative vs SUP**	**Single-use alternative vs SUP**
Canteen	Semi-viscous	-42%	-59%
	Creamer	-55%	-30%
	Jam	-43%	-14%
	Sugar	-70%	23%
Restaurant	Semi-viscous	88%	71%
	Creamer	-18%	7%
	Jam	53%	665%
	Sugar	-63%	23%
Café	Semi-viscous	-36%	-53%
	Creamer	-12%	13%
	Jam	53%	665%
	Sugar	-70%	23%
Hotel	Semi-viscous	-31%	-46%
	Creamer	-12%	13%

	Jam	53%	665%
	Sugar	N/A	23%

Note: a difference of at least 20% between the base case and the alternative needs to be reached before a conclusion can be made. Below this threshold of 20%, we assume the difference is too small to make a definite statement on the performance of the alternative compared to the base case. This threshold is needed due to inherent uncertainty in the LCA (methodology, database, assumptions, data etc.) which by itself could explain the difference between the compared packaging options. The threshold is defined based on practitioner experience, as there is no clear guideline on how to define such threshold.

For 12 out of 31 comparisons, the **base case has a lower environmental impact** than the alternative:

- **Restaurant – semi-viscous (both)**: both alternative options use the squeeze bottle in combination with the reusable plastic cup or single-use paper cup, ultimately leading to a higher weight of packaging/serving options per functional unit compared to the base case (SUP). This results in an environmental impact 71-88% greater than the SUP base case.
- **SUP vs. alternative SUP comparison for jam** in the restaurant, hotel and café location: in these scenarios, the alternative SUP is a glass jar with steel lid. This serving option has a much higher weight of the packaging than a plastic dip cup, leading to increased environmental impact during manufacturing (more material needed), transport (higher weight) and end-of-life (more material to treat, recycling partly offsets impact of manufacturing). This results in an environmental impact 665% greater than the SUP base case.
- **Plastic vs. paper sachet for sugar**: the result of this comparison is mainly driven by packaging weight. On a per kg-basis, paper has a lower environmental impact than the plastic option but the total weight of the paper sachet is much higher than the plastic sachet and may still requires a plastic liner. [48]

For 12 out of 31 comparisons, **the alternative has a lower environmental impact** than the SUP base case:

- Ten comparisons model the plastic pouch fitted into the manual dispenser as part of the alternative packaging system (for scenarios Canteen - Creamer/Jam/Sugar; Canteen/Café/Hotel - Semi viscous), for which the alternative has a lower environmental impact ranging from 30 - 59% lower than the SUP base case.
- Two comparisons model the sugar bowl as a reusable alternative and result in a 70% lower environmental impact than the SUP base case.

[48] Sachet weights are probable estimates. In other words, it is possible to find products on the EU market with this or similar weight. This study does not, however, include extensive market research to find average weight and standard deviation on these weights. As such, the comparison for this packaging type (the sachet) for two material types (plastic vs paper-based) would require a more in-depth LCA study to draw definitive conclusions on the environmental performance of these two formats. Companies considering a switch from plastic to paper-based sachets may require a dedicated LCA using product-specific and company-specific data (e.g. on logistics) rather than relying on these results.

These scenarios all use packaging/serving configurations that lead to a lower weight of packaging per FU compared to the base case, leading to the improved environmental impact.

5.3.2 Breakdown of impact contributions by lifecycle phase: Example of Canteen - Semi viscous – SUP base case versus Reusable alternative

The following section aims to aid the interpretation of the results presented in the above sections by describing how the aggregated results are reached.

The SUP base case versus the reusable alternative in the **Canteen - Semi viscous** scenario is used as an example. To recall, this comparison includes:

- **SUP base case**: 25ml sealed SUP dip cup
- **Reusable alternative**: 5L plastic pouch packaging that fits into a manual dispenser, served into a 25 ml reusable PP cup.

The following figure illustrates how we arrive at an aggregated result (the difference in total societal impact) between an alternative and the SUP base case, step by step:

1. For each packaging option we model the monetised impacts for relevant steps within a lifecycle phase for each pillar separately. As a reminder, the total impacts for the economic and social pillars do not equal the "total cost", as we only consider economic and social costs where a cost difference occurs between the alternatives and the base case.
2. Next, we calculate the difference between the reusable alternative and the SUP base case for each life cycle step within each pillar.
    - A positive result (+) indicates that the SUP performs better than the alternative
    - A negative result (-) indicates that the SUP performs worse than the alternative
3. Next, we aggregate the differences in impact at a pillar level.
4. Finally, we aggregate the results from all three pillars to obtain a overall difference in societal impact.

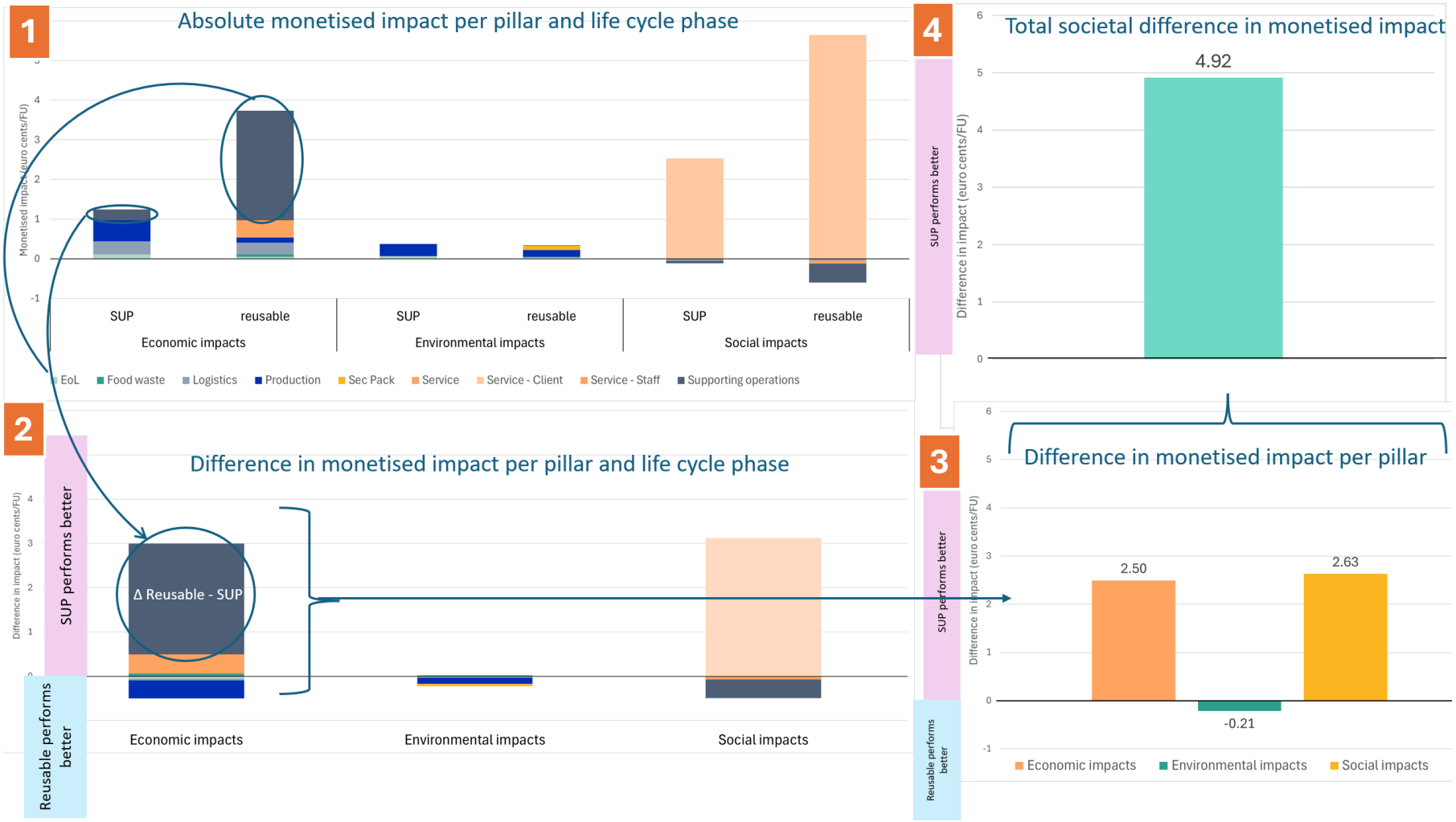


Figure 6 Pedagogical diagram explaining how the difference in societal impact between an alternative and the SUP base case is calculated.

Bearing this logic in mind, the following interpretations can be offered to explain the final result of the comparison:

- The difference in **social cost in the service phase** between the reusable alternative (plastic pouch packaging in a manual dispenser, served into a reusable PP cup) and the SUP base case (plastic consumer portion dip cup) contributes significantly to the overall difference in impact. This is driven by the difference in serving time which is on average 4 times greater for the alternative compared to the base case.
- The difference in **economic cost in the supporting operations phase** between the reusable alternative (plastic pouch packaging in a manual dispenser, served into a reusable PP cup) and the SUP base case (plastic consumer portion dip cup) contributes significantly to the overall difference in impact. This is driven by the additional staff (labour) time needed to clean dispensers and cups as well as additional training and monitoring for the dispensing alternative compared to the base case.
- Even though the alternative performs better, from an **economic and environmental** perspective, in terms of production and end-of-life (due to less packaging weight required per functional unit) as well as logistics (due to a denser packaging, more functional units can be transported in a lorry, under an optimised logistics scenario), the higher economic service costs of serving the alternative outweigh these gains, meaning that the SUP base case performs better than the alternative from a societal point of view.

5.3.3 Focus on the contribution of food waste to the difference in impact

Food waste impacts are included in the results presented above. This section aims to present the relative contribution of food waste impacts to the difference in societal impact between alternatives and the SUP base case.

Recall that we do not consider food waste related to consumption behaviour, i.e. when customers do not finish their sauce during a meal, due to the high level of variability and uncertainty associated with this parameter. Instead, we consider food waste related to residue remaining in bulk packaging (for semi viscous (sauce) and jam only), throwing out unfinished bulk packaging for quality/food safety reasons (where consumption is low) and accidental spillage when customers serve themselves from a dispenser.

Contribution to the societal impact results (aggregated economic, environmental, social impact)

The table below presents the contribution of food waste associated for the reusable and alternative single-use packaging options to the difference in societal impact compared to the SUP base case, aggregating economic and environmental impacts.

Table 25 Contribution of food waste to the difference in societal impact between the reusable and single-use alternatives compared to the base case.

Scenario		Food waste as % of difference in societal impact	
		Reusable vs SUP	Single-use alternative vs SUP
Canteen	Semi-viscous	1%	2%
	Creamer	0.2%	0.2%
	Jam	2%	3%
	Sugar	1%	0%
Restaurant	Semi-viscous	6%	8%
	Creamer	0.4%	0.5%
	Jam	7%	0%
	Sugar	1%	0%
Café	Semi-viscous	4%	5%
	Creamer	1%	1%
	Jam	6%	0%

	Sugar	2%	0%
Hotel	Semi-viscous	1%	2%
	Creamer	0.4%	0.5%
	Jam	3%	0%
	Sugar	N/A	0%

The additional food waste generated by the alternative options has a very small impact on the difference in the difference in total societal impact between the base case and the alternatives. At most, it contributes 8% to the total difference between an alternative and the base. Furthermore, the food waste rate was not identified as a parameter with high influence in the sensitivity analysis.

Contribution to the environmental impact results

The table below presents the absolute contribution of food waste, from both reusable and alternative single-use packaging options to the difference in environmental impact relative to the single-use plastic base case.

Table 26 Absolute contribution of food waste to the difference in environmental impact between the reusable and single-use alternatives compared to the base case.

Scenario		Share of Food waste (%)	
		Reusable vs SUP	Single-use alternative vs SUP
Canteen	Semi-viscous	5%	3%
	Creamer	2%	4%
	Jam	15%	44%
	Sugar	2%	0%
Restaurant	Semi-viscous	7%	9%
	Creamer	0%	0%
	Jam	36%	0%
	Sugar	13%	0%
Café	Semi-viscous	18%	12%
	Creamer	52%	45%
	Jam	36%	0%
	Sugar	2%	0%
Hotel	Semi-viscous	18%	12%
	Creamer	52%	45%
	Jam	36%	0%
	Sugar	N/A	0%

In 23 of 31 comparisons, food waste accounts for less than 20% of the difference in environmental impact between packaging options. In the remaining 8 comparisons, its contribution ranges from 36% to 52%. In no scenario does food waste contribution exceed 100%, indicating that it does not reverse the net environmental benefit of any alternative packaging option.

Absolute impact results for food waste are reported in Annexe 12.

5.3.4 Environmental pillar: focus on climate change impact

The previous graphs present environmental impacts in monetary terms. In this section, we focus on the absolute results for one of the environmental indicators covered by the environmental pillar; climate change.

The following graph shows the difference in climate change impact (kg CO_2-eq.) between the single-use alternative and the reusable alternative, compared to the SUP base case, across all modelled scenarios. Similar to the results presented in monetary value:

- A positive result (+) indicates that the SUP base case performs better (lower carbon footprint) than the alternative
- A negative result (-) indicates that the SUP base case performs worse (higher carbon footprint) than the alternative

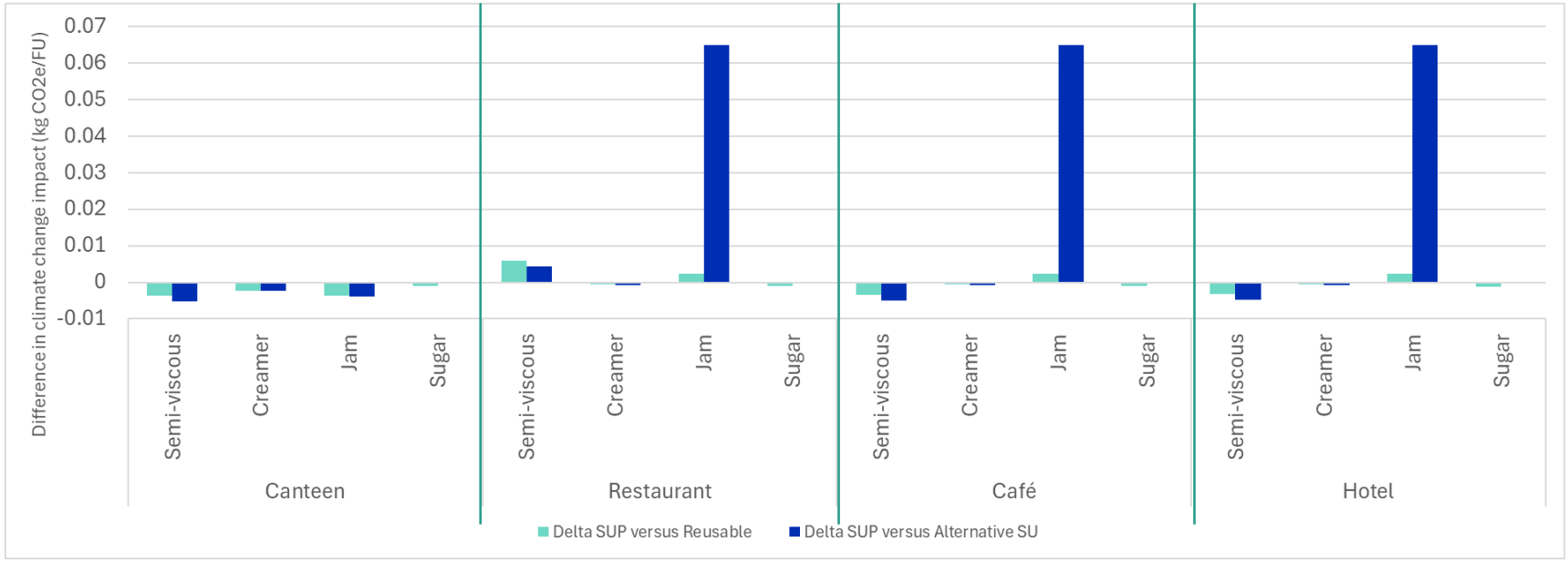


Figure 7 Difference in climate change impact between the single-use plastic base case and each of the alternatives: single-use and reusable alternative in kg CO_2e per functional unit.

This graph shows a similar result to that of the monetised environmental impact: the SUP base case outperforms the reusable alternative in all scenarios except in scenarios where a plastic pouch packaging for a manual dispenser (for both single-use and reusable alternatives) or a sugar bowl is used as a reusable alternative. This outcome is due to the reduced packaging required per functional unit compared to the SUP base case, resulting in fewer emissions during production, secondary packaging, and the end-of-life phase.

The glass based single-use alternative result in a particularly higher impact compared to the SUP base case. This outcome is due to the greater weight of packaging required per functional unit compared to the SUP base case, resulting in greater emissions during production and secondary packaging phase as well as end-of-life.

Results for total climate change impact per packaging type (SUP base case, alternative single-use, reusable alternative) as well as the relative contributions per lifecycle phase are provided in Annexe 12.

6. Extrapolation - Economic impact at EU level

6.1 Introduction

The cost-benefit analysis results presented in Section 5 are expressed in euros per functional unit (i.e. serving one portion). The objective of this section is to extrapolate the economic impacts to the EU-level, to answer the following question

What would be the EU-wide additional cost borne by consumers and producers if the current single use packaging is replaced by a reusable alternative or by a PPWR-compliant single use alternative in the assessed consumption locations for the assessed condiments?

