Making the business case for **Packaging reuse systems**

Methodology

Circular Economy Portugal
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Contents

1. Research and literature review

In the first phase of this study a research and literature review were undertaken. This review focused on existing reports and scientific papers about the definition, characteristics, and implementation of reuse business models mostly in Europe. Existing LCA studies were also reviewed, focusing on the comparison between single-use vs reusable packaging business models focusing, amongst other subjects, on the environmental impacts of each of the systems or the operational costs of these systems. In this phase, the experience and knowledge of the consultants on various packaging reuse systems was also leveraged to complement and deepen the theoretical information mostly found online. 20 interviews and personal contacts were also conducted in order to assess and confirm information and data found in the literature review and to gather updated and in-depth information from relevant stakeholders in the field. Examples from different geographical locations in Europe were selected in order to have a broader coverage of the implementation of reuse systems given this can vary according to local/regional context and specifications.

The interviews were carried out through virtual meetings and email exchanges with businesses, manufacturers, retailers, experts on logistics, packaging, and manufacturers' associations, who are testing reuse models such as reusable packaging and different reuse systems. Case studies for existing reuse systems were elaborated. The goal with these case studies was to inspire and inform the readers on how specific barriers were overcome, what are the environmental and socio-economic impacts of these models (specially compared to the single-use ones) and to identify the potential opportunities these cases demonstrate. In total, four case studies were developed. For the HoReca channel, CupClub (United Kingdom) as a best practice for beverage containers and Uzaje (France) for food containers; for e-commerce for fashion, we selected RePack from Finland and, for large retail, we selected a combination of pilot projects and initiatives from different companies and locations.

2. Product groups prioritization

The aim of this task was to define an approach to prioritise the product groups to focus the study on.

Prioritization Process and Products selection

Figure 1 presents the methodology followed in the prioritization process.

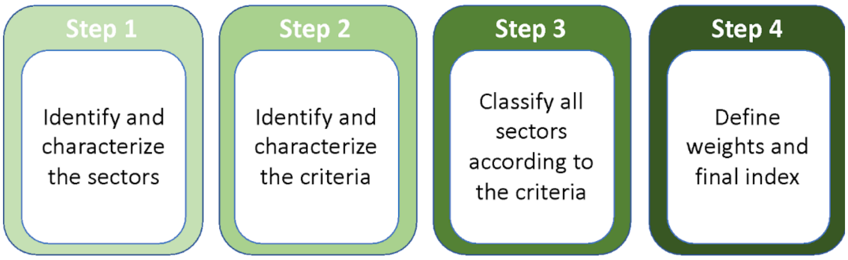

Figure 1: Prioritization methodology

Each step of the methodology will be explained as follows.

Step 1: Identify and characterise the sectors

Since the aim of the study is to propose reuse systems for different sectors/products, the main three distribution channels were identified:

i- HoReCa: Covering restaurants, hotels, and cafés. This distribution channel represents the channel where a user goes to an outlet to pick up food/ beverage and take with him/her, which creates the need for a reusable packaging system.

ii- E-commerce: Covering all products that are shipped from warehouses/retailers directly to users' houses. The need to protect the goods being delivered drives the use for secondary packaging.

iii- Retail: Covering small and big supermarkets and chains. This channel considers all the goods that are commercialised in a physical space, where the user goes there to buy. Most goods are pre-packed and displayed on shelves/fridges often in several layers of multimaterial packaging. For each distribution channel, the main product groups sold through the channel were identified.

They are summarised in Table 1.

HoReCa	E-commerce	Retail
Take-away food	Fashion, shoes and accessories	Fruits and vegetables
Hot beverages	Cosmetics	Dried food
Cold beverages	Books	Refrigerated and frozen food
Dried food (e.g.: sandwiches, pastries)	Electronic and Electric Equipment	Household care
Beer	Food	Cosmetics
Wine	Toys and games	Beverages

Table 1: Main product groups sold through the three main distribution channels

Step 2: Identify and characterise the criteria

A multicriteria decision analysis method has been applied in the following steps of the methodology. For that, a group of decision makers, composed of four experts (consultants in the study) in the field of reuse systems and circular economy have discussed and defined the main criteria that should be applied to select the most promising systems to be analysed. It is important to note that these criteria were defined not to select the "best" products, but instead to select the most promising products that can be used as a pilot for reuse systems, serving as examples to others. The selected criteria are presented in Table 2, with the correspondent description and scale.

Criteria	Definition	Score 1 Low interest	Score 5 High interest
Packaging waste generated	Volume of waste generated. Focus on products that generate more packaging weight and high frequency of disposal.	High quantity of waste	Low quantity of waste
Packaging recyclability	Potential for recyclability of the material. Focus on products where the packaging is mainly not recyclable and therefore reuse systems are a cornerstone.	High recyclability	Low recyclability
Health & Safety	Assess health and safety constraints and regulations. Focus on products where refill systems have less restrictions.	Very restrictive rules	Less restrictive rules
User perception	Evaluate the perception and acceptance of the user in the use of a refill system for a specific product. Focus on products with potential higher acceptance from the user.	Low acceptance	Higher acceptance
Product value-added	Profit margin of the product. Focus on products with higher profit margins which could more easily accommodate more expensive packaging and/or where a deposit for the packaging could be more acceptable by users	Low value-added	High value-added
Supply chain control	Evaluate the structure of the supply chain through vertical integration VS different entities, local VS international supply chain. Focus on more local and vertically integrated supply chains, since control and capacity to implement a refill system is higher.	International and decentralised	Nacional and centralised
Data availability	Availability of data to define and characterise possible future refill systems as part of the study. Focus on products with more available data.	Low availability	High availability
Evidence of case studies	Existence of pilot cases that show evidence of the feasibility of such models. Focus on products that packaging reuse systems exist.	Low evidence	Strong evidence

Table 2: Criteria definition and scale

Step 3: Classify all products according to the criteria

A direct rating, as defined by Winterfeldt & Edwards, 1986 [1] has been applied to classify each product according to each criterion. This means a numerical estimate, defined by the decision makers is presented, based on the anchored scale presented in Table 2. Table 3 to 5 present the scores given to each criterion for each product category in each of the three channels covered.

HoReCa	Take-away food	Hot beverages	Cold beverages	Dried food	Beer	Wine
Packaging waste generated	5	4	4	3	4	1
Packaging recyclability	5	4	1	4	2	2
Health & Safety	1	5	3	3	5	5
User acceptance	2	4	4	3	4	4
Product value-added	3	4	3	3	5	5
Supply chain control	5	5	3	5	3	2
Data availability	2	2	1	1	1	1
Evidence of case studies	3	4	2	1	3	3

Table 3: Scores for the HoReCa channel products in each criterion

E-commerce	Fashion, shoes & accessories	EEE[1]	Books	Cosmetics	Food	Toys & games
Packaging waste generated	5	3	4	3	2	3
Packaging recyclability	4	3	1	3	2	1
Health & Safety	5	5	5	4	1	5
User	5	5	5	5	2	5
Product value-added	3	5	3	4	1	5
Supply chain control	2	2	3	2	4	2
Data availability	1	1	1	1	1	1
Evidence of case studies	4	1	4	3	3	2

Table 4: Scores for the e-commerce channel products in each criterion

[1] EEE: Electrical and Electronic Equipments

Retail	Fruits and veg	Dried food	Refrigerated & frozen food	Household care	Cosmetics	Beverages
Packaging waste generated	1	4	4	3	3	4
Packaging recyclability	5	5	4	2	3	1
Health & Safety	3	1	2	5	3	1
User	5	3	4	5	3	4
Product value-added	1	3	4	5	5	4
Supply chain control	5	2	3	2	2	3
Data availability	1	1	1	2	2	3
Evidence of case studies	2	3	1	3	3	5

Table 5: Scores for the retail channel products in each criterion

Step 4: Define weights and final index

To define the weights and be able to aggregate the individual scores of each criterion in a final index, the Swing Weighting Method was selected due to its quantitative-based analysis [2]. The final index, calculated for each channel and product, allows to determine the most promising product to study, considering the preferences of the decision-makers regarding the specified criteria.