The following figure illustrates how cost-benefit analysis (CBA) results are used to extrapolate results for the EU, expressed in millions of euros per year.



Figure 8 Extrapolation overview

The additional economic impact is first calculated for each food type and consumption location combination and then aggregated to obtain the total economic cost for each food type and overall.

6.2 Results

The following table presents the extrapolated, annual additional economic cost (in million euros per year - 2026) of the EU-wide replacement of single-use plastic packaging in restaurants, cafés, hotels and canteens by using a reusable or signal-use alternative.

Table 27 Estimated economic impact of the EU-wide replacement of single-use plastic packaging by reusable and single-use alternatives.

Condiment type	Economic impact of the EU-wide replacement of single-use plastic packaging in restaurants, cafés, hotels and canteens by:	
	Reusable alternative M€/year	Single-use alternative, PPWR compliant M€/year
Semi viscous	172	115
Creamer	488	418
Preserve	59	41
Sugar	87	3
Total	**806 million €/year**	**577 million €/year**

At an EU-level, the estimated additional economic cost of using a reusable alternative for the four food types modelled in this study is 806 million euros per year, while the single-use alternative would cost an additional 577 million euros per year.

6.3 Data and assumptions used

To estimate the EU-wide annual economic impact of replacing single-use plastic packaging with an alternative, data is required on the number of condiments served in the EU per year in the consumption locations studied. However, no available dataset exists with this information. The next-best approach is to make an estimation based on the available statistics and assumptions.

The estimation of the number of condiments served in the EU per year requires two types of parameters, presented in the table below.

Table 28 Parameters for estimating the number of condiments served in the EU annually.

Parameter needed for estimation	Approach
1. Number of food service visits per year in the HoReCa consumption locations studied (canteens, restaurants, cafés and hotels)	Estimated using publicly available sources (Eurostat or national statistics datasets, Industry federation reports, market analysis reports etc.). Sources are provided in Annexe 13.
2. Number of condiments in SUP packaging served per visit (in %)	Given the lack of available data, percentages are considered by the authors for each food type in each consumption location, reflecting likely consumption and food service practices in the EU.

The following table presents the proportion of meals/beverages served with a condiment in SUP packaging considered by the authors for the different consumption location and food type combinations. These reflect likely consumption and food service practices in the EU.

Table 29 Proportions of meals/beverages served with a condiment in SUP packaging for each consumption location and food type studied.

Food type	Canteen	Restaurant and Café	Hotel
Semi viscous	20%	30%	5%
Creamer	30%	30%	30%
Preserve	10%	5%	50%
Sugar	30%	30%	30%

Taking the top-left cell as an example, the percentage can be interpreted as follows: *20% of meals served in a canteen are currently served with a semi viscous sauce packaged in sealed single-use plastic packaging.*

7. Sensitivity analysis and alternative scenarios

The previous chapter presents the baseline results, which means an average value is used for all parameters in the model that are defined with a range of values. To ensure robust conclusions, we perform **sensitivity analyses** to assess if the expected range of values on these parameters could lead to **tipping points in the conclusions**.

Furthermore, we investigate alternative scenarios, not covered by the baseline results nor by the ranges on the parameters. These alternative scenarios are:

- Assessment of a **constrained wood market**, which is of high relevance for all fibre-based packaging and serving options (e.g. paper cup, paper sachet…). In the baseline results, it is assumed the wood market is not constrained.
- Assessment of **an alternative single-use, sealed alternative with max. 20% plastic for serving semi viscous sauce** compared to the SUP base case**.** In this comparison, the principal drivers of the main results (i.e. additional supporting operations and service times) are the same for the two packaging options. Rather, the differences in impact are primarily driven by the packaging material and occur during the production, logistics and end-of-life phases.

7.1 Key messages

Sensitivity analysis of main results

- The parameters with the most influence on the results are the **labour cost** and the **serving times of the alternatives**.
- The sensitivity analysis shows that the **main conclusions hold in 100% of the considered cases for 26 of the 31 comparisons** between an alternative and the SUP base case, given the parameter ranges defined in this study.
- In the comparisons for which cases exist where the alternative systems perform better, **reversing the conclusion requires a combination of parameter values that are favourable to the alternative** (example: low production cost of the alternative, efficient logistics and service of the alternative, low labour cost, low extra food waste, etc.).

Zoom on environmental impact

- The **number of uses of the reusable cup is a key parameter** in the comparison of environmental impact between the reusable alternative and the base case SUP.
- The environmental benefit of each additional use diminishes as the total number of uses increases: the impact reduction from going from 5 to 6 uses is greater than from 30 to 31 uses.
- The **minimum number of reuses**, above which the alternative always outperforms the base case SUP, is **scenario-specific**.

Alternative scenario for wood constraint

- The constrained wood market scenario mainly impacts the alternative SU packaging since these are often fibre-based packaging options.
- A scenario with a constrained wood market increases the difference in monetised impact between the single-use alternative and the base case in the same direction, **therefore reinforcing the conclusion that holds in a scenario without a wood constrained market**.

Alternative sealed single-use packaging for semi viscous sauce with maximum 20% plastic

- In the comparison between the single-use max. 20% plastic alternative and the SUP base case, the SUP base case performs better from a societal perspective. This conclusion holds for 99.7% of scenarios where the full range of parameter values are tested.

7.2 Sensitivity analysis of main results

The objective of this sensitivity analysis is to determine whether the findings presented in section 5 would change when considering the full range of all parameters for which ranges are defined.

To perform the sensitivity analysis, the model uses a Monte Carlo simulation with 1000 iterations. In each iteration, a random value is assigned to every parameter within its defined range. The software then calculates the total impact for that iteration.

This results in a set of 1000 outcomes, where each point represents a possible result based on a unique combination of parameter values. Together, these points form a "point cloud" that represents the full range of possible results for the scenario.

More information on the software used for this sensitivity analysis can be found in Annexe 1.

7.2.1 Sensitivity of total societal impact results

7.2.1.1 Alternative single-use versus single-use plastic base case

The table below presents the summary of the results of the sensitivity analysis. For each scenario, the percentage of iterations with a different result trend is reported. This represents the share of iterations for which the conclusion is opposite to that of the baseline results.

Table 30 Sensitivity analysis results for the difference between the single-use alternative and the SUP base case.

Location	Food type	% of iterations with opposite conclusion to baseline results
Canteen	Semi-viscous	0.1%
	Creamer	0.0%
	Jam	0.0%
	Sugar	3.0%
Restaurant	Semi-viscous	0.0%
	Creamer	0.0%
	Jam	0.0%
	Sugar	5.0%

Café	Semi-viscous	0.0%
	Creamer	0.0%
	Jam	0.0%
	Sugar	3.0%
Hotel	Semi-viscous	0.0%
	Creamer	0.0%
	Jam	0.0%
	Sugar	4.3%

In 11 out of the 16 scenarios, the conclusion that the SUP base case outperforms the single-use alternative remains valid across the entire range of modelled parameter values.

Situations in which the conclusion is reversed for the 5 other scenarios are discussed here:

- In 4 of the remaining 5 scenarios, the paper-based sugar sachet is modelled. The situations in which the conclusion is reversed are a combination of values of parameters that are favourable to the alternative. The most influential parameter on the difference in impact is the difference in the cost of production of the packaging materials (PP plastic defined as 1300 – 4815 €/t and paper packaging defined as 1615 – 3088 €/t).
- The one other scenario concern the plastic pouch packaging in a manual dispenser alternative for serving semi viscous (sauce) or jam (Canteen-Semi viscous (sauce)). In these cases, labour cost (defined as 6.4 – 41.1 €/h) and dispenser serving time (defined as 5 – 10 s) are the parameters with highest influence on the results.

The cases where the alternative single-use option performs better than the base case, in terms of societal impact, remain marginal (maximum 5%).

7.2.1.2 Reusable alternative versus single-use plastic base case

The objective of this sensitivity analysis is to determine whether the finding that the base case performs better than the reusable alternative (presented in section 5) would change when considering the full range of all parameters for which ranges are defined.

Table 31 Sensitivity analysis results for the difference between the reusable alternative and the SUP base case.

Location	Food type	% of iterations with opposite conclusion to baseline results
Canteen	Semi-viscous	0.0%
	Creamer	0.0%
	Jam	0.0%
	Sugar	0.0%
Restaurant	Semi-viscous	0.0%
	Creamer	0.0%
	Jam	0.0%
	Sugar	0.0%
Café	Semi-viscous	0.0%
	Creamer	0.0%
	Jam	0.0%
	Sugar	11.3%
Hotel	Semi-viscous	0.0%
	Creamer	0.0%
	Jam	0.0%
	Sugar	N/A

In all scenarios, except one, the base case consistently outperforms the reusable alternative, with a positive impact difference maintained across the full range of modelled parameter values.

In the remaining scenario (Café-Sugar), the sugar bowl alternative performs better than the SUP base case in 11.3% of the cases.

- The most influential parameters in the comparison between the sugar bowl versus the single-use plastic sachet in this scenario are labour cost (defined as 6.4 – 41.1 €/h) and time needed to throw away the single-use plastic sachet (defined as 1 - 2 s).
- However, reversing the conclusion requires a combination of parameter values that are favourable to the alternative (example: low production cost of the alternative, efficient logistics and service of the alternative, low labour cost, low extra food waste, etc.).

7.2.2 High impact parameters

It should be noted that, within the ranges of uncertain parameters considered in this study, no single parameter alone was sufficient to reverse the difference in societal impact between an alternative and the base case. The instances where the alternative outperformed the base case, as highlighted above, resulted from the combined effect of multiple parameters.

However, the following parameters were identified as having the greatest impact on the difference in societal impact between the alternatives and the base case across the scenarios. The range considered in the modelling is presented.

Table 32 Parameters with the greatest impact on the difference in societal impact between alternatives and SUP base case.

Parameter with high impact on the results	Lower bound	Upper bound
Cost of labour	6.4 €/hour	41.1 €/hour
Serving time for the alternative options	See section 4.2.1.3 – specific to scenario	See section 4.2.1.3 – specific to scenario

7.2.3 Zoom on the impact of number of uses parameter – reusable versus base case

One of the parameters that defines most of the difference in environmental impact between reusable alternatives and the SUP base case is the **number of uses of the reusable PP cup,** defined between 5 and 100 uses in the model. This range is high to account for the uncertainty in the actual number of times a reusable cup will be used in an optimised scenario. The use rate is the inverse of the loss rate: if 1 in 20 cups is lost per round of use (5% loss rate), each cup is used 20 times on average. A use rate range of 5–100 therefore corresponds to a loss rate range of 20–1%.

Note: The graph below is intended to illustrate the importance of this parameter on the result for the scenario Canteen – Jam. **While this graph would look different for each scenario, the principle remains the same.**

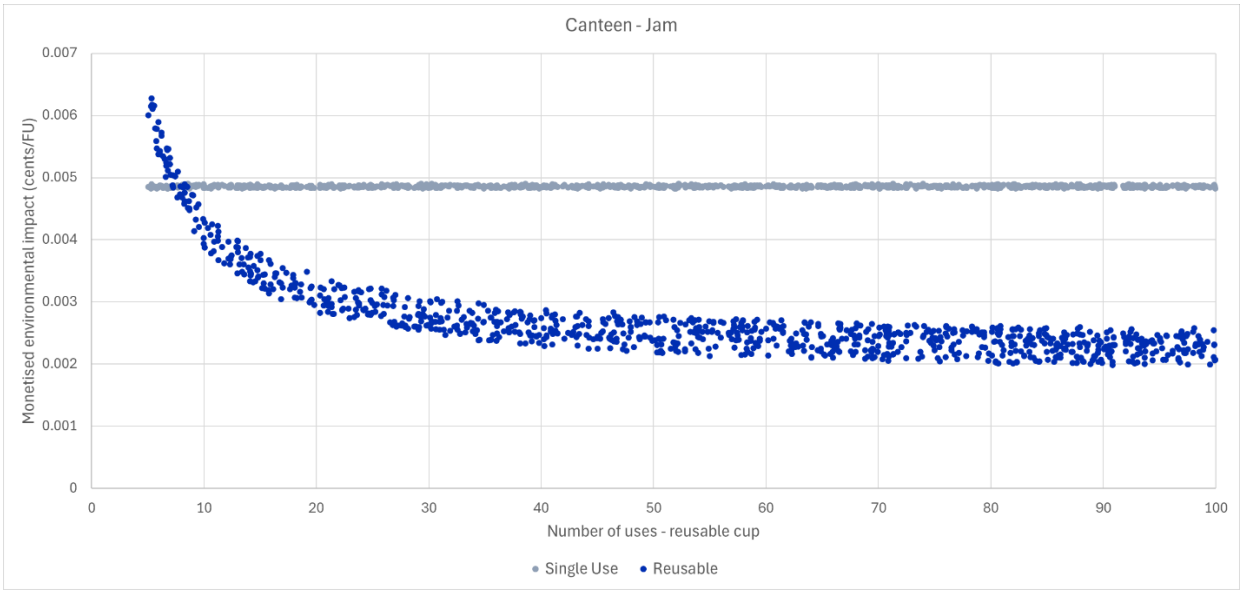


Figure 9 Absolute environmental impact (euro cents per functional unit) shown across the range of number of uses for the reusable cup defined in the model, for the reusable alternative and SUP base case (Canteen - Jam scenario).

Each point represents the monetised environmental impact given a randomly selected number of uses of the reusable cup, as tested in the sensitivity analysis across 1000 iterations. There are two point clouds in this graph:

- Grey point cloud representing the SUP base case: the point cloud for SUP base case displays a constant trend, as the result is not affected by the number of uses.
- Blue point cloud representing the reusable alternative: this point cloud displays a logarithmic trend. When the number of uses is small, an increase in the number of uses results in a large decrease in environmental impact but as the number of uses increases, the marginal decrease in environmental impact gets smaller.

The width of the point clouds (along the y-axis) is defined by the ranges on the other parameters, in other words, it is the residual uncertainty.

This graph helps to identify tipping points in conclusions:

- **The maximum number of uses for which the SUP base case will always perform better than the alternative, regardless of the variation in other parameters**: In this comparison, when the number of uses is below 7 in this particular scenario.
- **The range of number of uses for which other parameters determine which alternative is better**: In this comparison, when the number of uses is between 7 and 9.
- **The minimum number of uses after which the alternative will always perform better than the SUP base case, regardless of the variation in other parameters:** In this comparison, when the number of uses is 9 and above.

The relatively low number of uses required for the alternative to always perform better than the base case can be partly explained by the assumption of in-house cleaning used in the study. As mentioned in 1.3.2, alternative washing configurations such as an external washing step in a washing facility are not in scope of the study. Such an alternative washing configuration could impact the tipping point, and will be determined by parameters such as the water and electricity consumption of the washing facility, the transport distance, the transport fuel, the loading rate of the truck etc.

7.3 Alternative scenario: Wood constrained market

7.3.1 Introduction and methodology

In this study, the production of the following packaging implies wood consumption:

- Primary packaging:
  - Paper sachet
  - Paper cup thin/rigid
- Secondary packaging: cardboard box

Renewable resources consumption may have non-proportional effects. Indeed, as long as the consumption rate is lower than the production rate, the resource is virtually unlimited or unconstrained. This is the case for example of oxygen or nitrogen in the air: no impact is due to the loss of resource. But if the consumption rate is higher than the production rate, as it is the case for fish stocks and some exotic forests, this will make these resources unavailable (or less available) to term.

As wood is a renewable material, it has the potential to be infinitely supplied. Currently, European forest stocks are growing and sustainable practices of forest management are spreading. However, several internationally recognized institutions, such as FAO and CEPI, indicate that:

- There may be a competition for access to resources between different sectors of wood consumers in the future (at least to a time-horizon of 40 years, which is the time taken by a tree to regrowth) and
- Concerted action is required if negative impacts on these areas should be avoided.

It is therefore important to check that there is no lack of wood over a period of 40 years to consider the resource wood is a renewable resource "virtually unlimited". Otherwise (and although there is no consensus on this position), wood has to be considered as "non-renewable", with competition on the market of this resource.

The main driver behind this increased competition is the increasing demand for wood from the energy sector. However, there are substantial uncertainties about the supply-demand balance on the horizon of 40 years, mainly due to variation in demand, as production capacity is known. In particular, the future development of renewable energy (wood energy is strongly stimulated by ambitious legislation) is a big question mark.

Failing to have reliable offer/supply curves, one can only consider extreme situations:

- Unconstrained wood supply
- Constrained wood supply

In practice, the ideal model is intermediate between the extremes because the supply is elastic (as productions vary depending on the types of trees, parcel size, accessibility...). In the model we assume the following cases:

- Base case: the results presented in section 5.3 are based on a model assuming unconstrained wood supply
- Alternative case: the results in this section show the results of the LCA assuming a constrained wood supply

Unconstrained wood supply



This scenario considers that wood supply is able to meet any increased demand for wood, without price increase. Therefore, wood consumption has no impact on other consuming wood sectors. It is the methodological choice made in most LCAs.