Goodwin & Wright (2014) [2] described the Swing Weighting Method as follows:

Step I – Criterion Comparison: Scoring each criterion according to the relevance of the criterion to the product. The decision makers must rank the criteria from the most important to the least and attribute to each criterion a weight under 100 points. Each criterion must weigh less than the criterion above, i.e., it can never be attributed a score higher than the one given before. The output of this step is a relevant list of criteria, from the highest to the lowest scored criteria with the corresponding weight.

Step II – Weight Generation: A normalisation of the scores is now required. This is made with the application of the following equation:

$$w = si \sum n \, 0 \, si \; \forall i = 1,2,3,4,5,6,7,8$$

Where si is the non-normalized score attributed to each criterion i, and wi is the normalized weight of each criterion i. The sum of the normalizations for each criterion must be equal to 1, and each value must be included in the following interval [0,1].

After 8 hours of discussion of the decision-makers, the ranking of the criteria and the weights were determined, and they are presented in Table 6.

	Ranking	Points	Weights
Packaging waste generated	1	100	0,27
Supply chain control	2	90	0,25
User	3	50	0,14
Health & Safety	4	49	0,13
Product value-added	5	40	0,11
Evidence of interest and case studies	6	20	0,05
Data availability	7	10	0,03
Packaging recyclability	8	5	0,01

Table 6: Weighting factors for final index calculation

Applying the weights to the criteria, the final score for each product was calculated and it can be seen in following Table 7.

HoReCa	Take-away food	Hot beverages	Cold beverages	Dried Food	Beer	Wine
Final Index	3,57	**4,27**	3,26	3,29	3,80	2,73
E-commerce	**Fashion, shoes & accessories**	EEE	Books	Cosmetics	Food	Toys & games
Final Index	**3,80**	3,31	3,78	3,18	2,25	3,37
Retail	Fruits and veg	Dried food	Refrigerated and frozen food	**Household care**	Cosmetics	Beverages
Final Index	2,85	2,66	3,18	**3,45**	2,90	3,32

Table 7: Final index for each of the products by channel

From the final index the following products were selected: HoReCa: Hot Beverages; E-commerce: Fashion, shoes & Accessories; Retail: Household care.

Despite the fact that take-away food has not been one of the most promising product groups, due to the increase in take-away (and delivery) food demand with the COVID-19 pandemic, it was decided by the decision-makers to also analyse this product. In addition, since hot and cold beverages require similar types of reusable cups, they were also analysed together. Therefore, in the HoReCa channel the system took into consideration two product categories, hereby designated: food & beverage containers.

The final product categories analysed in the study are:

- HoReCa: Food & Beverage containers;
- E-commerce: Fashion, shoes & accessories;
- Retail: Household care.

These four product groups are a good representation of different distribution channels and shopping environments, covering both food and non-Food products, with different challenges, players and user habits, leading to a broad analysis with a wide coverage of the main issues that should be considered when designing reuse systems under different contexts.

3. Quantitative analysis

This chapter starts by identifying and describing the characteristics of each system for each group product, performing a comparison analysis between a product from the current system and one in the proposed reuse system. In addition, a quantitative analysis was performed to assess their environmental, economic, and social impacts. For each group product, the best option available for the single-use system (with the lowest impacts and most used in Europe) and the worst option for a reuse system were chosen. The goal is to achieve a fair comparison between both systems. A decision was taken to follow this approach since the environmental impact of single-use packaging is more dependent on raw material and energy use in packaging manufacture and, therefore if clean technologies are applied to single-use, the number of reuses of the reusable packaging might have to increase to compensate for the application of clean technology.

For this analysis a set of criteria was established to be used to evaluate both systems: product used, type and location of production, distances and transportation, number of cycles, washing consumption and destiny of products at the end-of-life. To develop this, different sources and references were used, including existing LCA conducted by existing reuse businesses, data from producers, and waste management entities reports.

3.1 Systems characterization

HoReCa: food containers

For food containers, the choice was made to compare a reusable take-away box with a single-use plastic box (PP - Polypropylene) (Table 8).

Categories	Reusable system	References	Single-use system	References
Product	79g box Polypropylene 1,80€/ unit including transport to EU and taxes	[8]	43g box Polypropylene 0,39€/unit including transport to EU and taxes	[9]
Production	Extrusion Thermoforming Manufacturing in China	[10]	Extrusion Thermoforming Manufacturing in China	[10]
Transportation	Shanghai to Rotterdam: 19.500km by sea Rotterdam to WH[2]: - 150 + 581km Truck, EURO6, full truck load, 2€/km Average distance to washing centre: 20km, one way in a centralized WH 20 km to waste management facilities	[10] [11] [12] [13]	Shanghai to Rotterdam: 19.500km by sea Rotterdam to WH: less than 150 km + 581km Truck, EURO6, full truck load, 2€/km 200 km to waste management facilities	[10] [12] [13]
Reuse	100 cycles of use per box 90% return rate 10% of losses/damaged box	[13] [14]	Single-use	-

[2] WH: Warehouse

Storage	2 inspections, before washing and after washing, 30 seconds. Average minimum wage in the EU, 5,78€/h. Holding cost 10% of acquisition costs	[15] [16] [34]	Holding cost 10% of acquisition costs	[16]
Washing	Energy consumption: 0.037kWh/ cup 0,21 €/kwh average for EU. Water consumption: 0.317 litres/ container. 0,0026€/litre, including water and sanitation cost EU average Detergent consumption (NaOH 50%): 0,5% of the water consumption	[13] [17] [18] [19] [33]	Not applicable	[33]
End of life	Average for EU (16% recycling, 38,5% incineration with energy recovery and 45,5% landfilling) - 200km truck Waste management cost EU average, 234€/ton	[10] [20]	Average for EU (16% recycling, 38,5% incineration with energy recovery and 45,5% landfilling) - 200km truck Waste management cost EU average, 234€/ton	[10] [20]

Table 8: Reusable food container and single-use plastic container

HoReCa: beverage containers

For reusable beverage containers, we compared the characteristics of a reusable cup with a paperboard cup, currently used in this channel, as shown in Table 9.

Categories	Reusable system	Reference	Single-use system	Reference
Product	Cup made of 49.3g of polypropylene Lid made of 22.03g of low-density polyethylene 1,59€/ unit	[13] [21]	Paperboard cup 10.2g Corrugated sleeve 3.7g Polystyrene lid 3.4g Polyethylene liner 1g 0,25€/unit	[13] [22]
Production	Injection moulded cups and lids Manufacturing in Europe[3]	[13]	Calendering for the cup and injection moulding for the lid Production in Germany [16]	[24]
Transportation	Truck, EURO 6, full truck load 2€/km Delivery distance from factory to Warehouse (WH): 300km Average distance to washing centre: 20km (one way) in a centralized WH 200 km to waste management facilities	[13] 11]] [25]	Truck, EURO 6, full truck load, 2€/km Average delivery distance from factory to Cafes 500 km 200 km to waste management facilities	[13]
Reuse	132 cycles of use for a cup 90% return rate 10% of losses/damaged cups	[13]	Single-Use	-
Storage	2 inspections, before washing and after washing (30 seconds) Average minimum wage in EU, 5,78€/h Holding cost 10% of acquisition costs	[15] [16]	Holding cost 10% of acquisition costs	[16]
Washing	Energy consumption: 0.037kWh/ cup, 0,21 €/kwh, EU average Water consumption: 0.317 litres/ cup, 0,0026€/litre, including water and sanitation cost EU average	[13] [17] [18] [19] [33]	Not applicable	[33]

[3] Injection moulding factories exist throughout Europe

	Detergent consumption (NaOH 50%): 0,25% of the water consumption; €1,98€/litre			
End of life	90% recycled 5% landfilled and 5% incinerated Waste management cost EU average, 234€/ton	[13] [20]	50% landfilled and 50% incinerated Waste management cost EU average, 145€/ton	[12] [13] [35]

Table 9: Reusable cup and paperboard cup

E-commerce: Fashion and accessories

For e-commerce fashion items we compared the characteristics of a reusable packaging with a polybag, the most used packaging used as secondary packaging in this category, as shown in Table 10.