Consequently, the wood consumption has no direct effect on the resource availability. If the wood would not been used for the production of bag-in-boxes, cups, sachets or cardboard boxes, it would remain in the forest.

Also, in case of recycling, avoided impacts are only linked to cutting and transporting wood.

Constrained wood supply



This scenario considers that wood supply cannot fully adapt to increased demand for wood. In other words, consumption rate is higher than the rate of forest growth. In a consequential approach, it is assumed here that the energy sector will have to substitute wood used as an energy resource by fossil fuels.

Consequently, if the rate of depletion is reached, the use of wood can lead to fossil fuel consumption. Then, in case of recycling, avoided impacts also involve avoided fossil fuel consumption.

In the constrained scenario, heat that could have been produced with virgin wood has to be produced by another source of heat, considered here as a mix of fossil production modes (assuming that the market of waste wood is also constrained). For each material consuming virgin wood at the production step, the amounts of softwood and/or hardwood under bark consumed are obtained from the UPR information from Ecoinvent (amounts expressed in m^3). The associated useful heat per m^3 is calculated as in Table 26 .

Table 26 Heat from wood to be substituted

Type of wood	Density (kg/m3)	LHV (MJ/kg)	Efficiency boiler (%)	→ MJ heat/m3
Softwood	430	19.1	75	6160
Hardwood	650	18.3	75	8921

Sources: activities in EcoInvent 3.11

Softwood: heat production, softwood chips from forest, at furnace 1000kW

Hardwood: heat production, hardwood chips from forest, at furnace 1000kW

A limit of this approach is that it considers the wood market as a single common market. This does not consider the fact that some wood is mostly used for material (including for packaging), and other for energy applications. Two distinct markets are maybe coexisting. In that case, the use of wood as material would not directly result in a substitution in the energy sector, but maybe rather in a substitution of packaging material, for example.

7.3.2 Results

The results presented below only show the environmental impact in monetary value, as it is assumed that the economic and social impacts remain unaffected in a constrained wood market scenario.

The figure below shows the difference in environmental impact between the alternative single-use option and the base case in scenarios where the effect of a constrained wood market is greater than 10%. The green bars represent the base results with a unconstrained wood market presented in section 5, whereas the orange bars present results with a constrained wood market.



Figure 10 Difference in environmental impact (single-use alternative versus SUP base case) in a scenario with and without a constrained wood market.

In a scenario with a constrained wood market, the average difference between the single-use alternative and the base case changes by a maximum of 100% compared to a scenario with no constraint (Scenario Restaurant-Creamer).

The direction of the effect is always the same as the delta. In other words, if the single-use alternative performs better from an environmental perspective without a constrained wood market (e.g. Canteen-Semi viscous), it performs even better in a constrained wood market. The opposite is also true: if the base case performs better from an environmental perspective without a constrained wood market (e.g. Canteen-Sugar), then in a constrained wood market, the base case performs even better.

The impact of the constrained wood market scenario on the difference in total societal impact is negligeable. A table presenting the difference in total societal impact with and without wood constraint is included in Annexe 12.

7.4 Alternative packaging for semi viscous sauce: sealed single-use max. 20% plastic alternative

7.4.1 Introduction

This sensitivity analysis compares the environmental, economic and social impacts of additional packaging option for serving 25 ml of semi-viscous sauce in a restaurant setting compared to the SUP base case:

- A sealed single-use moulded carton cup (fibre-based with a PE lining), referred to as the *SU max. 20% plastic alternative*

This section presents additional data and the assumptions used to perform the analysis, as well as the main results of the comparison. A complete description of the methodology and data inventory can be found in sections 3 and 4.

7.4.2 Data inventory for the SU max. 20% plastic alternative

7.4.2.1 Primary packaging production

The SU max. 20% plastic alternative is made up of the following components:

- A moulded fibre pot and lid, made of fibre-based (paper) material
- A liner, made of Low-density polyethylene (LDPE)

Given that this packaging option is not currently used at scale, CPIC member data was consulted to define ranges for the following parameters.

Table 33 Primary packaging production and End of Life phases – key parameters for the moulded carton cup

Parameter	Range
Total weight of the SU max. 20% plastic alternative	2.5 – 3.1 g
Fraction of material weight that is plastic (PE)	10% - 20%
% of recycled content	0%
Recycling rate	75%
Collection rate	84%
Recycling efficiency	90%
Sorting efficiency	99%
Incineration rate	25%

Source: ranges defined by consulting industry data provided by CPIC members.

When the SU max. 20% plastic alternative is heavy, the PE plastic content is around 10%. However, when the SU max. 20% plastic alternative is lightweight, the PE plastic content is around 20%.

7.4.2.2 Secondary packaging

We assume that the same model of cardboard carton as that used for the SUP base case is used for the SU max. 20% plastic alternative. The table below summarises the key parameters.

Table 34 Secondary packaging production – key parameters for the SU max. 20% plastic alternative

Parameter	Value or range
Number of cups per carton	125
Cardboard weight (g)	120

7.4.2.3 Logistics phase

The key parameters for the logistics phase presented in the table below. The ranges are driven by the difference in total primary packaging weight (defined between 2.5 and 3.1 g per cup).

Table 35 Logistics – key parameters for the SU max. 20% plastic alternative

Logistics step	Parameter	Value
First leg (production site to distribution)	Number of cartons per lorry – 28t semi-trailer	6700
Second leg (distribution site to consumption location	Number of cartons per lorry – 7.2t lorry	636 - 648

If the weight of the primary packaging is higher, fewer cartons or pallets can be transported in the lorry.

7.4.2.4 Use phase

The same parameter values for use phase (service and supporting operations) are taken for the SU max. 20% plastic alternative as the SUP base case. See sections 4.2.1.3 and 4.2.1.4.

7.4.3 Results

Societal impact results (aggregated environmental, economic and social impacts)

The figure below presents the difference in societal impacts for the 39 comparisons reported in the main report plus the additional comparison between the SU max. 20% plastic alternative and the SUP base case in Scenario Restaurant-Semi viscous, aggregating all three pillars. The green box indicates the comparisons in Restaurant- Semi viscous scenario. Impacts with monetary valuation are presented in cents per functional unit (FU). The error bars indicate minimum and maximum values of these differences resulting from the sensitivity analysis where the full range for all parameters with a range are assessed.

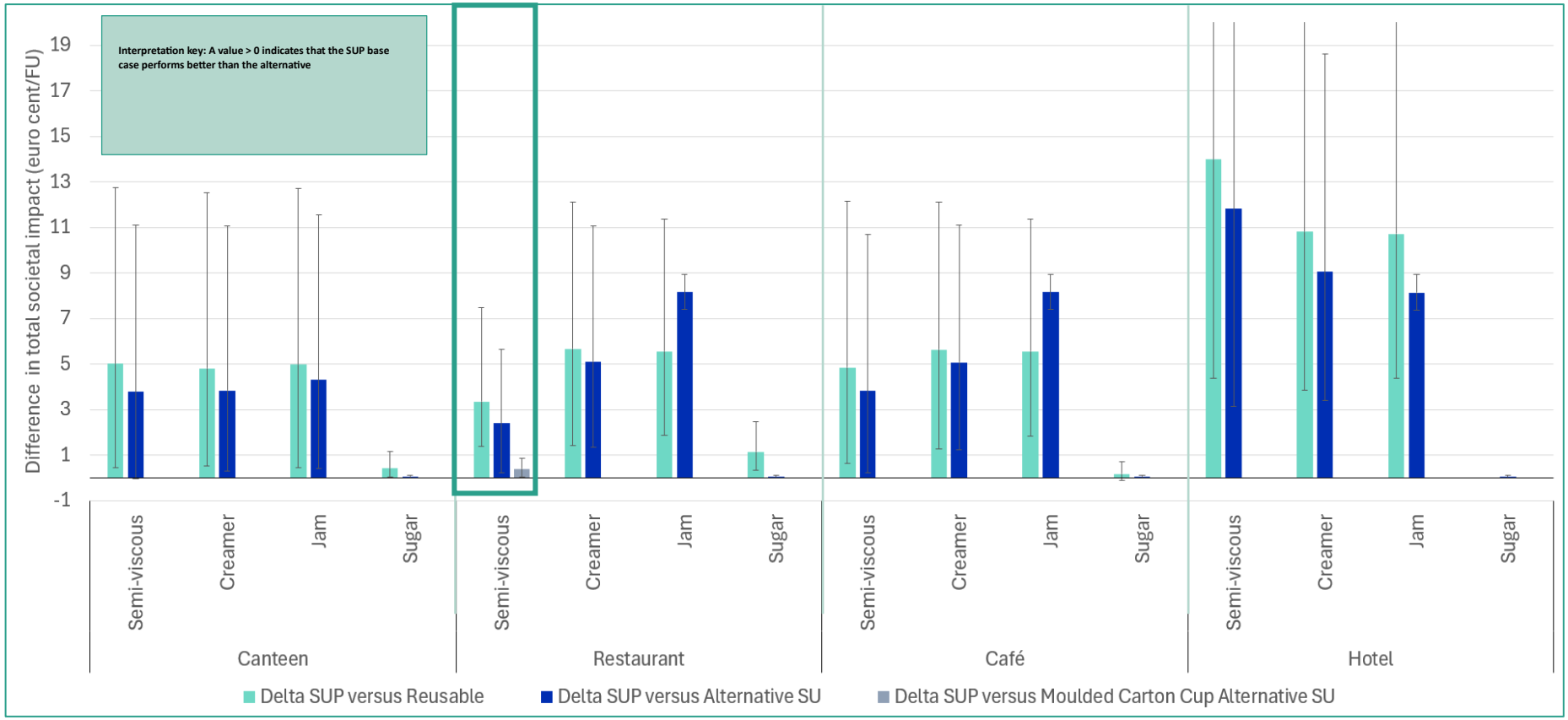


Figure 11 Difference in total societal impact between the single-use plastic base case and each of the alternatives: single-use and reusable alternative, in euro cents per functional unit.[49]

[49] The upper bound values for delta SUP versus reusable and delta SUP versus alternative single-use are cut off for Scenarios Hotel- Semi viscous (Upper bound value Delta Reusable: 34 euro cents/FU; Upper bound value Alternative SU: 31 euro cents/FU), Hotel-Creamer (Upper bound value Reusable: 21 euro cents/FU), Hotel-Jam (Upper bound value Reusable: 20 euro cents/FU) for visibility of the graph.

To illustrate how the results from the above graph can be interpreted, consider the third bar to the left, for scenario Restaurant-semi-viscous, comparing the SU max. 20% plastic alternative and the SUP base case:

> *"In a Restaurant setting, serving a semi-viscous portion (ketchup) from a moulded carton cup (with max. 20% plastic) is estimated to cost on average **0.39 euro cents (or 0.0039 euros)** more to society, aggregating economic, environmental and social perspectives, compared to the single-use plastic dip cup."*

In the comparison between the SU max. 20% plastic alternative and the SUP base case, the SUP base case performs better from a societal perspective. This conclusion holds for 99.7% of scenarios where the full range of parameter values are tested.

Results per impact pillar

The results for the comparison between the SU max. 20% plastic alternative and the SUP base are presented in the figure below, separated into environmental, economic, and social monetised impacts, in euro cents per functional unit.

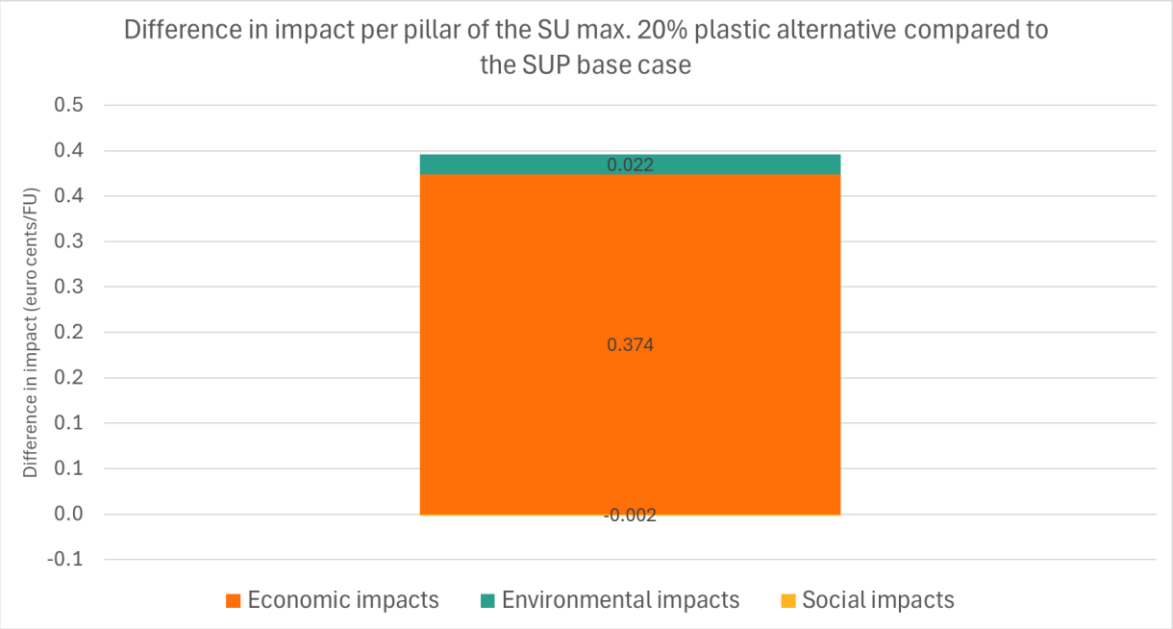


Figure 12 Difference in impact per pillar between the SUP base case the SU max. 20% plastic alternative, in euro cents per functional unit.

The SUP base case performs better than the SU max. 20% plastic alternative from an economic perspective. This result is mainly driven by the additional packaging weight required per functional unit for the SU max. 20% plastic alternative which is associated with a higher economic cost in primary packaging production and logistics.

The total weight of the SU max. 20% plastic alternative is higher than the SUP base case (2.5 – 3.1 g for the SU max. 20% plastic alternative versus 1.13 g for the SUP base case) and still requires a plastic liner. The higher weight of the SU max. 20% plastic alternative results in a 4% greater environmental impact compared to the SUP plastic base case. However, this difference falls within the defined threshold of 20%, so no definitive conclusion can be drawn on which option performs better.

When a wood constrained market scenario is tested, the SU max. 20% plastic alternative results in a 12% greater environmental impact compared to the SUP plastic base case. However, this difference

falls within the defined threshold of 20%, so no definitive conclusion can be drawn on which option performs better.

From a social perspective, the SU max. 20% plastic alternative performs marginally better than the SUP base case, linked to the logistics phase.

8. Health and food safety impact assessment results

The food safety comparative risk level conclusions by scenario are available in

8.1 Food safety

8.1.1 Base case vs alternative

8.1.1.1 Sealed individual-portion pack composed of alternative material

These scenarios (paper sugar sticks with plastic lining, ketchup in paper based sachet, and small glass lidded jar for jam) generally have a very low impact on food safety compared to the base case as the product is as it is also sealed right up to point of consumption by the customer, preventing contamination, and allows for clear branding/labelling identification of the product and for allergens/ingredients to printed on the pack.

- **Glass**: whilst it is a well-established, widely used packaging format (including in hospitality/hotels), is a much higher risk material for use as a packaging format in a food operation. Glass may break into sharp pieces and is transparent so is difficult to see if it falls into food/food-contact equipment, presenting a higher severity and likelihood of injury. Many food businesses therefore have a policy of not handling foods in glass on the premises. Businesses handling glass should have robust handling controls in place and procedures to follow in the event of a breakage for safe cleaning up and disposal of broken glass and careful inspection of product and surrounding environment for contamination and potentially disposing of product that may have been at risk from contamination.
- **Paper-based alternative sachets**: If a paper-based alternative can be sourced with the same physical robustness, rigidity, seal integrity and barrier properties as a plastic sachet, then there should be no difference in risk for food safety (or quality impacts). However, suitability must be assessed on a product-specific case-by-case basis and may be challenging to achieve particularly for more liquid / wet products.

Best practice is for extensive trials to be carried out by the product manufacturer in collaboration with the packaging manufacturer assessing the safety and quality performance of the product through its shelf life in the new packaging type. The recipe/formulation of the product could also affect its suitability to be packaged in a paper-based alternative - for example, different ketchups/condiment sauces with different acidity/pH levels or different oil contents may behave differently through life when in contact with the packaging material, and therefore different types should be trialled, rather than assuming one format/material will be suitable for all sauces.

We have assumed that a paper-based product could certainly be fit for purpose, but that the robustness and barrier properties and therefore product shelf life could be very slightly reduced compared to the base case. If slightly less robust then potentially there could be a higher rate of broken packs during handling by staff and customers, resulting in slightly higher risk for hygiene and requirement for more frequent cleaning. There would not however be a significant difference in food safety risk compared to the base case as long as the alternative had been suitably trialled and approved for suitability.

8.1.1.2 Sealed to open single use disposable container

These scenarios present a higher risk to food safety as the product is open, and additional process steps are introduced into the serving process which present additional physical, chemical, microbiological and allergenic hazards.