Categories	Reusable system	References	Single-use system	References
Product	Polypropylene packaging, 55 g; zip: nylon 1g, polyester 3g and POM 6g; thread 0.4g 2,10€/unit	[28]	15g LDPE 0,28€/unit	[29]
Production	Plastic film extrusion manufacturing in China Assembly in China	[28]	Plastic film extrusion manufacturing in China	[28]
Transportation	Truck, EURO 6, full truck load, 2€ / km Distance from manufacture-assembly: 10 km (PP film) & 300 km (zip) Assembly site in China to reusable central WH 1,000 km by truck and 16,000 km by ship Central WH to storage location: 0.7 km Storage location to e-commerce: 275 km E-commerce - customer: 500 km 50% of customers return the packaging directly to central WH 500 km truck 50% of customers return to the e-commerce due to order returns 500 km and then e-commerce returns to central WH 275 km 200 km to waste management facilities Package return by mail 1,30€/unit	[12] [13] [25] [28]	Truck, EURO 6, full truckload, 2€/ km Distance from factory in China to central WH in EU-16 000 km ship and 1000 km truck Distribution to clients 500 km 200 km to waste management facilities	[13] [25] [28]
Reuse	30 cycles of use for package 90% return rate 10% of losses/damaged box	[13] [30]	Single-Use	-
Storage	2 inspections, before washing and after washing, 30 seconds. Average minimum wage in the EU, 5,78€/h. Holding cost 10% of acquisition costs	[15] [16]	Holding cost 10% of acquisition costs	[16]
Washing	Alcohol (70%) 5ml. 1,98€/litre	-	Not applicable	-
End of life	69% incineration and 31% landfilled - 200km truck Waste management cost, average in EU, 234€/ton	[28]	69% incineration and 31% landfilled - 200km truck Waste management cost, average in EU, 234€/ton	[28]

Table 10: Reusable e-commerce packaging and single-use packaging

Large retail: Household care

For household care products sold in retail we compared the characteristics of a stackable reusable 1 litre cup with lid with a HDPE single use packaging, standard for this product category, as shown in Table 11.

Categories	Reusable system	Reference	Single-use system	Reference
Product	HDPE, 102 g 4,79 € (estimation for a stackable 1lt cup)	[36]	48 g HDPE 0,15€/unit	[37]
Production	Blow moulding manufacturing in Europe[4]	[31] [32]	Blow moulding manufacturing in Europe	[31] [32]
Transportation	Truck, EURO 6, full truck load, 2€ per km Distance from packaging producer to reuse system central WH, 300km Average distance for bulk supply from brand manufacturer, to central WH, 581 km Average distance from retailers to a washing centre 20km one way in a centralized WH 200 km to waste management facilities	[11] [12] [25]	Truck, EURO 6, Full truck load, 2€ per km Delivery distance from packaging producer to detergent producer is 300km Average distance from detergent producer, to retailers is 581 km 200 km to waste management facilities	[11] [12] [25]
Reuse	100 cycles of use for a box 10% of losses/damaged box	[13] [14]	Single-use	-
Storage	2 inspections, before washing and after washing, 30 seconds. Average minimum wage in EU, 5,78€/h Holding cost considered to be 10% of acquisition costs	[15] [16]	Holding cost considered to be 10% of acquisition costs	16]
Washing	Energy consumption 0.037kWh/ cup. 0,21 €/kwh, average value for EU. Water consumption 0.317 litres/ cup. 0,0026€/l, including water and sanitation cost EU average Detergent consumption (NaOH 50%) 0,25% of the water consumption. 1,98€/litres	[13] [17] [18] [19] [33]	Not applicable	-
End of life	Average for EU (16% recycling, 38,5% incineration with energy recovery and 45,5% landfilling) - 200km truck Waste management cost average in EU, 234€/ton	[10] [20]	Average for EU (16% recycling, 38,5% incineration with energy recovery and 45,5% landfilling) - 200km truck Waste management cost average in EU, 234€/ton	[10] [20]

Table 11: Reusable Household care packaging for large retail and single-use packaging

[4] As blow moulding factories exist throughout Europe

3.2 Environmental assessment

For the environmental assessment of both systems in each of the product groups, a Life Cycle Assessment (LCA) was conducted. LCA analyses and assesses the environmental impacts of a product, process, or activity over its whole life cycle. LCA identifies and quantifies the energy and materials used, wastes released to the environment and assesses the impact of those inputs and outputs. This methodology is widely applied by industries, government, NGOs, users, and academia. This methodology is described in ISO14040 and involves four steps as described in Figure 2.

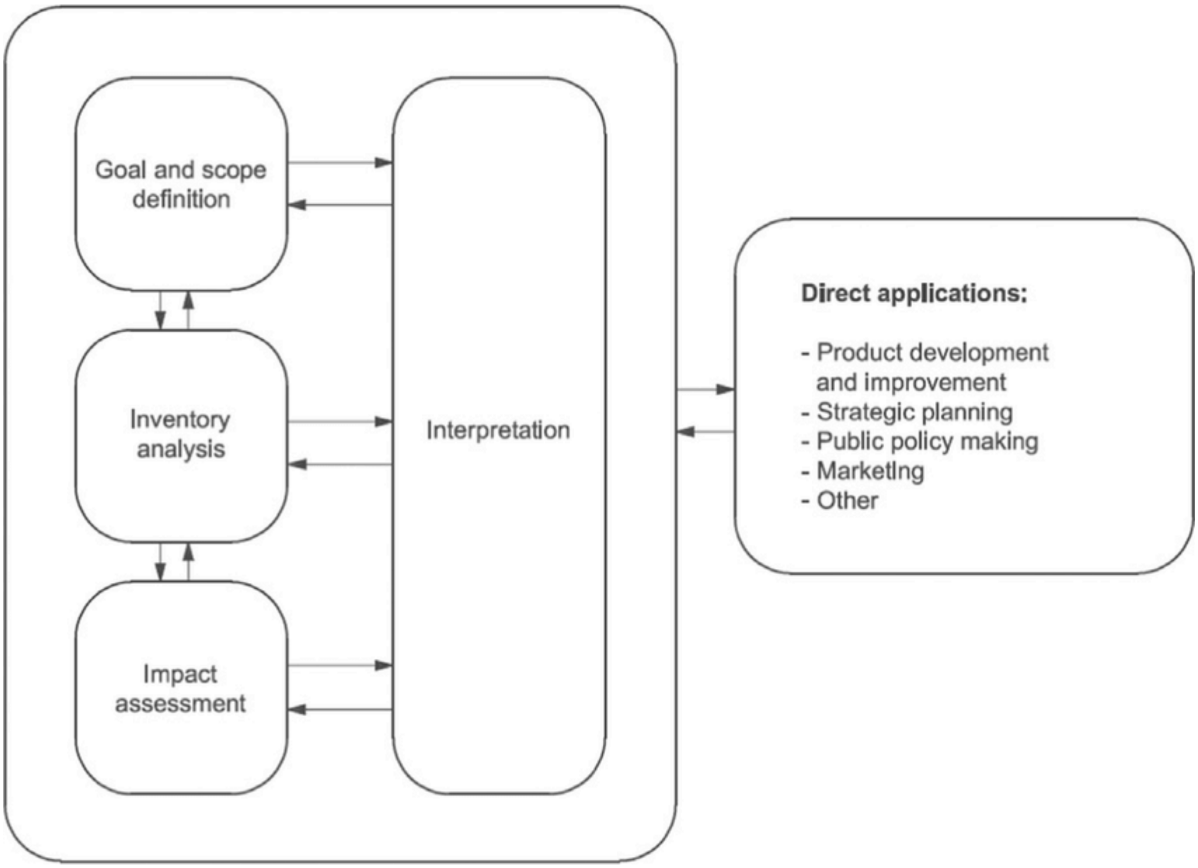

Figure 2 - Phases of LCA (ISO 14040:2006)