Open, unsealed containers present a higher risk of physical, chemical and microbiological contamination of the food itself from people (staff and customers), the environment/equipment, and a higher risk of allergenic contamination from other foods handled in the setting.

Physical - The alternative scenarios with dispensers and cups introduce additional equipment/food contact surfaces into the process, which presents a greater potential for physical contamination through broken or damaged plastic and metal parts –e.g. plastic cups / metal pot / tongs / dispensers. Open cups would need to be stored hygienically back-of-house to prevent foreign bodies falling in during storage.

Chemical - Open, unsealed containers present a greater risk of contamination from chemicals within the food environment – such as cleaning chemicals. Dispensers and open cups would need to be stored appropriately back-of-house, segregated from chemicals to prevent contamination in the event of spillage/leakage.

The additional equipment, such as dispensers, sugar pot, introduce an additional hazard relating to the cleaning of these and appropriate usage / rinsing of cleaning chemicals for example.

Microbiological/Hygiene – Open, unsealed containers present a higher risk of contamination from people or pests (such as insects), such as staff or customers coughing/sneezing over open product or not using the tongs for sugar cubes and using their fingers or a dirty, already-used spoon.

Open, unsealed containers present a higher risk of contamination to the surrounding environment - food preparation and serving areas through spillages and drips and sauce debris around nozzle of dispensers/ lids of bottles. In self-service scenarios there is likely to be a higher incidence of spillage, causing more debris/contamination to the area and requiring more frequently cleaning/tidying by staff. Spillages of sticky, high sugar products can attract pests and as well as oily sauces, can be more difficult to clean effectively, especially if they become dried on to surface, so frequent cleaning of the self-service area by staff.

The jam in café and hotel scenarios uses a bulk container/bucket to be decanted into cups. This would result in opened, part-used containers being returned to storage. It would need to be ensured that these containers are properly re-lidded/covered whilst in storage and would need to be identified with the date of opening, so that manufacturers storage instructions post-opening can be followed in terms of shelf life. If the opened jam container (or other similar breakfast food – honey, syrup, soft cheese, peanut butter) has residue of the product spilled around the edge/outsides of the container from the decanting process this could cause contamination to the storage area, so containers must be kept clean.

Manufacturers' instructions for many ketchup and jam type products advise that once opening they should be kept refrigerated and typically used within 6 weeks - 3 months. Depending on the product formulation and the pH / salt / sugar level this would typically be for the prevention of growth of spoilage organisms which would affect the taste, odour, appearance of the product. This is easier to do with the jam bulk containers after decanting back-of-house but would be more difficult with dispensers and table-top bottles which need to be out at ambient temperature for service. Best practice would be to label the containers with date of opening and to return the table top bottles and opened bags in dispensers / dispensers to refrigerated storage at the end of the service period, i.e. at the end of the

day in the restaurant and replaced the next day. This adds work and complexity to the process. In settings/sites with a lower rate of sale of the product, it would need to be assessed what volume of product would sell through within its advised shelf life, e.g might an opened table top sauce bottle be potentially in use for 8 weeks before it is finished.

The alternative scenarios with dispensers introduce additional food contact equipment into the process which would require cleaning. Dispensers may have narrow/intricate pipes/nozzles which may be difficult to clean effectively, leaving residues which could allow the growth of microorganisms. Ineffective cleaning could also cause a quality issue, for example taste or colour taint from residue of a previous sauce coming through when the dispenser is used with a new sauce. Also, spillages of milk, or equipment used for containing milk can develop a sour, unpleasant smell if ineffectively cleaned.

Allergenic - Clear identification of a product during storage and serving is key control in managing allergen risk, to ensure that the customer is served with the correct food that they ordered, and avoiding a customer accidentally being served a food that they have an allergy to. In the worst case, food allergy can cause anaphylaxis and be fatal. Compared to the base case of fully sealed printed packs, the alternative cups present a greater risk of 'mix ups' by staff and customers – particularly where various types of product may be offered which contain different ingredients and allergens – e.g. sauce choices in addition to ketchup – barbecue sauce, mustard, mayo, curry sauce, or milk choices which are alternatives to cows' milk e.g. soya, almond, oat, which may all contain different allergens, and may not always have a clear visual difference.

For fast-moving, high volume of customer settings such as a busy cafe or restaurant it is assumed that a cup of sauce may not be dispensed on request to order for each customer, but an interim stock of cups may be pre-dispensed a short time in advance for staff to take from when assembling an order. (However this would be subject to the suitability of the individual product. Pre-dispensing may not be possible for all product types for quality reasons, if it very quickly dries out / oxidises when in contact with the air). This pre-dispensing introduces an additional process step of 'short interim storage.' This presents a risk of contamination to the sauce in the open cups from other foods or other contaminants, as well as the risk of staff picking up the wrong type of sauce when assembling the customer order.

If different sauce (or breakfast jams, spreads) types (potentially with different allergens & ingredients) are dispensed in close proximity to each other. Spray or drip from the dispenser nozzles could cause contamination from one sauce into an open cup of the neighbouring sauce. Design and performance of the dispenser, , pressure of the nozzles, and it's layout / positioning within the kitchen or service area would need to be assessed for allergen cross-contamination risk. .

Sites would have to introduce a clear system for identifying what product is in which dispenser, and single use cup both back-of-house for staff if served to the customer, and if self-service at front of house, to make products clearly identifiable to the customer. In addition to staff serving the wrong product to the customer, there is also a risk in a self-service scenario if a member of staff refills product into the incorrect dispenser – so the customer believes they are dispensing one product but it is a different one, one that could contain ingredients they are allergic to. Allocating one dispenser to always be used for the same one type of sauce would also control the risk of allergen cross contamination from ineffective cleaning resulting in residues of previous sauce type used in the dispenser. Narrow pipes/nozzles in dispensers could be difficult to clean effectively.

The ketchup restaurant scenario with original bottles from manufacturer on the tables gives the benefit of allowing for clear branding and labelling visible to customers which controls the risk of product / allergen 'mix up', and is disposed of once empty, therefore considerably lower risk than a dispenser – however see also section on Food Fraud.

8.1.1.3 Sealed to open re-usable container

Scenarios with reuseable cups/jugs/pots present the highest risk for food safety compared to the base case. Reuseable containers present the physical, chemical, microbiological and allergenic risks referred to in the previous section – in terms of open cups and part-opened bulk containers, bottles and dispensers, but they also present additional risks related to re-use and cleaning of the reusable cups between uses.

Reuseable cups and jugs will foreseeably develop some damage over the course of their use and through cleaning. Damage such as scratches and cracks on food contact equipment surfaces can trap food residues and make them more difficult to clean effectively, which can present a microbiological and allergenic risk. If damage and wear and tear results in pieces of hard plastic breaking/scraping away and falling into the container, this can present a risk of injury or choking. The specification of the cups/jugs would need to be assessed as suitably durable and hard wearing to withstand the cleaning process and re-use. An additional control of inspecting and monitoring the condition of the cups/jugs would need to be in place to ensure that any damaged ones are removed from use, and system for replacing the stock of cups/jugs at an appropriate frequency before their condition presents a risk.

The cleaning and storage steps introduce additional risks and operational considerations. The risk of physical and chemical contamination to the cups is increased through these additional steps when cleaning chemical and cleaning utensils equipment are used - such as ineffective rinsing and removal of chemicals, incorrect amount of chemicals, spillage of chemicals, as well as contamination from damaged cleaning utensils – fibres from cleaning brushes/scourers etc.

Reuse presents additional microbiological and allergenic risks from ineffective cleaning, resulting in food residues remaining, especially if a cup has previously been used for a different type of food with different ingredients/allergens. An additional control of inspecting the cups post-clean and monitoring the cleaning process would need to be in place.

8.1.2 Operational considerations

The base case in each scenario is likely to be the most simple and efficient in terms of operations, requiring fewer process steps/procedures and presenting fewer risks. In turn this would require less staff input for monitoring, record-keeping, training and supervision. The alternative scenarios with dispensers and cups, and particularly reusable cups, require additional equipment on site, so appropriate storage space would need to be considered. Cleaning of reusable cups would be a significant additional process step to implement on site. The capacity of additional equipment sinks, cleaning utensils such as bottle brushes for dispenser pipes, and/or dishwashers would need to be assessed and potentially additional ones installed, (if space allows) and they would need to be cleaned and maintained. Kitchen layout and 'dirty to clean' flow is an important consideration especially if an increased volume of equipment has to be cleaned.

To note that for some busy chain café settings, their site layout is typically based on an efficient flow for an operation that was designed for serving food and drink in a small high-street location with limited space, for example. On-site cleaning of reusable containers, particularly the required volume turnover of sauce dip cups, is unlikely to fit with this model and sites may consider having the dirty cups collected

and cleaned off-site by a 3rd party specialist provider (who in turn would need to be monitored for their suitability and service provision in terms of food safety systems).

Systems to aid identification and segregation of products are considered best practice within the food industry – potentially different coloured dispensers or different coloured reusable plastic dip cups could be used for different sauces, to avoid the allergen risk of ineffective cleaning if a previous sauce has been used with that cup. This however would add additional cost and complexity to the business – sourcing different coloured items - and would require staff training and monitoring to ensure understanding and compliance to the colour-coding system.

As discussed previously, the manufacturer's instructions may advise returning opened product to refrigerated storage, in operational reality this may not be done as it introduces additional work and complexity to return bottles/dispensers to storage at the end of every service period.

8.1.3 Food Fraud - sealed to open / part-opened packaging

Moving from presenting the food to the customer in the base case, a sealed pack, to in an open or from an opened partly used bottle/dispenser format could present an increased risk of food fraud.

Food fraud can be defined as fraudulent and intentional substitution, dilution or addition to a product, or misrepresentation of the product or material, for the purpose of financial gain, by increasing the apparent value of the product or reducing the cost of its production. The level of food fraud risk can be considered as the combination of amount of opportunity to do so, and amount of potential financial gain. Presenting food in an open container, or from an opened partly-used bottle, provides increased opportunity compared to a sealed pack. Price differential between products with different composition / quality / provenance characteristics and claims presents a financial incentive to misrepresent a cheaper, lower quality product as a more premium one.

Of the food types assessed, ketchup/sauce products would likely be at highest risk, followed by jam type products.

Ketchup and condiment sauces is a heavily branded food category with a number of well-established globally recognised brands. In a heavily branded food category, price differential between branded and unbranded provides a potential financial incentive for misrepresenting a lower quality generic product as a premium brand.

Ketchup products could carry claims for composition /nutrition, such as reduced salt / sugar, or with no artificial flavourings. Mayonnaise products could potentially have claims for sourcing/production, such as made with free-range eggs.

Jam products have specific EU legislation and definitions around product name and fruit content – e.g. for minimum quantity of fruit used for the manufacture of finished product for a 'jam' and an 'extra jam 'product with a higher fruit content, therefore these products could be vulnerable to food fraud. Honey, also in the breakfast foods type category is particularly vulnerable to food fraud e.g. through misrepresentation of country of origin and provenance, and adulteration with sugar syrup, or lower quality blends from multiple countries of origin.

Milk is typically a commodity product, without particular branding, however potential claims for milk products could be made for sourcing / production method, such as Organic, or country of origin.

Sugar is typically a commodity product, without particular branding, however potential claims for sugar products could be made for sourcing / production method, such as Fairtrade or Organic.

Unscrupulous hospitality/food retail business owners could potentially advertise premium products and claims on menu boards/marketing information but then serve lower quality product in the open containers – for example in the restaurant scenario, the bottles on tables could be labelled as a premium brand tomato ketchup, but could be refilled with a cheaper, lower quality alternative.

8.1.4 Food Threat - sealed to open / part-opened packaging

Food threat is the risk of deliberate malicious contamination with the motivation of causing actual harm to a business or persons, or making a point, typically for ideological reasons, or drawing attention to a cause.

The level of food threat risk can be considered as the combination of amount of opportunity to do so, and the motivation to commit such acts. The term 'food defence' may also be used in this context, meaning procedures adopted to ensure the safety of raw materials and products from malicious contamination. Malicious contamination acts may be committed by a disgruntled customer, or a disgruntled employee who may wish to damage a food business and its reputation.

Security seals and tamper evident packaging formats are common food defence controls and therefore presenting food in an open or from an opened partly-used bottle for example, provides increased opportunity for malicious contamination, compared to a sealed pack.

8.1.5 Impact of setting

Individual hospitality / food retail outlet settings vary greatly within the industry, in terms of the following characteristics, and these all have an impact on the level of food safety risk and the business's ability to comply with required food safety legislation, and controls and procedures.

- Management structure / management systems and commitment (including level of food safety culture)
- Volume of food product served / turnover
- Complexity of food preparation and handling processes
- Size, space and layout design of the individual site
- Location / nature of adjacent businesses/operations/environment/climate – e.g. some sites may have a higher inherent risk of pests
- Customer demographic and behaviours

Management structure / management systems and commitment: there is a huge amount of variation of structure, experience and competency within the hospitality / food retail sector, for example, a global established cafe/restaurant brand with their own centralised food safety management systems, supplier assurance programmes, food safety training and culture programmes for staff and restaurant operators, with an audit/monitoring programme delivered at their request independently by 3rd party experts, compared to an independent, privately owned, single-site cafe/restaurant, which is a recent start-up, managed by a small team inexperienced in food safety and legislation.

Training, competency and turnover of staff is also a key factor for food safety risk, as well as clear communication on food safety at and between various levels of the business and the development and maintenance of a positive food safety culture. Food safety culture can be defined as the attitudes and values prevalent at the site relating to the importance of food safety and always keeping it at 'front of mind' and 'doing the right thing.'

Volume of food product served / turnover: Higher risk settings overall would typically be those with a higher footfall, higher number of customers/volume of food served, presenting more challenges for implementing the necessary food safety controls and standards in a busy/fast moving business environment. If more customers are served per day, there is a greater chance of a customer being served the incorrect product (allergen risk) for example, particularly in the alternative ketchup scenarios.

Low rate of sale / lower footfall settings can also present food safety risks as products will sell through more slowly, potentially resulting in them being served and consumed further into their shelf-life, which would have a negative impact on safety, quality and organoleptic properties. For some businesses with low turnover there could be an incentive to continue to serve products after the Best Before Date has expired having a negative impact on product quality, and potentially also safety.

Customer demographic and behaviours: A HACCP assessment approach should also consider "unintended use" and "reasonably expected misuse" of a food product, which typically involves considering possible end-user behaviour. It is foreseeable in the self-service alternative scenarios that customers may not always comply with the desired approach, e.g. customers not using the tongs for sugar cubes and using their fingers or a dirty, already-used spoon, which would contaminate the product, or by using self-service areas in a careless manner causing spillage/debris to contaminate the surrounding area. This may be more likely to happen in settings such as cafés where there is high footfall, and potentially a higher proportion of children / teenagers in the customer base (e.g. if the cafe brand appeals more to this demographic group), compared to a workplace canteen which would have a higher proportion of adults demonstrating more compliant behaviours.

8.2 Quality

The base case in each scenario is likely to be the best for maintaining product quality as it is sealed up to the point of consumption. For alternatives, there is a period of time of storage in a part-used opened container and in open cups prior to serving which could potentially lead to detrimental quality impacts. Quality impacts could lead to increased wastage of the product.

Some quality considerations have been referred to above but examples are:

- Sugar absorbing moisture from the air, becoming sticky and then becoming hard and clumping
- Sugar cubes breaking up and resulting in loose sugar in bottom of container
- Sauce drying out – e.g. a 'skin' layer forming on the top of a pre-dispensed cup, giving an unappealing texture and dull appearance
- Sauce drying out within the pipes / nozzles of a bottle / dispenser and forming darkened hardened pieces which are then dispensed into the cup/onto the food.
- Sauce separation if sitting unused for a long period of time – often manufacturers' instructions on bottles are to shake well before use – this is not possible to shake a dispenser.

- Taste taint from reusable cups from the previous product, particularly with strong flavoured sauces
- Staining on the reusable cups – unappealing appearance, may look unclean – if previously used for a strongly coloured sauce – e.g. tomato ketchup / mustard.
- Milk developing a sour taste/aroma from time open at ambient temperature
- General deterioration in organoleptic properties if used towards end of shelf life and having been an opened container for a period of time – e.g. fading of flavours/aromas, fading of colour, less vibrant and appealing appearance.
- If a jam is to be served via a dispenser, such as in the Canteen scenario, then this may limit some of the quality parameters of the jam type – it is likely a 'thin', low viscosity jam without fruit pieces would have to be used to be able to flow through the dispenser.

Quality impacts could be minimised as long as the rate of usage in the setting is sufficiently high and the time between depositing/decanting into the cups/jugs/pot and serving is managed in line with rate of sale to minimise 'open time'.

If moving from the base to case to an alternative serving scenario, the food business operators may seek alternative product recipes with different properties that perform better from a quality/ shelf-life point of view in this setting.

8.3 Health

There is not a significant difference between the base case and alternatives or settings in terms of health and nutrition, i.e. in terms of likelihood of excessive consumption. This is due to the product being served by staff - rather than self-service – in all scenarios, except for sugar in all settings, for ketchup on the table in the restaurant setting, and for all products in the canteen setting. Overall, service mode - self-service or service by staff - is the more important factor than the serving/packaging format for impact on health and nutrition. In the sugar base case, for example, if the single portion sealed packaging sticks are self-service from a service point, the number of sugar sticks a customer could take compared to the number of sugar lumps they could take from a bulk pot is not likely to be significantly different.