The steps of the LCA methodology are briefly explained in the following points:

- **Step 1** - Goal and Scope Definition: Defines the main objectives of the study and characterizes the scope of the system, where functional units and boundaries of the system are defined.
- **Step 2** - Life Cycle Inventory (LCI): Quantifies the inputs of the system, where materials, water and energy consumptions are quantified and the outputs, and emissions, waste and effluents are determined for the system defined in the previous step.
- **Step 3** - Life Cycle Impact Assessment (LCIA): The environmental impacts are calculated by converting the inventory collected in the previous step into environmental impacts.
- **Step 4** - Results Interpretation: Analysing and interpreting the results of the previous steps.

The goal of this study is to assess the environmental impacts of the reusable containers and compare them with the single-use ones. In the scope definition a set of specifications should be defined:

i) System boundaries: A complete analysis of the system and therefore a Cradle-to-Grave approach has been followed. A Cradle-to-Grave approach considers the whole life cycle of the product, starting with raw material extraction, then considers the material production, product fabrication, use, recycling (when possible), and end-of-life disposal.

ii) Functional unit: To enable comparison of the single-use packaging with the reusable packaging the two systems should be equivalent and should translate the reality of the two products. The functional unit should translate the function of the product from the user perspective, it should be measurable, and it should translate the efficacy and the durability of the product. The primary function of packaging is to hold goods so they can be distributed. Therefore, the functional unit was defined in terms of number of uses. The functional unit was established at 132.000 uses for all product categories to make it easier to compare criteria results across all product groups.

iii) Allocation methods: The cut-off method has been applied, which means that only the processes included to produce these products are considered. Recycling processes for subsequent product production incorporating recycled materials should be allocated to the new products.

As recommended by the European Commission the Product Environmental Footprint [38] method is applied in the LCIA method, based on a set of 16 impact categories, including land use, human toxicity, climate change, and water use, as described in the tables below. For each of the product groups, a comparative analysis was done between a reusable container and a single-use one. A second analysis was performed for each of the product groups by aggregating the impact categories to compare in absolute terms the score of each system. This means the higher the score, the worse the impact of the system.

HoReCa: Food containers

A comparative analysis was done between a reusable take-away box and a single-use plastic box. The results are highly positive in most of the categories as shown in table 12. From a total of 16 categories, 12 show an improvement of more than 90% when compared to a single-use system, proving the reusable containers present a much lower environmental impact.

Impact category	Unit	Reuse system	Single-use system	Improvement (%)
Particulate matter	disease inc.	4,90E-05	9,81E-04	95%
Photochemical ozone formation	kg NMVOC eq	5,08E+00	9,20E+01	94%
Eutrophication, marine	kg N eq	1,96E+00	3,20E+01	94%
Resource use, minerals and metals	kg Sb eq	1,37E-02	2,20E-01	94%
Eutrophication, terrestrial	mol N eq	1,82E+01	2,84E+02	94%
Climate change	kg CO2 eq	1,93E+03	2,89E+04	93%
Human toxicity, cancer	CTUh	6,03E-07	8,99E-06	93%
Resource use, fossils	MJ	3,72E+04	5,40E+05	93%
Acidification	mol H+ eq	1,00E+01	1,28E+02	92%
Ecotoxicity, freshwater	CTUe	2,47E+04	3,15E+05	92%

Land use	Pt	8,24E+03	9,07E+04	91%
Human toxicity, non-cancer	CTUh	1,93E-05	1,97E-04	90%
Water use	m3 depriv.	1,79E+03	1,07E+04	83%
Ozone depletion	kg CFC11 eq	2,34E-04	1,01E-03	77%
Eutrophication, freshwater	kg P eq	1,31E+00	5,57E+00	76%
Ionising radiation	kBq U-235 eq	6,71E+02	1,19E+03	44%

Table 12: PEF impact categories [31] – Characterization values for Food containers

Based on a number of different categories analysed through the LCA, figure 3 shows that impacts on main environmental impact categories such as climate change, resource use (fossils) and resource use (minerals and metals) present a better performance (a lower impact) for the reusable system. In fact, for all categories the use of reusable food containers features improvement rates when compared to a single-use packaging.

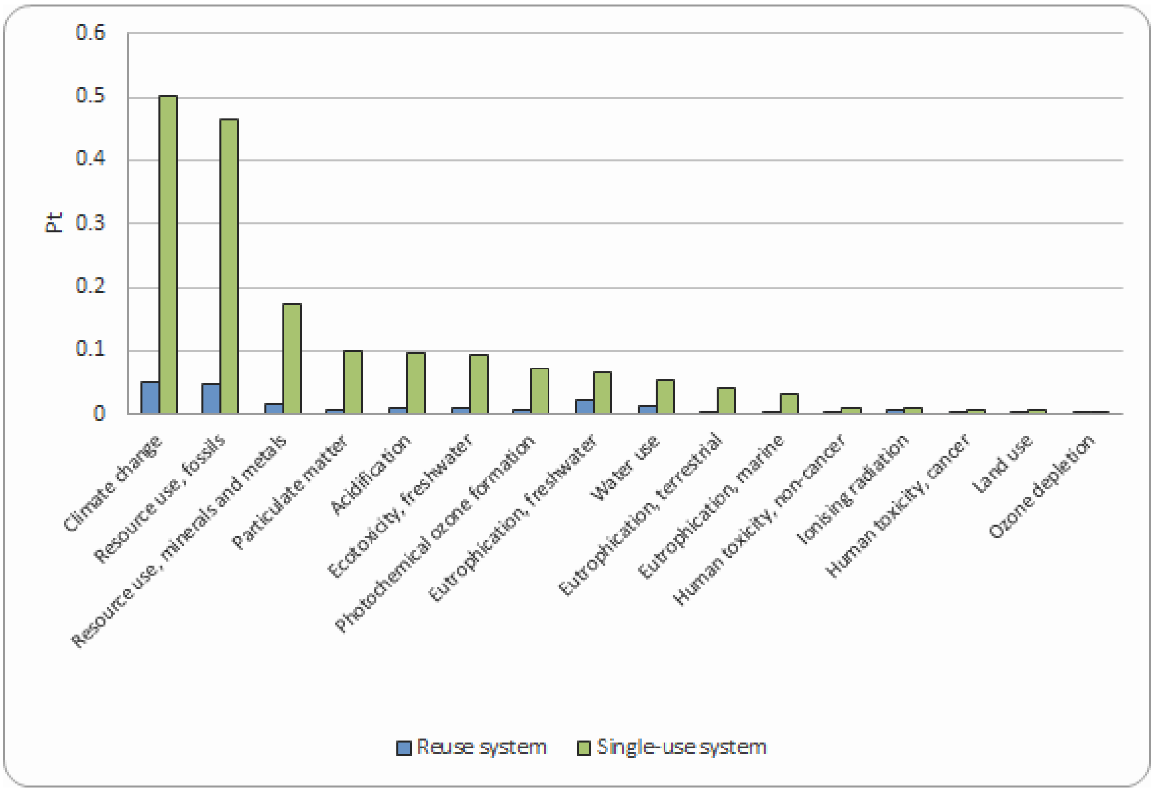

Figure 3: PEF impact categories – Weighting values food containers

When comparing the overall impact of both systems we can conclude reuse systems have nearly 13 times less impact than single-use systems, as shown in figure 4.

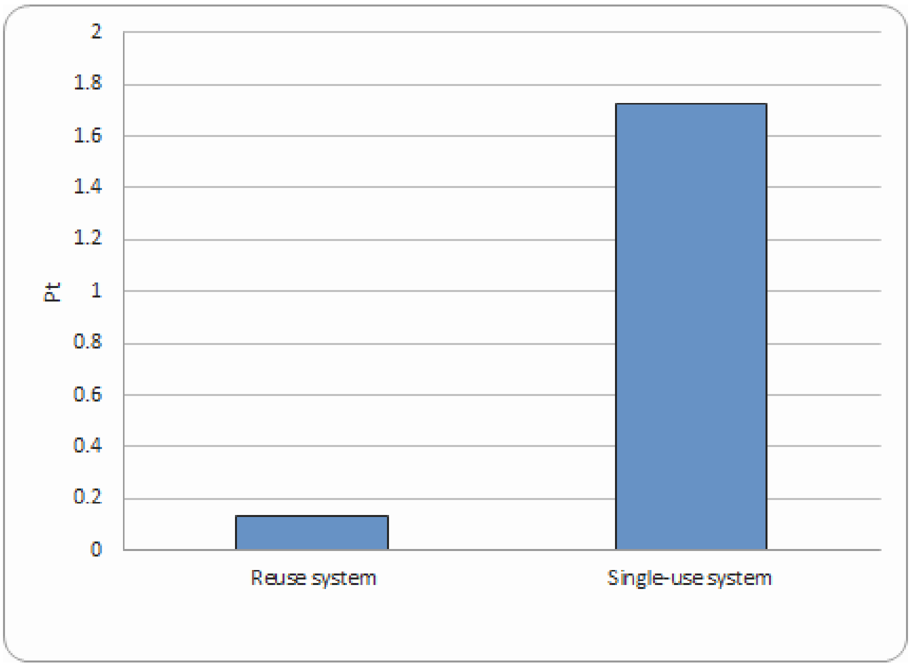

Figure 4: PEF impact categories – Single Score food containers

HoReCa: beverage containers

For beverages, as displayed in Table 13, from the 16 categories analysed, 14 showed a 50% and higher improvement from the single-use system and only two categories fell below 50%, but they are still positive. Based on the analysis done between a reusable cup and a paperboard cup, we can conclude that the first option presents a much better environmental performance.

Impact category	Unit	Reuse system	Single-use system	Improvement (%)
Land use	Pt	1,16E+04	7,28E+05	98%
Particulate matter	disease inc.	4,99E-05	6,11E-04	92%
Resource use, minerals and metals	kg Sb eq	1,38E-02	1,40E-01	90%
Ecotoxicity, freshwater	CTUe	3,12E+04	2,39E+05	87%
Human toxicity, cancer	CTUh	7,45E-07	4,62E-06	84%
Eutrophication, marine	kg N eq	2,37E+00	1,19E+01	80%
Photochemical ozone formation	kg NMVOC eq	6,04E+00	2,81E+01	78%
Human toxicity, non-cancer	CTUh	2,57E-05	1,10E-04	77%
Eutrophication, terrestrial	mol N eq	2,27E+01	9,59E+01	76%
Climate change	kg CO2 eq	2,55E+03	1,05E+04	76%

Acidification	mol H+ eq	1,36E+01	4,37E+01	69%
Water use	m3 depriv.	2,55E+03	6,76E+03	62%
Resource use, fossils	MJ	5,29E+04	1,31E+05	60%
Ozone depletion	kg CFC11 eq	2,87E-04	6,92E-04	59%
Eutrophication, freshwater	kg P eq	2,19E+00	3,09E+00	29%
Ionising radiation	kBq U-235 eq	1,20E+03	1,22E+03	2%

Table 13: PEF impact categories –characterization values for reusable beverage containers

The same analysis based on LCA was done for beverage containers. From figure 5 it can be concluded that, once again, reuse packaging has a lower impact, specially, in the categories of climate change, resource use (fossil fuels) and resource use (minerals and metals). However, in all categories the impacts of a reuse system are always lower than a single-use one.

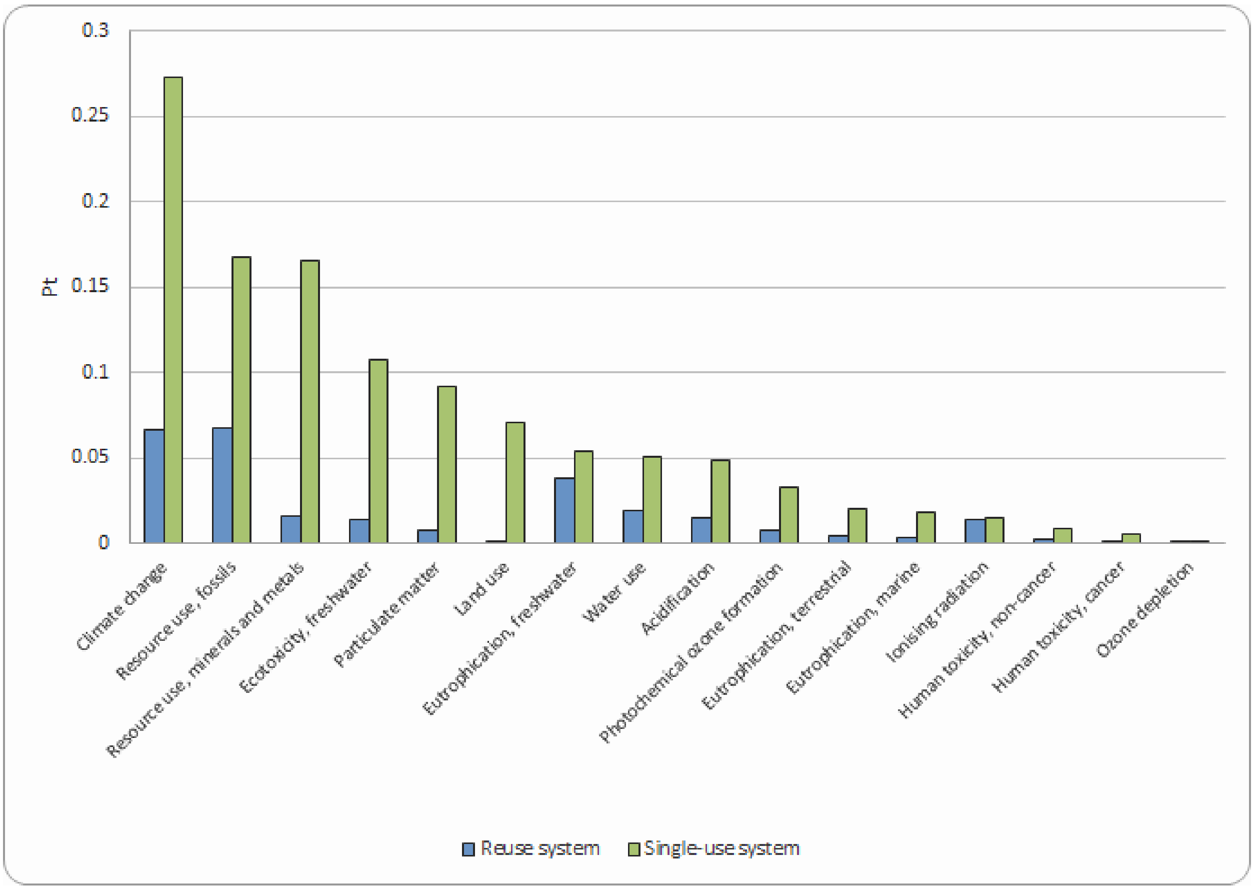

Figure 5: PEF impact categories – Weighting values for Reusable beverage containers

When comparing the overall impact of both systems we can conclude reuse systems have around 4 times less impact than single-use systems, as shown in figure 6.