The alternative formats using individual cups/small jugs/glass jam portion/paper sugar portion/sugar cubes would all provide an actual or visible portion size as a guide.

However, "reasonably expected misuse" should be considered, whereby in self-service bottle or dispenser formats, customers may not use the provided cup to take a reasonable portion size but may try to dispense a greater amount directly onto their food/drink. However, the amount available in the bottle/dispenser would limit this.

Sugar and jam are the higher risk products from a health and nutrition point of view due to their high sugar content. Ketchup/sauces may also be high in sugars, salt (or fat, in the case of mayo / oil-based sauces). In many countries national nutritional guidelines are in place recommending a maximum intake of sugar, salt, calories (energy) or fat. These are typically based on World Health Organisation guidelines.

Ketchup salt consideration example:

The World Health Organization (WHO) recommends limiting sodium consumption in adults to < 2 g/day (< 5 g salt/day) (WHO, 2023).

Typical tomato ketchup contains 1.8g of salt per 100g. To exceed the <5g per day recommendation, over 275g of ketchup would have to be consumed, which seems unlikely. (This is a rough consideration only as it does not take into account intake of salt from other meals/sources). Food business operators could consider limiting the size of the bottles on the tables in the restaurant self-serve scenarios; however this would lead to operational challenges of more frequent running out and replacement, (and smaller bottles means also more plastic bottles disposed of for the same volume of ketchup used).

Sugar cubes sugar consideration example:

The World Health Organization (WHO) recommends limiting free sugar intake to <10% of daily energy (ideally <5%). This is the equivalent of 50g of sugar (5% is 25g). Free sugar is any sugar added to a food, and also includes sugar that is already in honey, syrup and fruit juice.

Typical white granulated sugar is considered to contain 100g of sugar per 100g. The self-service sticks and cubes in the scenario are 4 g. To exceed the <25g per day recommendation, over 6.25 sticks/cubes would have to be consumed, which seems unlikely. (This is a rough consideration only as it does not take into account intake of sugar from other meals/sources). Food business operators could consider not having sugar as a self-service item and making it served on request only.

To minimise impact on health and nutrition, particularly when served / available for self-service not in sealed single portions, food manufacturers and retailers may wish to consider reformulating recipes to reduce sugar and salt, or to select existing reduced sugar and reduced salt alternatives. Artificial sweeteners as alternative to sugar is however a less ‘clean’ ingredient declaration.

As referred to above in the Quality section, food business operators may seek alternative product recipes with different properties that perform better from a quality/ shelf life point of view in these settings/scenarios, which could include for example moving from a more ‘clean’ ingredient declaration without additives, to a recipe with more preservatives, stabilisers and artificial colours/ flavours.

9. Pillar-specific limitations and how are they addressed in the study

This section outlines the key limitations of this study per pillar and explains how they were mitigated as far as possible.

9.1 Economic impacts

Time parameters for serving from dispensers and bulk packaging

- As these service configurations are not currently deployed at scale in the European Union, some remaining uncertainty exist on the actual ranges of values in an optimised operational scenario.
- *To address this limitation, time parameters for serving from dispensers and bulk packaging were defined as ranges based on data collected through industry interviews.*

The analysis does not consider the possible co-existence of single use AND reusable systems for a same product.

- Each scenario in this study assesses packaging alternatives for a single system. In reality, locations offering both dine-in and takeaway service may have to design operations to accommodate both packaging formats, which may introduce inefficiencies not reflected in the modelled costs. A similar constraint applies at the producer level: where demand is split across formats, producers may lose economies of scale.
- *Considering dual systems as an alternative to the single use base case would increase the impacts of the alternative and reinforce the conclusion that the base case outperforms the alternatives.*

9.2 Social impacts

Job creation as an unemployment-sensitive benefit

- To model job creation in this study, we use an average of coefficient factors from the EU Cost-benefit Analysis Guidelines. Since the value of job creation is highly sensitive to the local unemployment rate, this is an inherently heterogenous benefit.
- *By following EU Cost-benefit Analysis Guidelines for modelling the value of job creation, we follow recognised methods.*

Residual impact on customer experience

- Scenarios were designed to minimise differences in consumer experience, including perceived hygiene, familiarity, and aesthetic preference.
- *While some residual difference may remain, the packaging systems have been made as comparable as possible. Residual health and food safety impacts are addressed separately through a systematic assessment in chapter 8.*

9.3 Environmental impacts

9.3.1 General LCA methodology limitations

As with any LCA study, inherent methodological limitations apply. All general limitations of LCA methodology are presented in Annexe 11.

9.3.1.1 Study-specific limitations

Assumption of sustainable forestry

The datasets related to the production of fibre-based products (paper sachet/cup, cardboard box) from ecoinvent all assume wood originating from sustainably managed forests. This assumption considers forests to be at carbon equilibrium, meaning the average carbon stock remains constant over time, and do not account for broader forestry system dynamics.

In reality, sustainably managed forests that have not yet reached this equilibrium continue to act as net carbon sinks, accumulating biomass and soil organic carbon, meaning the environmental benefits of fibre-based materials may be somewhat underestimated. Conversely, situations where fibre-based products are sourced from non-sustainably managed forests or worse, from deforestation of old-growth forests are explicitly outside the scope of this study. In such cases, the environmental performance of scenarios involving fibre-based products would be significantly worse than the results presented here.

The impact of this assumption, built into the datasets of the LCI database, is not further investigated because it is reasonable to assume the producers of these fibre-based packaging/serving options carefully select their suppliers to ensure the material originates from sustainable forests.

Lack of microplastics assessment

The environmental impact of microplastics is not captured in this study, as the Product Environmental Footprint (PEF) methodology currently does not include an impact category to assess microplastic emissions and their effects.

This represents a gap particularly relevant to scenarios involving plastic packaging/serving options, for which microplastic release, occurring across various life cycle stages such as use and end-of-life, is a known environmental concern. Were such an impact category to be included, the environmental performance of scenarios containing plastic products would be expected to worsen, potentially affecting the relative comparison between plastic and non-plastic alternatives.

10. Conclusions

10.1 Societal impacts (aggregated environmental, economic and social impacts)

Conclusion 1. The single-use plastic base case performs better than both the single-use and reusable alternatives, in the average situation, across all comparisons modelled, considering the aggregated environmental, economic and social impacts.

The **difference in economic costs** between the base case and the alternatives **drives this conclusion**. This is explained by the **additional labour associated with the longer serving times** and **additional supporting operations** required to manage the service of products in reusable systems or in the alternative single use system.

The study is a prospective study and the **possible level of optimisation of alternative scenarios in the future is unknown** as they are not currently applied at scale. To address this challenge, we used large conservative ranges of values for all relevant parameters for the sensitivity analysis:

- The parameters with the most influence on the results are the labour cost and the serving times of the alternatives.
- The sensitivity analysis shows that this conclusion holds in 100% of the considered cases for 26 of the 31 comparisons between an alternative and the SUP base case, given the parameter ranges defined in this study.
- In the comparisons for which cases exist where the alternative systems perform better, reversing the conclusion requires a combination of parameter values that are favourable to the alternative (example: low production cost of the alternative, efficient logistics and service of the alternative, low labour cost, low extra food waste, etc.).

10.1.1 Economic impacts

Conclusion 2. From an economic perspective, the base case performs better on average than both alternatives in all tested scenarios.

The key explanation is that alternatives where portions are served from bulk packaging or dispensers require more time to serve and involve additional supporting operations (cleaning, training, monitoring etc.) that generate labour costs. Even when the alternative allows for a more optimised transport, this does not compensate the extra service costs.

This study does not consider the coexistence of single-use and reusable systems in locations where both dine-in and takeaway options are available. This would result in fewer economies of scale and less operational optimisation, potentially leading to higher additional costs.

10.1.2 Environmental impacts

Conclusion 3. From an environmental perspective, the base case has a lower environmental impact than the alternative for 12 of 31 comparisons and the alternative has a lower environmental impact than the SUP base case for 12 out of 31 comparisons. For 7 out of 31 comparisons, the difference between the base case and the alternative is too small to make a definite statement on the performance of the alternative compared to the base case.

For 12 of 31 comparisons, the **base case has a lower environmental impact** than the alternative, notably:

- **Restaurant – semi-viscous (both)**: both alternative options use the squeeze bottle in combination with the reusable plastic cup or single-use paper cup, ultimately leading to a higher weight of packaging/serving options per functional unit compared to the base case (SUP).
- **SUP vs. alternative SUP comparison for jam in the restaurant, hotel and café locations**: in these scenarios, the alternative SUP is a glass jar with steel lid. This serving option has a much higher weight of the packaging than a plastic dip cup, leading to increased environmental impact.
- **Plastic vs. paper sachet for sugar**: on a per kg-basis, paper has a lower environmental impact than the plastic option but the total weight of the paper sachet is much higher than the plastic sachet and still requires a plastic liner.

For 12 out of 31 comparisons, **the alternative has a lower environmental impact** than the SUP base case. These scenarios all use packaging/serving configurations that lead to a lower weight of packaging per FU compared to the base case, leading to the improved environmental impact.

- Ten comparisons model the plastic pouch for a manual dispenser as part of the alternative packaging system , for which the alternative has a lower environmental impact than the SUP base case.
- Two comparisons model the sugar bowl as a reusable alternative and result in a lower environmental impact than the SUP base case.

Conclusion 4. The number of uses of the reusable cup is a key parameter in the comparison of environmental impact between the reusable alternative and the base case SUP. The tipping point (number of uses) after which the alternative always outperforms the base case SUP, depends on the scenario configuration.

The number of uses (directly related to the loss rate; for example a loss rate of 5% equals a use rate of 20) is the main parameter that will define the environmental impact of the reusable alternative option. The wide range is intentional, covering the variety of real-world situations and allowing the sensitivity of this parameter on societal impact to be assessed; it is also reflected in the error bars for total societal impact.

The inversely proportional relationship of this parameter to total environmental impact means increasing the number of uses is very impactful starting from a low number of uses, the added benefit of an additional use decreases with an increasing number of uses (e.g.: the reduction in environmental impact of going from 4 to 5 uses, is much larger than the reduction when going from 30 to 31 uses).

Use rate is typically not a material-specific limitation but a systemic parameter: a low use rate represents a systemic failure that can be addressed through measures such as deposit schemes, awareness campaigns, or unbranded cups to discourage theft. While each material has a theoretical maximum use rate based on physical durability, this value is very high and in practice never the binding constraint. Systemic losses will limit the achieved use rate long before material degradation becomes relevant. A currently low use rate therefore cannot justify its use as an LCA input when clearly feasible pathways to high use rates exist.

Conclusion 5. A scenario with a constrained wood market increases the difference in monetised impact between the single-use alternative and the base case in the same direction, therefore reinforcing the conclusion that holds in a scenario without a wood constrained market.

The constrained wood market scenario mainly impacts the alternative SUP since these are often fibre-based packaging options.

10.1.3 Social impacts

Conclusion 6. From a social perspective, the base case performs better than alternatives when the alternative requires clients to serve themselves, and worse when staff serves.

The explanation is that client time is considered as a social cost, while staff labour is associated with job creation, which has a positive societal value. Note that staff labour considered overall is a cost, as the economic cost associated with labour exceeds the social benefit.

10.2 Residual health and food safety impacts

10.2.1 Food safety

- **All scenarios within the assessment are comparatively low risk overall** (in the overall context of food safety/food industry as a whole, and this is largely in part to the food type selected for the scenarios).
- **The base case is the lowest risk scenario in each setting and for each product type.** It is the most simple and efficient in terms of operations, requiring fewer process steps/procedures and therefore presents fewest risks.
- **The base case in each scenario – plastic, sealed individual packaging – presents the lowest risk for food safety.** It provides the best format for prevention of contamination (as it is sealed right up to point of consumption by the customer), clear identification of the product (allowing for labelling with product name, allergens and ingredients on the pack that is served directly to the customer), traceability (a traceability code can be printed on each pack), and shelf life (a Best Before Date can be printed on each pack).
- **Alternatives using single-use disposable paper containers present a comparatively higher risk for food safety compared to the base case.** This is overall due to going from a sealed format to an open format, and the additional process steps for decanting into individual containers presenting additional risks.
- **Reusable cups/jugs/pots present the highest risk for food safety compared to the base case.** This is overall due to going from a sealed format to an open format, and the additional process steps for decanting into individual containers presenting additional risks. The introduction of additional steps for cleaning and reuse of containers also presents additional risks.
- **Alternatives** – the sealed individual format of the base case is what drives the lower risk for food safety. If non-plastic sealed alternatives could be sourced and demonstrated to provide the same food-contact suitability, physical robustness, seal integrity and barrier properties as plastic, then in theory there should be no difference in risk for operational food safety, whether the material is plastic or other.



Figure 13 Illustration of the increasing level of food safety risk between packaging options (increasing risk from left to right)

10.2.2Quality

- **Sealed single-use formats (base case) best preserve quality**; alternatives introduce open storage risks.
  - Key quality risks: sugar clumping/hardening, sauce skinning or pipe blockages, sauce separation, milk souring, flavour/colour fading, and staining or taste taint in reusable cups.
- **Risks can be mitigated** by **high turnover** and **tight management of open time** between opening/decanting and serving.
- Operators switching formats may need reformulated products with better open-air stability.

10.2.3Health

- **No significant health/nutrition difference** between base case and alternatives; service mode (staff vs. self-service) matters more than format.
  - Alternative individual formats (cups, small jugs, portion pots) provide a visible portion size cue.
  - Self-service dispensers carry some risk of "reasonably expected misuse" (over-dispensing), though container size limits this.
- **Sugar and jam are the highest nutritional risk products**; ketchup/sauces also relevant due to sugar, salt, or fat content.
- **To reduce health impact**, manufacturers can **reformulate to lower sugar/salt**, but this may compromise ingredient “cleanliness” (e.g. artificial sweeteners, preservatives).

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Appendix

Annexe 1. RangeLCA software

The software used to calculate the results in this report is RangeLCA, a tool developed by RDC Environment.



The software used for the modelling is RangeLCA.

The ILCD EF3.0 nomenclature is used.

This software has innovative characteristics that improve the reliability (and consequently, the credibility) of the results of an LCA.

The basic concept is that the results must reflect the diversity of individual cases (instead of being limited to an average of possible cases and a few alternative scenarios) and thus automatically integrate the sensitivity analysis of the parameters.

From a mathematical point of view, this concept is expressed by the use of random variables instead of fixed values (known as “typical” values). In a model, there can be two types of parameter variability:

- Variation of the situations; these express non-concurrent alternative situations (for example: choice X or Y for fume treatment).
- Data uncertainty: this is expressed by probability distributions around the average value of the parameters (for example, a transport distance described by a normal distribution); the probability distributions can be uniform, normal, log-normal, etc.

Practically, each time minimum and maximum values are proposed in the report, (hypothesis and data) a uniform random variable between them is used in our modelling.

The results can be obtained for each parameter combination (for example, 1000 combinations). These results can be plotted on a graph based on the value of one of the variable parameters of the model. These graphs, known as "Range" graphs, allow to evaluate the sensitivity of the results with respect to the parameter plotted on the x-axis.

This type of results ensures a precise and comprehensive analysis of the studied system. The software enables the study of a large number of possible scenarios. In practice, it allows for:

- Creating Range graphs to:
  - Identify the possible results (minimum and maximum values).
  - Evaluate the probability of the studied scenarios.
  - Graphically represent the sensitivity of the results to a specific parameter (slope of the linear regression line).
- Determining all the causal links between the variables of the model.
- Identifying the critical point (or critical zone) where the conclusions may change.
- Identifying the list of the most sensitive parameters (automatically calculated by the software).

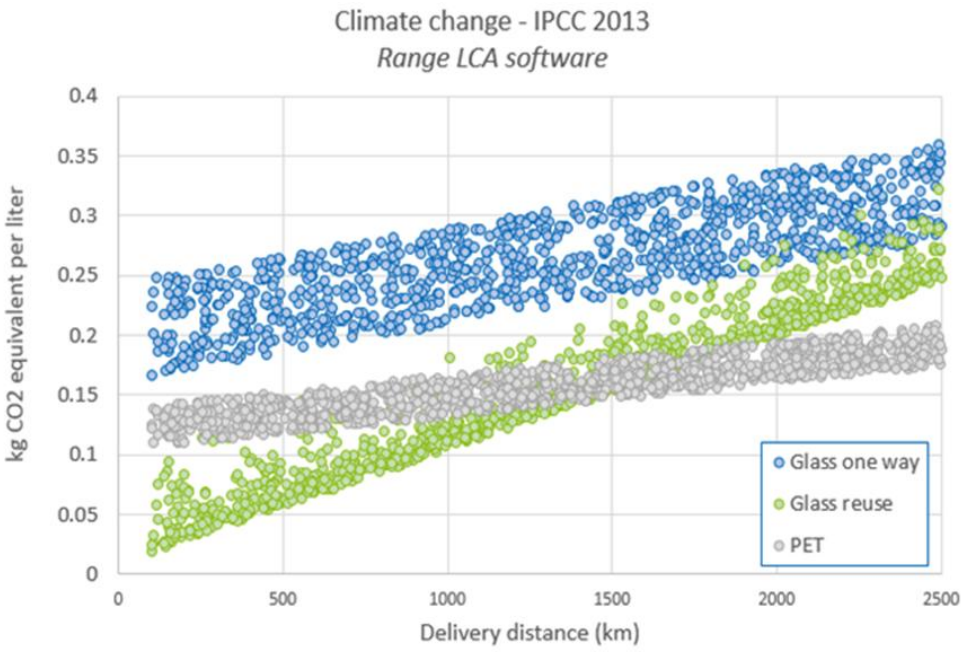


Figure 14: Example of a "Range" graph calculated on RangeLCA

Note that the results shown above are examples and don't correspond to the present study.