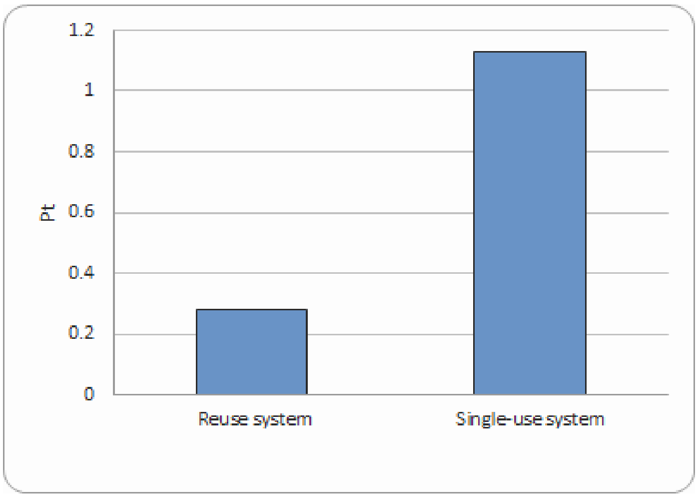

Figure 6: PEF impact categories – Single Score beverages containers

E-Commerce: Fashion and accessories

For the E-commerce channel, the environmental impacts of reuse systems present in all categories analysed a better performance than single-use systems, as we can see on Table 14.

Impact category	Unit	Reuse system	Single-use system	Improvement (%)
Eutrophication, terrestrial	mol N eq	2.67E+01	9.41E+01	72%
Eutrophication, marine	kg N eq	2.95E+00	1.03E+01	71%
Acidification	mol H+ eq	1.18E+01	4.03E+01	71%
Ecotoxicity, freshwater	CTUe	2.96E+04	1.01E+05	71%
Ionising radiation	kBq U-235 eq	1.16E+02	3.96E+02	71%
Water use	m3 depriv.	1.38E+03	4.62E+03	70%
Photochemical ozone formation	kg NMVOC eq	1.05E+01	3.48E+01	70%
Eutrophication, freshwater	kg P eq	5.39E-01	1.75E+00	69%
Climate change	kg CO2 eq	3.23E+03	1.03E+04	69%
Human toxicity, cancer	CTUh	9.22E-07	2.81E-06	67%
Resource use, fossils	MJ	6.25E+04	1.75E+05	64%
Human toxicity, non-cancer	CTUh	2.48E-05	6.40E-05	61%
Particulate matter	disease inc.	1.27E-04	2.85E-04	55%
Land use	Pt	1.62E+04	3.08E+04	47%
Resource use, minerals and metals	kg Sb eq	4.16E-02	6.73E-02	38%
Ozone depletion	kg CFC11 eq	2.41E-04	3.27E-04	26%

Table 14: PEF impact categories –characterization values for e-commerce fashion packaging

In the graph below it is also possible to assess the difference between the two systems and how the most important reduction is related with climate change, resource use (fossil fuels) and resource use of minerals and metals. For the rest of the categories, reuse systems always present a better performance, even if in some cases the variation is not significant.

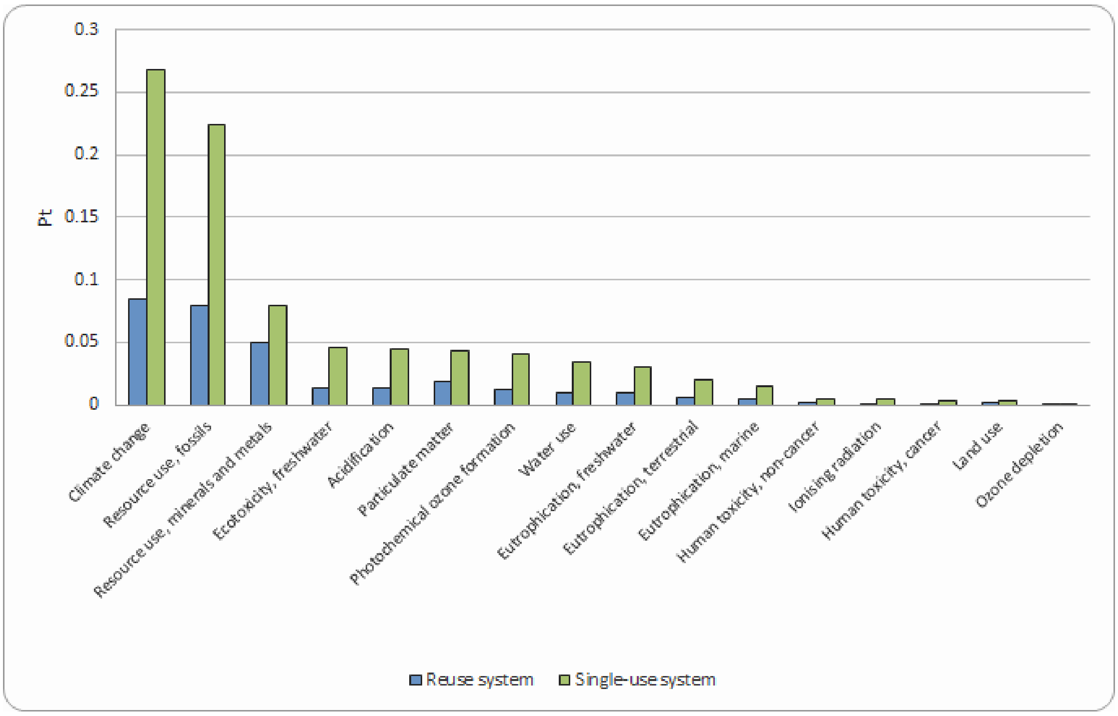

Figure 7: PEF impact categories – Weighting values for e-commerce fashion packaging

When comparing the overall impact of both systems we can conclude reuse systems have nearly 3 times less impact than single-use systems, as shown in Figure 8.

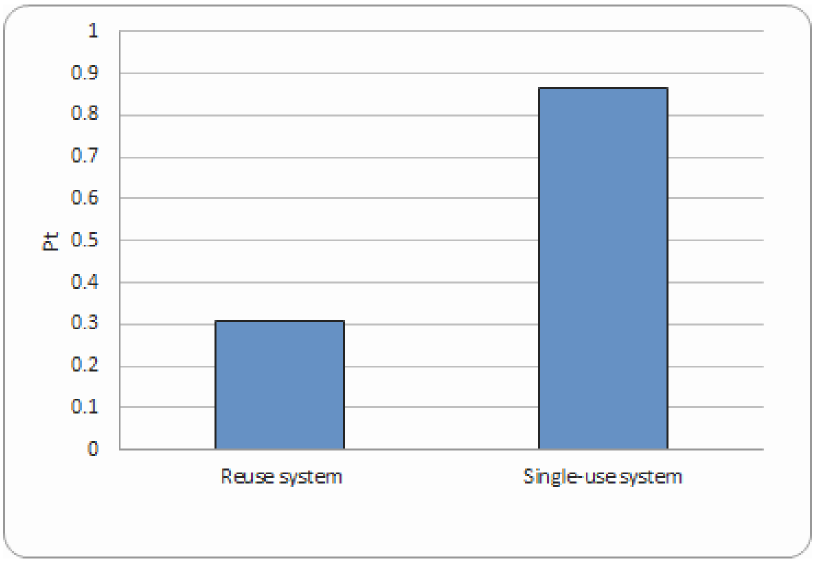

Figure 8: PEF impact categories – Single Score e-commerce fashion packaging

Large retail: household care

Finally, on large retail, specifically on household care products, the environmental analysis demonstrates a very positive performance by reuse systems. In all categories there is an improvement of more than 70%, compared to single-use systems.