The interpretation keys for the results are as follows:

- Each point corresponds to a result for a specific set of fixed parameters. Thus, all results corresponding to all potential parameter combinations of the model's variables are represented on this figure.
- The steeper the trend line, the more sensitive the results are to the parameter presented on the x-coordinate axis.
- The vertical dispersion (width of the point band) directly corresponds to the relative importance of residual variability.

For the inventory part of the data, this software also allows automatic calculation of the contribution of each elementary flow (emissions into air, water, soil…) and/or each process to total impacts. This makes it possible to focus on the search for key data.

The results are classified according to the value of parameters, which makes it possible to identify the sensitivity of the result related to this parameter.

Annexe 2. Methodology life cycle assessment (LCA)

LCA is the most advanced tool for comprehensive, multi-criteria environmental impact assessment. This method measures the quantifiable effects of products (goods or services) on the environment. Its objective is to present a global overview of the potential impacts generated by products throughout their life, i.e., from the production of raw materials to the product's end-of-life (EoL) management (this is called cradle-to-grave analysis).

LCA is standardised by the ISO 14040:2006 and ISO 14044:2006 standards describing the different steps of its realization. The practical requirements and guidelines are described in ISO 14044:2006:

- Goal and scope of the study,
- Life Cycle Inventory (LCI),
- Life Cycle Impact Assessment (LCIA),
- Life Cycle Interpretation.

Phase 1 defines the objectives of the LCA, specifying its application(s): e.g. eco-design, comparison of goods or services, or an environmental declaration. The target of the study is specified at this stage, as well as how the results will be disclosed (for comparative claims, for example). The scope definition of the study includes a description of the function, the functional unit, the system boundaries (including omissions of life cycle stages, processes or data needed, quantification of energy and material inputs and outputs, and assumptions about electricity production) and the cut-off criteria for initial inclusion of inputs and outputs (including the effect of selection on results, and the inclusion of mass, energy, and environmental cut-off criteria).

In **phase 2**, each system is broken down into several unit processes. Each of these processes corresponds to a specific action in the sector. These end-to-end processes lead to the development of a process tree for each system.

Each unit process is characterised by a multitude of elementary incoming and outgoing flows (CO_2, SO_2, NO_X, PO_4, Fe, Ag, Au...) generally resulting from a data collection allowing to determine the inputs (consumption of water, energy, raw materials...) and the outputs (emissions in air, water, soils, waste and products and co-products generated by the process). This approach is called a life cycle inventory. Inventory is therefore an analytical accounting of flows.

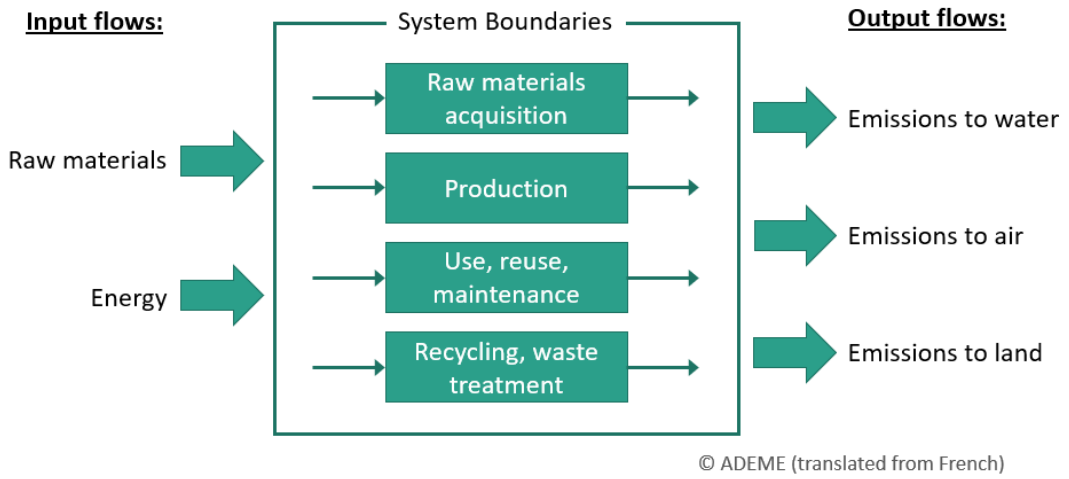


Figure 15: Unit process characterisation, adapted from ADEME

Once the processes have been identified, their integration will make it possible to reconstitute the entire chain. The construction of the process tree is progressive and starts from the Functional Unit (function performed by the system under study, e.g. "packaging 1 litre of goods").

During the LCIA (**phase 3**), the different flows are grouped into impact categories (e.g. climate change) according to their contribution to an environmental problem/issue. For each impact category, specific characterisation factors are applied to each flow value to reflect an effect on the environment in a common unit (for example, for the climate change contribution indicator, kg CO_2-eq is used, see Table 36 below). Environmental impact indicators can thus be evaluated.

Table 36: Simplified example of impact characterisation for the "climate change" impact category

Elementary flows	Inventory	Characterisation factors	Characterised results
Unit	kg / functional unit	kg CO_2-eq / elementary flow	kg CO_2-eq
CO_2	1.2	1	1.2 (1.2 x 1)
CH_4	0.01	29.8	0.298 (0.01 x 29.8)
N_2O	0.0017	273	0.464 (0.0017 x 273)
Total	-	-	1.96 (1.2+0.298+0.464)

When interpreting the results (**phase 4**), the life cycle phases and flows that contribute most to the environmental impact indicators are identified. Actions can be taken to prevent or limit impacts. The multi-criteria LCA approach also helps to avoid, or at least limit to a minimum, pollution transfers (from one impact category to another and from one phase of the life cycle to another) when making decisions.

Annexe 3. Impact categories LCA

The Joint Research Centre (JRC) is the organisation providing scientific support to the European Commission. The JRC defined a set of 16 environmental indicators[50] to be used for life cycle assessments, listed in table below (EF package 3.1, 2023 https://eplca.jrc.ec.europa.eu/LCDN/developerEF.html).

Table 37: List of impact categories and related assessment methods defined by the PEF (Zampori & Pant, 2019); EF package 3.1

Impact category	Indicator	Unit	Recommended default LCIA method	Robustness
Climate change (CC)	Radiative forcing as Global Warming Potential (GWP100)	kg CO_2 eq	Baseline model of 100 years of the IPCC (based on IPCC 2021)	I
Ozone depletion (OD)	Ozone Depletion Potential (ODP)	kg CFC-11 eq	Steady-state ODPs as in (WMO 2014 + integrations)	I

[50] Supporting information to the characterization factors of recommended EF Life Cycle Impact Assessment methods, European Commission, 2018

Impact category	Indicator	Unit	Recommended default LCIA method	Robustness
Human toxicity, cancer (Tox_h_c)	Comparative Toxic Unit for humans (CTU_h)	CTUh	USEtox model 2.1 (Frankte et al, 2017)	III
Human toxicity, non- cancer (Tox_h_nc)	Comparative Toxic Unit for humans (CTU_h)	CTUh	USEtox model 2.1 (Frankte et al, 2017)	III
Particulate matter (PM)	Impact on human health	disease incidence	PM method recommended by UNEP (UNEP 2016)	I
Ionising radiation, human health (IR)	Human exposure efficiency relative to U^{235}	kBq U^{235} eq	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al, 2000)	II
Photochemical ozone formation, human health (POF)	Tropospheric ozone concentration increase	kg NMVOC eq	LOTOS-EUROS (Van Zelm et al, 2008) as applied in ReCiPe 2008	II
Acidification (Ac)	Accumulated Exceedance (AE)	mol H+ eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	II
Eutrophication, terrestrial (Eu_t)	Accumulated Exceedance (AE)	mol N eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	II
Eutrophication, freshwater (Eu_fw)	Fraction of nutrients reaching freshwater end compartment (P)	kg P eq	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe	II
Eutrophication, marine (Eu_mw)	Fraction of nutrients reaching marine end compartment (N)	kg N eq	EUTREND model (Struijs et al, 2009b) as implemented in ReCiPe	II
Ecotoxicity, freshwater (EcoTox)	Comparative Toxic Unit for ecosystems (CTU_e)	CTUe	USEtox model 2.1 (Frankte et al, 2017)	III
Land use (LU)	Soil quality index Biotic production Erosion resistance Mechanical filtration Groundwater replenishment	Dimensionless (pt) kg biotic production kg soil m^3 water m^3 groundwater	Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016)	III
Water use (WU)	User deprivation potential (deprivation-	m^3 world eq	Available Water Remaining (AWARE) as	III

Impact category	Indicator	Unit	Recommended default LCIA method	Robustness
	weighted water consumption)		recommended by UNEP, 2016	
Resource use, minerals and metals (Res_m)	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq	CML 2002 (Guinée et al., 2002) and van Oers et al. 2002.	III
Resource use, fossils (Res_f)	Abiotic resource depletion – fossil fuels (ADP-fossil)[51]	MJ	CML 2002 (Guinée et al., 2002) and van Oers et al. 2002	III

These indicators have distinct levels of robustness, indicated in the last column in the above table, according to the JRC. The robustness levels are defined in the table below:

Table 38: Robustness levels of the impact categories defined by the JRC

I	Recommended and satisfactory
II	Recommended, but needs improvements
III	Recommended, but to be used with caution

Also, the LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

Annexe 4. Bill-of-Material automated dispenser

The values in Table 39 represent an estimated BOM based on LCA practitioner experience with electronical products. The estimated BOM assumes a dispenser that has a container volume of 10l product and requires no heating or cooling, the motor is only used for dispensing.

Table 39: Bill-of-Material automated dispenser

Weight material (g)	Relative weight material (%)	Material	Use of material
1600	32	Stainless steel	frame, nozzle, pump housing, screws, bolts...
1600	32	Acrylonitrile Butadiene Styrene (ABS)	Outer housing, reservoir
150	3	Aluminium	heat sink, motor frame

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

800	16	Polypropylene (PP)	reservoir, food-contact inner liners
250	05	Silicone	tubing, seals, gaskets
150	3	EPDM	O-rings, seals
200	4	Copper	motor windings, electrical contacts
150	3	Printed Circuit Board	control board, sensor
100	2	Magnet	DC motor permanent magnets
5000	**100**	TOTAL	

Annexe 5. Ecoinvent datasets used in model

Table 40: ecoinvent datasets used in model

Life cycle phase	Process	Ecoinvent dataset
Production: upstream transport	Lorry transport (>32 metric ton)	market for transport, freight, lorry, >32 metric ton, diesel, EURO 6, RER
	Train transport	market group for transport, freight, train, fleet average, RER
	Container ship transport	market for transport, freight, sea, container ship, heavy fuel oil, GLO
Production: raw material	Virgin polypropylene (PP) production	polypropylene production, granulate, RER
	Recycled polypropylene (PP) production	treatment of waste polyethylene, low density, packaging, recycling, RER
	Virgin paper production	kraft paper production, RER
	Recycled paper production	graphic paper production, 100% recycled, RER

	Virgin low density polyethylene (LDPE) production	polyethylene production, low density, granulate, RER
	Recycled low density polyethylene (LDPE) production	treatment of waste polyethylene, low density, packaging, recycling, RER
	Virgin high density polyethylene (HDPE) production	polyethylene production, high density, granulate, RER
	Recycled low density polyethylene (HDPE) production	treatment of waste polyethylene, high density, packaging, recycling, RER
	Virgin tinplated steel	Steel tinplated Europe 2022, Europe
	Recycled tinplated steel	steel production, electric, low-alloyed, EU w/o CH & AU
	Virgin stainless steel	market for steel, chromium steel 18/8, GLO
	Recycled stainless steel	steel production, electric, low-alloyed, EU w/o CH & AU
	Virgin glass production	packaging glass production, white, without cullet, GLO
	Recycled glass production	Container glass, ER, Recycled Content 100% (provided by FEVE) – Aggregated, EU-27
	Cardboard box	market for corrugated board box, RER
Production: transformation processes	Extrusion	extrusion, plastic film, RER
	Thermoforming	thermoforming, with calendering, RER
	Injection moulding	injection moulding, RER
	Blow moulding	blow moulding, RER
	Metal forming	market for metal working, average for steel product manufacturing, GLO
Logistics	Lorry transport	COPERT V modelling, see Annexe 7
Use phase	Electricity	market group for electricity, low voltage, RER

	Water consumption	market for tap water, EU w/o CH
	Wastewater treatment	treatment of wastewater, average, wastewater treatment, EU w/o CH
	Soap consumption	soap production, RER
	Washing machine	Cut-off: not modelled
End-of-Life	Recycling polypropylene (PP)	treatment of waste polyethylene, low density, packaging, recycling, RER
	Avoided virgin polypropylene (PP) production	polypropylene production, granulate, RER
	Recycling paper	graphic paper production, 100% recycled, RER
	Avoided virgin paper production	kraft paper production, RER
	Recycling low density polyethylene (LDPE	treatment of waste polyethylene, low density, packaging, recycling, RER
	Avoided virgin low density polyethylene (LDPE) production	polyethylene production, low density, granulate, RER
	Recycling low density polyethylene (HDPE)	treatment of waste polyethylene, high density, packaging, recycling, RER
	Avoided virgin high density polyethylene (HDPE) production	polyethylene production, high density, granulate, RER
	Recycling tinplated/stainless steel	steel production, electric, low-alloyed, EU w/o CH & AU
	Avoided virgin steel production	steel production, electric, low-alloyed, EU w/o CH & AU
	Recycling glass	Container glass, ER, Recycled Content 100% (provided by FEVE) – Aggregated, EU-27
	Avoided virgin glass production	packaging glass production, white, without cullet, GLO

	Recycling cardboard	containerboard production, fluting medium, recycled, RER
	Avoided virgin cardboard production	containerboard production, linerboard, kraftliner, RER
	Incineration polypropylene (PP)	treatment of waste polypropylene, municipal incineration, GLO
	Incineration low density polyethylene (LDPE)	treatment of waste polyethylene, municipal incineration, GLO
	Incineration high density polyethylene (HDPE)	treatment of waste polyethylene, municipal incineration, GLO
	Incineration paper/cardboard	treatment of waste paperboard, municipal incineration, GLO
	Incineration tinplated/stainless steel	treatment of waste steel, municipal incineration, EU w/o CH
	Incineration glass	treatment of waste glass, municipal incineration, GLO

Annexe 6. Circular Footprint Formula (CFF) & values

The Circular Footprint Formula (CFF) combines "Material", "Energy" and "Disposal" as follows:

Material $(1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_P}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right)$

Energy $(1-B)R_3 \times \left(E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec}\right)$

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

With the following parameters:

A: allocation factor of burdens and credits between supplier and user of recycled materials.

B: allocation factor of energy recovery processes: it applies both to burdens and credits.

Q_{Sin}: quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.

Q_{Sout}: quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.

Q_P: quality of the primary material, i.e. quality of the virgin material.

R_1: *it is the proportion of material in the input to the production that has been recycled from a previous system.*

R_2: *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.*

R_3: *it is the proportion of the material in the product that is used for energy recovery at EoL.*

$E_{recycled}$: *specific emissions and resources consumed (per unit of analysis) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.*

$E_{recyclingEoL}$: specific emissions and resources consumed (per unit of analysis) arising from the recycling process at EoL, including collection, sorting and transportation process.

E_v: specific emissions and resources consumed (per unit of analysis) arising from the acquisition and pre-processing of virgin material.

E^*_v: specific emissions and resources consumed (per unit of analysis) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.

E_{ER}: specific emissions and resources consumed (per unit of analysis) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, …).

$E_{SE,heat}$ and $E_{SE,elec}$: specific emissions and resources consumed (per unit of analysis) that would have arisen from the specific substituted energy source, heat (assumed to be 40.4% coal, 52.7% natural gas, and 6.9% light fuel) and electricity respectively.

E_D: specific emissions and resources consumed (per unit of analysis) arising from disposal of waste material at the EoL of the analysed product, without energy recovery.

$X_{ER,heat}$ and $X_{ER,\ elec}$: the efficiency of the energy recovery process for both heat and electricity

LHV: Lower Heating Value of the material in the product that is used for energy recovery.

The material-specific values for the parameters from the CFF formula are presented in the table below.

Table 41: material-specific parameters CFF

Material	A	Qs / Qp	LHV (MJ / kg)
Steel	0.2 [1]	1 [1]	0 [2]
Paper/cardboard	0.2 [1]	0.9 [1]	15.9 [2]
PP	0.5 [1]	0.9 [1]	38.9 [2]
HDPE	0.5 [1]	0.9 [1]	39 [2]
LDPE	0.5 [1]	0.75 [1]	39 [2]
Glass	0.2 [1]	1 [1]	0 [2]

[1]: Commission recommendation on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations v2.1, 16.12.2021 (Annex C)
[2]: Ecoinvent 3.11

Annexe 7. Lorry transportation modelling

Fuel consumptions and airborne emissions from lorries are obtained from the COPERT 5 methodology (version 5.0). This methodology considers several parameters which influence fuel consumption and related emissions:

- Type of lorry used (lorry capacity, European norm…).
- Average speed throughout the trip.
- Average slope of the route.
- Payload.

Via COPERT V, it is possible to calculate the fuel consumption of a fully loaded lorry.

The payload and empty return rate are considered as follows:

$$\text{Consumption(liters)} = \text{distance(km)} * \frac{x}{100} * \left(\frac{2}{3} + \frac{1}{3} * \frac{\text{payload}}{\text{payload max}} + \text{empty return rate} * \frac{2}{3}\right)$$

Empty return rate: part of the trip that the lorry must achieve empty before being reloaded

Where x is the fuel consumption of the fully loaded lorry expressed in litres/100 km. I.e., two-thirds of the fuel consumption of the fully loaded lorry is associated with the lorry weight and one third with the load.

Table 42: Breakdown between the EURO standards

	Europe	Asia	US
EURO 3	0%	33%	0%
EURO 4	13.5%	34%	0%
EURO 5	13.5%	33%	0%
EURO 6	73%	0%	100%
Source	Eurostat 2025 data 2023 – RDC Environment calculation based on age of lorries	Hypothesis	Hypothesis

Finally, according to the PEF guidance document, a fraction of the impacts from transportation activities is allocated to the unit of analysis (to the considered product) based on the load-limiting factor. For goods transport, the following modelling principles should be considered: time or distance AND mass or volume (or in specific cases: pieces/pallets) of the transported good.

If the maximum authorised weight is reached before the vehicle has reached its maximum volume capacity: at 100 % of its volume (high density products), then allocation shall be based on the mass of transported products.

When not specified in the report, loading rates and return rates of average goods are applied (see table below)

When a specific loading rate is applied, the empty return rate is assumed to be 29% (European average published by Eurostat, 2008).

Table 43: Loading rate and empty return rate depending on the type of goods

Parameter	Average goods	Heavy goods
Empty return rate	20%	60%
Loading rate	60%	30%
Source	Ecotransit 2022	Ecotransit 2022

The proportion of the route travelled in urban areas can influence the impact of lorry transport.

Table 44: Proportion of urban area depending on the distance travelled

	Short distance (< 300km)	Long distance (> 300km)
Urban area	15%	10%
Rural / highway	85%	90%
Source	Hypothesis	Hypothesis

Annexe 8. Functional units transported per transportation trip

Table 45 Number of functional units transported per lorry in the logistics phase.

Packaging type	#FU per lorry - First leg	#FU per lorry - Second leg
25ml dip cup	871,000	84,625
500 ml Squeeze bottle	870,000	83,040
12 ml single use plastic cup	1,302,840	183,720
1L milk carton	2,040,000	195,000
30g (22ml) single use plastics cup	833,040	79,200
3kg tub	832,600	79,300
30g sealed mini glass jar	365,760	34,680
4g single - use sugar sachet PP	4,653,000	569,000
4g single - use sugar sachet paper	4,653,000	550,000
1 kg of sugar cubes	6,490,385	607,500
Plastic pouch 5L - Semi viscous (sauce)	904,400	88,000
Plastic pouch 5L - milk	2,054,167	200,000
Plastic pouch 5L - jam	893,617	82,890
12 ml paper cups - rigid	7,698,240	2,514,240
22 ml paper cups - rigid	4,062,960	1,308,960
25 ml paper cups - thin	5,775,000	2,730,000
25 ml reusable cups	1,346,400*	318,048*
12 ml reusable cups	2,803,680*	662,592*
22 ml reusable cups	1,463,616*	345,696*

Values noted with an asterisk (*) for the reusable cups, indicate this is before considering the number of uses, i.e. represents the number of reusable cups that are transported, before allocation to the functional unit.

This is calculated based on:

- The weight and volume limitations of the lorry [52]
- The loading rate
- The number of units per carton

Annexe 9. Transformation processes packaging & serving options

The transformation processes used to model the production of the different packaging types are presented here.

Single-use plastic dip cup and reusable plastic cup:

1. Plastic pellets are converted into plastic sheets through an extrusion process
2. The sheet is then shaped into cups using thermoforming

Plastic sachet:

1. Plastic pellets are converted into a plastic film through an extrusion process
2. The plastic film is heat sealed and cut into a sachet (not included in LCA, negligible impact)

Paper sachet with plastic liner:

1. Kraft paper is produced in a paper mill via pulping, sheet forming, pressing, drying
2. Plastic liner is added to paper base through extrusion lamination
3. The large laminate roll is slit into smaller rolls, and fed into form-fill-seal machine (not included in LCA, negligible impact)

Paper cup:

1. Kraft paper is produced in a paper mill via pulping, sheet forming, pressing, drying
2. Forming process to convert the paper sheet into a cup (not included in LCA, negligible impact)

Sealed moulded carton cup with plastic liner:

1. Kraft paper is produced in a paper mill via pulping, sheet forming, pressing, drying
2. Plastic liner is added to paper base through extrusion lamination
3. The large laminate roll is slit into smaller rolls, and fed into form-fill-seal machine (not included in LCA, negligible impact)

Glass jar + steel lid:

1. Glass jar is produced (ecoinvent dataset for 'packaging glass' already includes all steps of the production process, with a glass packaging as output)
2. Steel lid; the steel is rolled into thin sheets , coated with lacquer, fed into a high-speed press to cut out circle shapes and finally formed to create the lids

[52] For the first leg, this includes the weight and volume occupied by the pallets. Number of cartons estimated per pallet also respect EUR pallet weight restrictions (25 kg/pallet).

- The lacquer is not included in the model due to cut-off reasons (less than 5% mass)
- The different transformation steps to turn the initial stele into the lid are modelled with the proxy dataset 'metal working, average for steel product manufacturing'

Plastic bottle/tub:

1. Plastic pellets are produced for the relevant plastic type (PP, HDPE)
2. The pellets are converted into the shape of a bottle or tub through a blow moulding process

Plastic cap (for bottle/tub):

1. Plastic pellets are produced
2. The pellets are converted into a cap through injection moulding

Plastic pouch :

1. The plastic pouch consists of a plastic (LDPE) pouch which is produced through a blow moulding process

Dispensers:

2. All dispensing solutions (manual dispenser, and the sugar pot) consist of stainless steel
1. The stainless steel is produced and subsequently converted into a final product by using the proxy dataset 'metal working, average for steel product manufacturing'

Cardboard box (secondary packaging):

1. The production of the cardboard box is fully covered in the ecoinvent dataset

Annexe 10. Monetarisation environmental impacts

Table 46: Additional information on monetarisation of environmental impacts

Impact category	Sub-category	Short explanation of the monetary valuation principle	Main characteristics of the model		Data source for reference monetised value
Global Warming Potential	Strong world climate politics	The monetary values correspond to the avoidance costs associated with an emissions trajectory (or carbon budget) making it possible to achieve zero net emissions in 2050.	Avoidance cost 2020	Extrapolation from CO_2 to other GHG using GWP from IPCC 2013	Quinet, 2019
Global Warming Potential	Weak world climate politics	The monetary values represent the marginal cost of CO2 emissions. The models are based on version 3 of the FUND (Climate Framework for Uncertainty, Negotiation and Distribution) integrated assessment model (IAM).	Damage cost 2020	Choice of model without preference for present, representing intergenerational equity Extrapolation from CO_2 to other GHG using GWP from IPCC 2013	Anthoff, 2007 from NEEDS project
Acidification	Lakes	This monetary value is based on the repairing cost corresponding to liming of lakes in Sweden and Norway.	Repair cost	Quantification of damage by kg SO_2 via literature Extrapolation to other elementary flows using the LCIA method recommended by EF3.0 (Accumulated	RDC-Pira 2003
	Crops	This monetary value is based on the cost of repairing, i.e. applying lime or limestone for neutralizing soil acidity.	Repair cost		IVM 2000

Impact category	Sub-category	Short explanation of the monetary valuation principle	Main characteristics of the model		Data source for reference monetised value
	Forests	This monetary value is based on the damage cost estimated as timber loss due to incremental emissions of SO_2.	Damage cost (loss of productivity))	exceedance model, Seppäla, 2006 et Posch, 2008)	IVM 2000
	Materials and structure	This monetary value is based on the cost of repairing, i.e. the cost replacing materials used in buildings because of their corrosion by acidifying pollutants.	Repair cost		Watkiss 2001
Stratospheric Ozone Depletion	-	This monetary value is based on the damage cost of UV rays on health.	Damage cost	Extrapolation using LCIA method recommended by EF3.0 (WMO 2014)	American study, 1998
Eutrophication	Freshwater	This monetary value is based on the cost of repairing eutrophication-related damage in the Flemish Region (Belgium).	Repair cost (ecosystem restoration cost)	Cost per kg P Extrapolation to other elementary flows using the LCIA method recommended by EF3.0 (EUTREND model, Struijs et al., 2009 as applied in ReCiPe 2008)	OVAM 2017
	Marine	This monetary value is based on the cost of repairing eutrophication-related damage in the Flemish Region (Belgium).	Repair cost (ecosystem restoration cost)	Cost per kg N Extrapolation to other elementary flows using the LCIA method recommended by EF3.0 (EUTREND model,	OVAM 2017

Impact category	Sub-category	Short explanation of the monetary valuation principle	Main characteristics of the model		Data source for reference monetised value
				Struijs et al., 2009 as applied in ReCiPe 2008)	
	Terrestrial	-	No default method	No default method	No default method
Natural Resource Consumption	Fossil	The monetary value is based on resource market prices that are corrected to take future generations into account.	Corrected market price of resources	The method covers all the resources.	Huppertz et al., 2019
	Mineral	The monetary value is based on resource market prices that are corrected to take future generations into account.	Corrected market price of resources	The method covers all the resources.	Huppertz et al., 2019
Water Use	-	The monetary value corresponds to the desalination of seawater and its transport. It includes the economic cost of desalination and transport, as well as the cost of environmental damage associated with these activities.	Avoidance cost	Cost of desalination and transport of water + Environmental cost of desalination Extrapolation to geographical areas using the LCIA method recommended by EF3.0 (AWARE model, Boulay et al., 2018; UNEP 2016)	Tol et al. 2005 Ecoinvent 3.7.1 for tap water production by desalination

Impact category	Sub-category	Short explanation of the monetary valuation principle	Main characteristics of the model		Data source for reference monetised value
Land Use	-	-	No default method	No default method	No default method
Ecotoxicity	freshwater	The monetary value corresponds to the value attached to protection of terrestrial biodiversity and is based on the costs citizens say are willing to pay to protect biodiversity. The underlying assumption is that all terrestrial species are valued equally and therefore that freshwater species are valued identical to terrestrial species.	Damage cost	Damage value by CTUe based on restoration cost Extrapolation to all elementary flows using the LCIA method recommended by EF3.0 (Usetox 2.1 model, (Fantke et al. 2017), adapted as in Saouter et al., 2018)	OVAM 2017
Photochemical ozone formation	Vegetation	This monetary value is based on the damage cost due to reduced crop yields as well as forest and grassland production.	Damage cost (loss of productivity for crops, forests and grasslands)	Marginal damage cost per kg NOx and per kg NMVOC for crops and forests (and extrapolated for grasslands) Extrapolation of value per kg NOx to all nitrates and NOx using the LCIA method "Ozone formation, Terrestrial ecosystems - Recipe 2016 – Midpoint" Extrapolation of value per kg NMVOC to all VOCs using the LCIA method "Photochemical ozone	ETC/ATNI 2020 ADEME 2019 (for extrapolation to grasslands)

Impact category	Sub-category	Short explanation of the monetary valuation principle	Main characteristics of the model		Data source for reference monetised value
				formation - human health" recommended by EF 3.0 (LOTOS-EUROS model, Van Zelm et al., 2008, as applied in ReCiPe 2008)	
Toxicity	Carcinogens	The highest value between two methods was chosen to be conservative: one method is based on the damage cost obtained through the impact pathway approach for one reference substance for the category and the other one is based on an end-point method where the impact is expressed in DALY.	Cost of damage to human health	Maximum between: Cost associated with 1kg Cr^{VI} extrapolated to all elementary flows using LCIA method recommended by EF3.0 (Usetox 2.1 model, Fantke et al. 2017, adapted as in Saouter et al., 2018) Recipe 2016 to assess human health damage in DALY x Maximum value of DALY by WHO- The Commission on Macroeconomics and Health	EcoSenseWeb Tool 2007 Commission on Macroeconomics and Health. 2001
	Non-carcinogens	The highest value between two methods was chosen to be conservative: one method is based on the damage cost obtained through the impact pathway approach for one reference substance for the category and the other one is based on an	Cost of damage to human health	Maximum between: Cost associated with 1kg Pb extrapolated to all elementary flows using LCIA method recommended by	EcoSenseWeb Tool 2007 Commission on Macroeconomics and Health. 2001

Impact category	Sub-category	Short explanation of the monetary valuation principle	Main characteristics of the model		Data source for reference monetised value
		end-point method where the impact is expressed in DALY.		EF3.0 (Usetox 2.1 model, Fantke et al. 2017, adapted as in Saouter et al., 2018) Recipe 2016 to assess human health damage in DALY x Maximum value of DALY by WHO- The Commission on Macroeconomics and Health	
	Particulate matter	The highest value between two methods was chosen to be conservative: one method is based on the damage cost obtained through the impact pathway approach for one reference substance for the category and the other one is based on an end-point method where the impact is expressed in DALY.	Cost of damage to human health	Maximum between: Cost associated with 1kg PM2.5 extrapolated to all elementary flows using LCIA method recommended by EF3.0 (PM model, Fantke et al. 2016 in UNEP 2016) Recipe 2016 to assess human health damage in DALY x Maximum value of DALY by WHO- The Commission on Macroeconomics and Health	IHME (Study "Global Burden of Disease", 2019) Commission on Macroeconomics and Health. 2001
	Tropospheric Ozone	The highest value between two methods was chosen to be conservative: one method is based	Cost of damage to	Maximum between:	EcoSenseWeb Tool 2007

Impact category	Sub-category	Short explanation of the monetary valuation principle	Main characteristics of the model		Data source for reference monetised value
		on the damage cost obtained through the impact pathway approach for one reference substance for the category and the other one is based on an end-point method where the impact is expressed in DALY.	human health	Cost associated with 1kg NMVOC extrapolated to all elementary flows using the LCIA method recommended by EF3.0 (LOTOS-EUROS model, Van Zelm et al., 2008, as applied in ReCiPe 2008) Recipe 2016 to assess human health damage in DALY x Maximum value of DALY by WHO- The Commission on Macroeconomics and Health	Commission on Macroeconomics and Health. 2001
Ionising Radiation	-	The damage is quantified in DALY. The health impacts from exposure to Ionising radiation relate to cancers (fatal and non-fatal) and severe hereditary effects.	Cost of damage to human health	Cost based on OVAM Extrapolation to other elementary flows using the LCIA method recommended by EF3.0 (Human health effect model, Frischknecht et al, 2000, as developed by Dreicer et al. 1995)	OVAM 2017

Annexe 11. General LCA methodology limitation

Limitations inherent in the LCA methodology (ISO 14040:2016, 5.4.3)

The LCIA addresses only the environmental issues that are specified in the goal and scope. Therefore, LCIA is not a complete assessment of all environmental issues of the product system under study. LCIA cannot always demonstrate significant differences between impact categories and the related indicator results of alternative product systems. This may be due to:

- Limited development of the characterization models, sensitivity analysis and uncertainty analysis for the LCIA phase,
- Limitations of the LCI phase, such as setting the system boundary, that do not encompass all possible unit processes for a product system or do not include all inputs and outputs of every unit process, since there are cut-offs and data gaps,
- Limitations of the LCI phase, such as inadequate LCI data quality which may, for instance, be caused by uncertainties or differences in allocation and aggregation procedures, and
- Limitations in the collection of inventory data appropriate and representative for each impact category.

The lack of spatial and temporal dimensions in the LCI results introduces uncertainty in the LCIA results. The uncertainty varies with the spatial and temporal characteristics of each impact category. There are no generally accepted methodologies for consistently and accurately associating inventory data with specific potential environmental impacts. Models for impact categories are in different stages of development.

Limitations inherent in the LCA methodology (ISO 14044:2016, 4.4.5)

An LCIA that is intended to be used in comparative assertions intended to be disclosed to the public shall employ a sufficiently comprehensive set of category indicators. The comparison shall be conducted category indicator by category indicator. An LCIA shall not provide the sole basis of comparative assertion intended to be disclosed to the public of overall environmental superiority or equivalence, as additional information will be necessary to overcome some of the inherent limitations in the LCIA. Value-choices, exclusion of spatial and temporal, threshold and dose-response information, relative approach, and the variation in precision among impact categories are examples of such limitations. LCIA results do not predict impacts on category endpoints, exceeding thresholds, safety margins or risks. Category indicators intended to be used in comparative assertions intended to be disclosed to the public shall, as a minimum, be;

- Scientifically and technically valid, i.e. using a distinct identifiable environmental mechanism and/or reproducible empirical observation, and;
- Environmentally relevant, i.e. have sufficiently clear links to the category endpoint(s) including, but not limited to, spatial and temporal characteristics.