Impact category	Unit	Reuse system	Single-use system	Improvement (%)
Land use	Pt	1,10E+04	1,88E+05	94%
Particulate matter	disease inc.	4,94E-05	8,17E-04	94%
Resource use, minerals and metals	kg Sb eq	1,51E-02	2,33E-01	94%
Photochemical ozone formation	kg NMVOC eq	4,99E+00	7,43E+01	93%
Resource use, fossils	MJ	4,06E+04	6,03E+05	93%
Climate change	kg CO2 eq	2,04E+03	2,91E+04	93%
Human toxicity, cancer	CTUh	6,20E-07	8,32E-06	93%
Eutrophication, marine	kg N eq	1,91E+00	2,48E+01	92%
Eutrophication, terrestrial	mol N eq	1,73E+01	2,03E+02	91%
Ecotoxicity, freshwater	CTUe	2,53E+04	2,90E+05	91%
Acidification	mol H+ eq	9,82E+00	1,00E+02	90%
Human toxicity, non-cancer	CTUh	2,01E-05	1,99E-04	90%
Eutrophication, freshwater	kg P eq	1,38E+00	7,76E+00	82%
Water use	m3 depriv.	1,79E+03	9,35E+03	81%
Ozone depletion	kg CFC11 eq	2,45E-04	1,16E-03	79%
Ionising radiation	kBq U-235 eq	7,23E+02	3,17E+03	77%

Table 15: PEF impact categories –characterization values for household care products in large retail

Figure 9 shows the main categories in which reuse systems present better impacts than single-use ones, mostly o resource use related to fossil fuels and climate change; both present more than 90% of improvement.

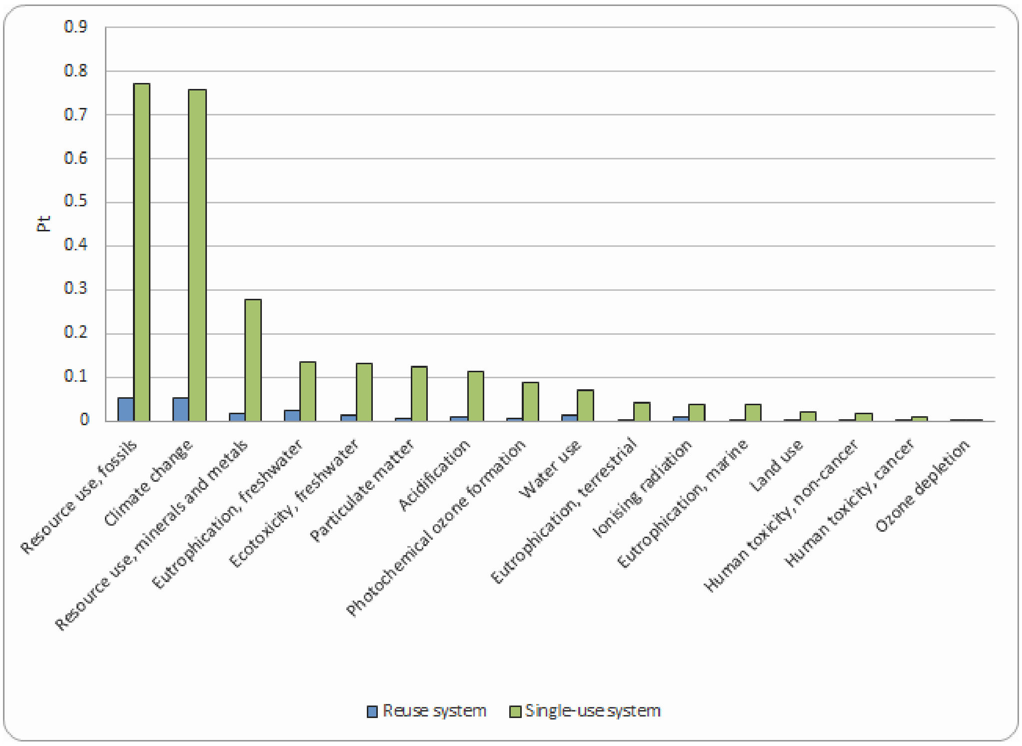

Figure 9: PEF impact categories – Weighting values for detergent packaging

When comparing the overall impact of both systems we can conclude reuse systems have around 12 times less impact than single-use systems, as shown in Figure 10.

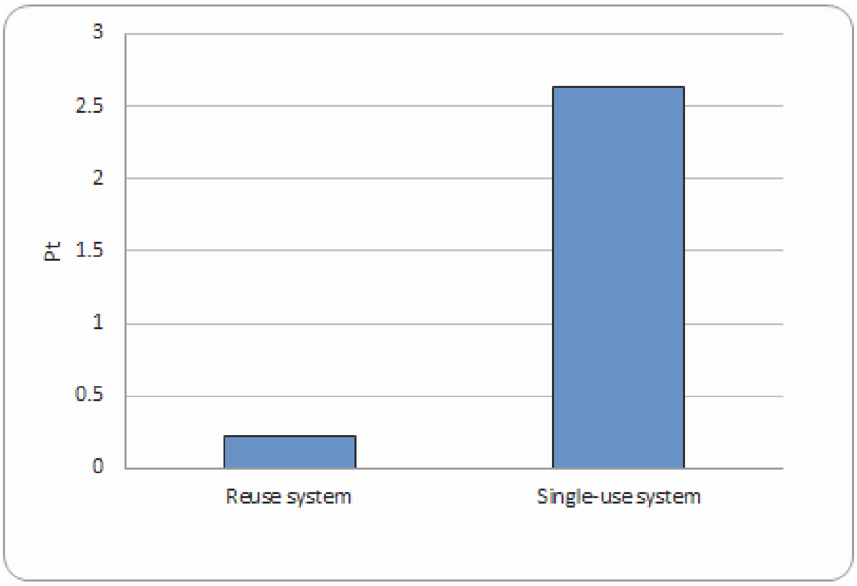

Figure 10: PEF impact categories – Single Score household care packaging

3.3 Economic assessment

An economic assessment of each of the systems was also conducted with the main objective to assess the economic savings at a European level. For that, an economic assessment was performed having into consideration the costs to two stakeholders:

1. The costs to the reusable system provider were calculated and compared to the selling price charged to the client (retailer/manufacturer), to assess whether there is a business case.
2. The cost to the retailer, when buying a single-use system, was compared to the cost of buying a reusable packaging, to verify if the retailer has an economic incentive to buy the reusable system.

Based on the model for reverse logistics costs proposed by Chen (2012) [3] this cost model has been followed:

- Collection costs – It involves the transportation costs of return (CR) and the cost of the return fee (CF) given to users depending on the good condition of the returned packaging.
- Inspection costs – Considers the classification of collected items into reusable items and waste material, the testing and inspection of the packaging. A first inspection before washing is done to remove the damaged items and a second inspection after washing is also performed to ensure that all items are in good condition for reuse.
- Washing costs – Considers the washing costs of the packaging to enter again in circulation. Energy, water and detergent costs were also considered.
- Environmental protection costs – The costs incurred to waste managers for the packaging in circulation were considered.
- New packaging acquisition costs – Acquisition of the packaging were considered in the model.
- Holding costs – The storage of the packaging requires space, logistics and management, which is contemplated in this cost.

HoReCa: Food containers

The first analysis is related to the costs of the company managing the reusable system. They were calculated and compared based on the selling price of the reference provided by CupClub. From the table below, it is possible to verify the profitability of the reusable business for food containers, with a profit margin of 0,37€/unit, if sold at 0,45€/unit for the client (HoReCa).

Costs for the service provider running the reusable system (1452 units, which means 132.000 uses)	
New packaging (€)	2609
Transportation (€)	252
Inspection (€)	6362
Washing (€)	902
Waste valorisation (€)	450
Holding (€)	261
Cost/use (€)	**0,082**
Selling price - Reuse (€/use)	**0,45**
Gross Profit Margin (€)	0,37
Gross Profit Margin (%)	**448%**

Table 16: Costs and gross profit margin for the company of the reusable system

An economic analysis was conducted for a company operating in HoReCa (restaurant, café), and it is possible to verify that the reusable system is in line with the single-use one for the client, meaning there should be no economic barrier to move to this system. Even with the cost of new packaging and transport, the price paid is 0,01€ lower in the reuse system.