Category indicators intended to be used in comparative assertions intended to be disclosed to the public should be internationally accepted. Weighting, as described in 4.4.3.4, shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public. An analysis of results for sensitivity and uncertainty shall be conducted for studies intended to be used in comparative assertions intended to be disclosed to the public.

Limitations related to impact categories

The robustness of impact assessment methods varies depending on the indicator considered. Some indicators still present significant limitations:

- Toxicity and ecotoxicity models are not very robust: they are incomplete (not all pollutants are assessed by the characterization method or covered by life-cycle inventories);
- Characterization models for fossil and mineral resource impact categories reflect usage rather than depletion:
  - The fossil resource use category is based on the lower heating value (LHV) of the resources (there is no availability factor in the method);
  - The mineral resource use category is based on the ultimate availability of the resource, even though certain resources may be very difficult to extract (very low concentration, very poor accessibility).
- Impact categories associated with local environmental issues require more detailed modelling than what databases currently allow. The following two examples illustrate these limitations:
  - A medium's response to an ecotoxic substance is directly linked to its initial quality (specific fauna and flora, existing pollution, etc.);
  - Water resource pressure must be assessed at the watershed level. The factors used in this study represent a European average.

LCA does not allow a comprehensive assessment of all environmental issues. In particular, no robust methods yet exist for assessing impacts on biodiversity.

Allocation factor recycling benefits (PEF methodology)

When packaging waste is recycled, the recycled material can be used as input for another product (same product = closed-loop recycling, different product = open-loop recycling). Using this recycled material avoids the production of virgin material, which is a benefit. This benefit must be allocated among the supplier of the waste material and the incorporator of the recycled material. In this case Henkel would be the supplier of the waste paper/PE to be recycled, and another company would be the incorporator.

The allocation of these benefits should be done on a market-based approach: depending on the supply and demand of the recycled product. For example when there is a large demand for recycled material (could be due to certain regulations on minimum % recycled content, as is the case for PET bottles) but a limited supply of the recycled material, the largest part of the benefits should be allocated to the supplier of the recycled material.

Default allocation factors for certain common materials (PET, PE, aluminium, steel…) can be found in the PEF Annex C and in case no default value exists, recommends using a '50/50' approach where half of the benefits of recycling are allocated to the supplier of the recycled material and half to the incorporator of the recycled material. These recommended allocation factors could be topic of discussion, since they are relatively underdeveloped.

The choice of the allocation factor has an impact on the environmental impact during manufacturing and End-of-Life (when recycling occurs).

Annexe 12. Results

Annexe 12 presents complementary tables for the results of the study.

A series of tables are presented in an additional Excel file sheet "CPIC_CBA_Annexe 12.xlsx".



4407_CPIC_CBA_Annexe 12.xlsx

This file contains the following tables:

- 12.1 - Absolute monetised impact modelled for all scenarios
- 12.2 - Climate Change Impact: Absolute impact modelled for all scenarios
- 12.3 - Climate Change Impact: Relative impact contributions per phase for all scenarios

In addition, the following table complements the results section 7.3 on the impact of the results in a wood constrained scenario.

Table 47 Impact of a wood constrained scenario on the difference in total impact between the alternative single-use and the SUP base case, as the % change to the delta impact.

Comparison	Consumption location	Food type	% change in the delta between SUP & alt SUP
Alternative SU vs. SUP base case	**Café**	Creamer	0.1%
		Jam	1%
		Semi-viscous	-0.4%
		Sugar	14%
	Canteen	Creamer	-0.2%
		Jam	0.1%
		Semi-viscous	-0.4%
		Sugar	14%
	Hotel	Creamer	0.04%
		Jam	1%
		Semi-viscous	-0.27%
		Sugar	14%
	Restaurant	Creamer	-0.4%
		Jam	1%

		Semi-viscous	-1%
		Sugar	14%

Annexe 13. Sources used to estimate the number of food service visits

The following table presents the main sources used to estimate the number of food service visits in each consumption location (canteens, restaurants, cafés and hotels) in the EU per year.

Table 48 Overview of key data sources to estimate the number of food service visits

Source	Link
Eurostat dataset *Mean consumption expenditure per household by COICOP consumption purpose [hbs_exp_t121]*	https://ec.europa.eu/eurostat/databrowser/view/hbs_exp_t121/default/table?lang=en
Belgian Household Survey 2024 - Average annual household expenditure (€) – Belgium	https://statbel.fgov.be/fr/themes/menages/budget-des-menages#panel-12
Numbeo - Europe: Prices by City of Meal for Two at a Mid-Range Restaurant (Three Courses, Without Drinks) (Restaurants)	https://www.numbeo.com/cost-of-living/region_prices_by_city?itemId=2&region=150&displayCurrency=EUR
Circana report - Expanding consumer choices: Foodservice and retail merge as boundaries blur in a transforming market	https://www.circana.com/post/expanding-consumer-choices-foodservice-and-retail-merge-as-boundaries-blur-in-a-transforming-market
Eurostat dataset *Nights spent at tourist accommodation establishments - monthly data [tour_occ_nim]*	https://ec.europa.eu/eurostat/databrowser/view/tour_occ_nim/default/table?lang=en&category=tour.tour_indm
FoodService Europe	https://foodserviceeurope.org/

Annexe 14. Food Safety Comparative Risk Level Conclusions by Scenario

Table 49: Food safety comparative risk level – ketchup scenarios

Food safety risk summary Ketchup			
Location type	**Base case**	**Alternative 1**	**Alternative 2**
Canteen	Standard sealed dip-cup Self-service	Manual dispenser & reusable cup Self-service	Manual dispenser & single use paper cup Self-service
	Very Low	**Low – Low medium** Additional risks due to opened, part-used containers in dispenser and additional food contact equipment and cleaning step for cups and dispenser. Higher risk of physical, chemical, microbiological and allergenic contamination from people, the environment, damaged/contaminated cups, insufficient cleaning. Self-service by customer reduces the allergen risk of receiving incorrect sauce type however there is also risk of staff filling the wrong container. Additional operational requirements for storage of cups, collection of cups, cleaning of cups, cleaning of dispenser.	**Low** Additional risks due to opened, part-used containers in dispenser and additional food contact equipment and cleaning step for dispenser. Higher risk of physical, chemical, microbiological and allergenic contamination from people, the environment to open paper cups. Self-service by customer reduces the allergen risk of receiving incorrect sauce type however there is also risk of staff filling the wrong container. Additional operational requirements for storage of cups, cleaning of dispenser.

Restaurant	Standard sealed dip-cup Self-service	Table-top bottle & reusable cup Self-service	Table-top bottle & single use paper cup Self-service
	Very Low	**Low (but slightly higher than Alternative 2)** Additional risks due to opened, part-used bottle and additional food contact equipment and cleaning step for cups. Higher risk of physical, chemical, microbiological and allergenic contamination from people, the environment, damaged/contaminated cups, insufficient cleaning. Fully labelled bottle reduces allergen risk. Additional operational requirements for storage of cups, collection of cups, cleaning of cups, best practice – return of bottles to refrigerated storage at end of day.	**Low** Additional risks due to opened, part-used bottle and additional food contact equipment. Higher risk of physical, chemical, microbiological and allergenic contamination from people, the environment, contaminated cups. Fully labelled bottle reduces allergen risk. Additional operational requirements for storage of cups, best practice – return of bottles to refrigerated storage at end of day.
Café	Standard sealed dip-cup Served by staff	Manual dispenser & reusable cup Served by staff	Manual dispenser & single use paper cup Served by staff
	Very Low	**Low (but slightly higher than Alternative 2)** Additional risks due to open/unsealed and unidentified format and additional food contact	**Low** Additional risks due to open/unsealed and unidentified format and additional food contact equipment and cleaning

		equipment and cleaning step. Higher risk of physical, chemical, microbiological and allergenic contamination from people, the environment, damaged dispenser/cups, insufficient cleaning. Allergen risk of serving incorrect sauce type Additional operational requirements for storage of cups, collection of cups, cleaning of cups, cleaning of dispenser.	via dispenser. Higher risk of physical, chemical, microbiological and allergenic contamination from people, the environment to open paper cups. Allergen risk of serving incorrect sauce type Additional operational requirements for storage of cups, cleaning of dispenser.
Hotel	Standard sealed dip-cup Served by staff	Manual dispenser & reusable cup Served by staff	Manual dispenser & single use paper cup Served by staff
	Very Low	**Low (but slightly higher than Alternative 2)** Additional risks due to open/unsealed and unidentified format and additional food contact equipment and cleaning step. Higher risk of physical, chemical, microbiological and allergenic contamination from people, the environment, damaged dispenser/cups, insufficient cleaning. Allergen risk of serving incorrect sauce type, however this risk is lower than for a cafe setting as the number of room service meals prepared is likely to be far lower and so give	**Low** Additional risks due to open/unsealed and unidentified format and additional food contact equipment and cleaning via dispenser. Higher risk of physical, chemical, microbiological and allergenic contamination from people, the environment to open paper cups. Allergen risk of serving incorrect sauce type, however this risk is lower than for a cafe setting as the number of room service meals prepared is likely to be far lower and so give more focused

		more focused preparation and delivery to room number is more targeted. Additional operational requirements for storage of cups, collection of cups, cleaning of cups, cleaning of dispenser.	preparation and delivery to room number is more targeted. Additional operational requirements for storage of cups, cleaning of dispenser.

Table 50: Food safety comparative risk level – creamer scenarios

Food safety risk summary Creamer (milk)			
Location type	**Base case**	**Alternative 1**	**Alternative 2**
	Standard sealed cup Self-service	dispenser/reuseable cup Self-service	dispenser/single use paper cup Self-service
Canteen	**Very Low**	**Low-Low medium (but slightly higher than Alternative 2)** Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse Consumer behaviour is difficult to control IF self-service allowed Serving environment may present more risk.	**Low-low medium** Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse Consumer behaviour is difficult to control IF self-service allowed Serving environment may present more risk. Additional operational requirements for

		Additional operational requirements for hygiene controls, date controls, recycling and reuse.	hygiene controls, date controls, waste collection and recycling
Restaurant	Standard sealed cup Served by staff	Plastic bottle/reuseable cup Served by staff	Plastic bottle/single use paper cup Served by staff
	Very Low	**Low(but slightly higher than Alternative 2)** Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse Additional operational requirements for supply, hygiene controls, date controls, recycling and reuse	**Low** Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse Additional operational requirements for supply, hygiene controls, recycling
Café	Standard sealed cup Served by staff	Plastic bottle/reuseable cup Served by staff	Plastic bottle/single use paper cup Served by staff
	Very Low	**Low** **(but slightly higher than Alternative 2)** Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse	**Low** Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse

		Additional operational requirements for supply, hygiene controls, date controls, recycling and reuse	Additional operational requirements for supply, hygiene controls, recycling
Hotel	Standard sealed cup Served by staff	Plastic bottle/reuseable cup Served by staff	Plastic bottle/single use paper cup Served by staff
	Very Low	**Low(but slightly higher than Alternative 2)** Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse Additional operational requirements for supply, hygiene controls, date controls, recycling and reuse	**Low** Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse Additional operational requirements for supply, hygiene controls, recycling

Table 51: Food safety comparative risk level – jam scenarios

Food safety risk summary Jam			
Location type	**Base case**	**Alternative 1**	**Alternative 2**
Canteen	Standard sealed cup Self-service	dispenser/reuseable cup Self-service	dispenser/single use paper cup Self-service
	Very Low	**Low-Low medium**	**Low-low medium**

		Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse Consumer behaviour is difficult to control IF self-service allowed Serving environment may present more risk. Additional operational requirements for hygiene controls, date controls, recycling and reuse.	Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse Consumer behaviour is difficult to control IF self-service allowed Serving environment may present more risk. Additional operational requirements for hygiene controls, date controls, waste collection and recycling
Restaurant	Standard sealed cup Served by staff	Catering tub/reuseable cup Served by staff	Single use jam in glass jar Served by staff
	Very Low	**Low** Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse Additional operational requirements for supply, hygiene controls, date controls, recycling and reuse	**Very Low** Some risk of glass shard contamination and broken seals Additional operational requirements for waste collection and recycling

Café	Standard sealed cup Served by staff	Catering tub/reuseable cup Served by staff	Single use jam in glass jar Served by staff
	Very Low	**Low** Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse Additional operational requirements for supply, hygiene controls, date controls, recycling and reuse	**Very Low** Some risk of glass shard contamination and broken seals Additional operational requirements for waste collection and recycling
Hotel	Standard sealed dip-cup Served by staff	Catering tub/reuseable cup Served by staff	Single use jam in glass jar Served by staff
	Very Low	**Low** Additional risk is post opening, introduction of pathogens and foreign objects. Includes exposure to allergen contamination and temperature abuse Additional operational requirements for supply, hygiene controls, date controls, recycling and reuse	**Very Low** Some risk of glass shard contamination and broken seals Consumer behaviour is difficult to control IF self-service allowed Additional operational requirements for waste collection and recycling

Table 52: Food safety comparative risk level – sugar scenarios

Food safety risk summary Sugar			
Location type	**Base case**	**Alternative 1**	**Alternative 2**
Canteen	Plastic sealed stick Self-service	Pot of sugar cubes Self-service	Paper lined sealed stick Self-service
	Very Low	**Low** Additional risks due to open/unsealed format and additional food contact equipment and cleaning step. Higher risk of physical, chemical, microbiological and allergenic contamination from people, the environment, damaged pot/tongs, insufficient cleaning, customer spillage/misuse. Additional operational requirements for storage of pot and tongs, cleaning of pot and tongs, cleaning of self-service area, monitoring of pot for contamination/misuse.	**Very Low** If a paper-based product can be sourced with the same barrier properties, then no difference in risk (or quality) impacts. It could be assumed that a paper-based product could certainly be fit for purpose, but that the robustness and barrier properties and therefore product shelf life could be very slightly reduced compared to the base case (however it will still be suitably 'long life'). Potentially there could be a higher rate of broken packs during handling by staff and customers, resulting in slightly higher risk for hygiene and requirement for more frequent cleaning.
Restaurant	Plastic sealed stick	Pot of sugar cubes	Paper lined sealed stick

	Self-service	Self-service	Self-service
	Very Low	**Low** Additional risks due to open/unsealed format and additional food contact equipment and cleaning step. Higher risk of physical, chemical, microbiological and allergenic contamination from people, the environment, damaged pot/tongs, insufficient cleaning, customer spillage/misuse. Additional operational requirements for storage of pot and tongs, cleaning of pot and tongs, cleaning of self-service area, monitoring of pot for contamination/misuse.	**Very Low** If a paper-based product can be sourced with the same barrier properties, then no difference in risk (or quality) impacts. It could be assumed that a paper-based product could certainly be fit for purpose, but that the robustness and barrier properties and therefore product shelf life could be very slightly reduced compared to the base case (however it will still be suitably 'long life'). Potentially there could be a higher rate of broken packs during handling by staff and customers, resulting in slightly higher risk for hygiene and requirement for more frequent cleaning.
Café	Plastic sealed stick Self-service	Pot of sugar cubes Self-service	Paper lined sealed stick Self-service
	Very Low	**Low** Additional risks due to open/unsealed format and additional food contact equipment and cleaning step. Higher risk of physical, chemical, microbiological and	**Very Low** If a paper-based product can be sourced with the same barrier properties, then no difference in risk (or quality) impacts.

		allergenic contamination from people, the environment, damaged pot/tongs, insufficient cleaning, customer spillage/misuse. High footfall and customer and demographic in this setting increases this risk further. Additional operational requirements for storage of pot and tongs, cleaning of pot and tongs, cleaning of self-service area, monitoring of pot for contamination/misuse.	It could be assumed that a paper-based product could certainly be fit for purpose, but that the robustness and barrier properties and therefore product shelf life could be very slightly reduced compared to the base case (however it will still be suitably 'long life'). Potentially there could be a higher rate of broken packs during handling by staff and customers, resulting in slightly higher risk for hygiene and requirement for more frequent cleaning.
Hotel	Plastic sealed stick Self-service	Paper lined sealed stick Self-service	
	Very Low	**Very Low** If a paper-based product can be sourced with the same barrier properties, then no difference in risk (or quality) impacts. It could be assumed that a paper-based product could certainly be fit for purpose, but that the robustness and barrier properties and therefore product shelf life could be very slightly reduced compared to the base case (however it will still be suitably 'long life').	

		Potentially there could be a higher rate of broken packs during handling by staff and customers, resulting in slightly higher risk for hygiene and requirement for more frequent cleaning.	

RDC environment

Research Development & Consulting Environment

EXPERTS AND SOLUTIONS IN SUSTAINABLE DEVELOPMENT

rdcenvironment.be - contact@rdcenvironment.be

Address

Av. Gustave Demey, 57

1160 Brussels, Belgium

Contact

+32 2 420 28 23

contact@rdcenvironment.be

Website

www.rdcenvironment.be