Costs for the client (HoReCa) of the system (for 132.000 containers)	
New packaging (€)	51797
Transportation (€)	2513
Waste valorisation (€)	1333
Holding (€)	5180
Cost/use (€)	**0,46**
Price paid by client - Reuse (€/use)	**0,45**
Price paid by client - Single-use (€/use)	0,46
Savings (€/use)	**0,01**

Table 17: Price difference for client of the reuse system

HoReCa: Beverage containers

The first analysis is related to the costs of the company managing the reusable system. They were calculated and compared based on the selling price of the reference provided in a report from CupClub. From the table below, it is possible to verify the profitability of the reusable business for the beverage containers, with a profit margin of 0,12€/unit.

Costs for the service provider running the reusable system (1100 units, which means 132.000 uses)	
New packaging (€)	1756
Transportation (€)	96
Inspection (€)	6362
Washing (€)	1786
Waste valorisation (€)	18
Holding (€)	176
Cost/use (€)	**0,077**
Selling price - Reuse (€/use)	**0,2**
Gross Profit Margin (€)	0,12
Gross Profit Margin (%)	**159%**

Table 18: Costs and gross profit margin for the company of the reusable system

An economic analysis was conducted for a company operating in HoReCa (restaurant, café), and it is possible to verify that the reusable system can represent a savings for the client, meaning there is an economic benefit to move to this system. Even with the cost of new packaging and transport, the price paid is 0,09€ lower in the reuse system.

Costs for the client (HoReCa) of the system (for 132.000 containers)	
New packaging (€)	32987
Transportation (€)	1400
Waste valorisation (€)	350
Holding (€)	3299
Cost/use (€)	0,29
Price paid by client - Reuse (€/use)	**0,20**
Price paid by client - Single-use (€/use)	0,29
Savings (€/use)	**0,09**

Table 19: Price difference for client of the reuse system

E-commerce: Fashion

The first analysis is related to the costs of the company managing the reusable system. They were calculated and compared based on the selling price of the reference provided by Hipli. From the table below, it is possible to verify that with this cost structure, whereby the cost of return by post (Europe) is €1,90 per unit, profitability of the reusable business is low. Some reuse systems mention that the cost of returning one item is higher than the cost of purchasing a reusable packaging unit[5].

Costs for the service provider running the reusable system (4840 units, which means 132.000 uses)	
New packaging (€)	10164
Packaging return (€)	250800
Inspection + cleaning (€)	44880
Waste valorisation (€)	63
Holding (€)	7920
Cost/use (€)	**2,38**
Selling price to client (€/use)	**2,75**
Gross Profit Margin (€)	0,37
Gross Profit Margin (%)	**16%**

Table 20: Costs and gross profit margin for the company of the reusable system

[5] RePack

From the online retailer point of view, at face value, and compared to the inexpensive polybags, it is very hard to show an economic benefit. The current business models are still highly reliant on merchants wanting to absorb the additional costs and/or users willing to share it.

Costs for the client (e-commerce) of the single-use system (for 132.000 units)	
New packaging (€)	37378
Transportation (€)	164
Waste valorisation (€)	512
Holding (€)	3738
Cost/use (€)	0,32
Price paid by client - Reuse (€/use)	**2,75**
Price paid by client - Single-use (€/use)	0,32
Additional cost (€/use)	**2,43**

Table 21: Price difference for client of the reuse system

Large retail: Household care

In the cost analysis for the provider of the reusable system, a €0,12/unit cost/use was calculated. As a selling price was unavailable, a gross margin of 30% was calculated, thus setting the sale price at 0,15€/unit.

Costs for the service provider running the reusable system (1452 units, which means 132.000 uses)	
New packaging (€)	6955
Transportation (€)	27
Inspection (€)	6362
Washing (€)	902
Waste valorisation (€)	450
Holding (€)	696
Cost/use (€)	0,12
Selling price - Reuse (€/use)	**0,15**
Gross Profit Margin (€)	0,03
Gross Profit Margin (%)	**30%**

Table 22: Costs and gross profit margin for the company of the reusable system

From the manufacturer point of view, the price represents a cost savings of 0,10€/unit.

Costs for the client (e-commerce) of the single-use system (for 132.000 units)	
New packaging (€)	19800
Transportation (€)	10572
Waste valorisation (€)	1488
Holding (€)	1980
Cost/use (€)	0,26
Price paid by client - Reuse (€/use)	**0,15**
Price paid by client - Single-use (€/use)	0,26
Savings (€/use)	**0,10**

Table 23: Price difference for client of the reuse system

3.4 Social assessment

For the assessment of the social impact proposed for all product groups, the establishment of the criteria was based on UNEP reports and from studies already conducted by the researchers.

The UNEP- SETAC [4] guidelines recommend that social assessment should analyse the system as a whole and the social impact among different stakeholders. In this study this methodology has been followed. The main stakeholders were identified, and the main subcategories of social impact assessment were selected. The subcategories were selected from the work presented by Simões (2014) [5, 6], where four end-points are assessed (Labor Practices and Decent Work, Society, Human Rights and Product Responsibility). Based on the work presented by Simões (2014) [5, 6] and Popovic (2018) [7] the mid-point categories were selected. The matrix showing the quantitative and qualitative social assessment of the reuse systems in general is presented below.

Labour Practices and Decent Work

In this category, four main aspects were analysed: number of jobs created; number of people trained; health & safety issues and diversity and equal opportunities.
Based on available data, reuse systems can promote the creation of 50 FTE[6] jobs in warehouse and transportation services (for dealing with 120.000 units/day). These new jobs will require the acquisition of new skills and knowledge, increasing the level of professional competences and the development of new careers of the local community. NGOS and local governments can also incentivise the inclusion of vulnerable social groups (such as disabled people) to work in these services and promote their social integration. In addition, these new jobs will develop and foster local economies since these systems require proximity services. Gender equality and inclusion of different groups can be achieved since the tasks in the systems can be done by any person and this presents an opportunity to include and focus on more vulnerable groups, not only by the businesses itself, but also with the support of local government. Finally, the health and safety of these systems are guaranteed since the washing process is performed by a provider within a certified and standardized process (e.g., HACCP).

	Number of jobs created	**Number of people trained**	**Health and Safety**	**Diversity and Equal Opportunities**
Managers of the reuse system	Jobs created for WH management and transportation in small vans is estimated to be around 50 jobs for 120.000 units/ day	Training on WH logistics and transportation will be provided to 50 people (in a system of 120.000 units distributed/day)	The reusable packaging complies with the health and safety regulation in the material selection and the washing system.	The jobs require functions that can be done by people under special social conditions, so managers can promote and accept their integration. Also, gender balance can be ensured in these systems, since many activities can be done by both genders
HoReCa/ Retailers	-	-	Ensured because the packaging is centrally washed	-
Workers in the reuse system	50 new employees for 120.000 units a day	50 workers will be trained in logistics activities (in a system	Ensured, since there is a standard production process	Workers of any type should have the same opportunities

[6] 6 Full Time Equivalent Jobs

		of 120.000 units distributed/day)		
Users	-	-	Ensured because they buy the product already packed	-
Local community	Since WH and transportation in these systems are local, local employment has been created, promoting the jobs opportunities for local communities	Local community will be able to learn new skill in the logistics field	-	Integration of people from the communities
Society	New employment opportunities are being created	New opportunities for career development will be created	-	Opportunities open to everyone
NGOs	Can promote the inclusion of long term unemployed, ex-prisoners, homeless people, disabled people, or other minorities to be considered as possible workers for these systems	Can promote capacity and social skill training for the inclusion of long term unemployed, ex-prisoners, homeless people, disabled people, or other minorities to be considered as possible workers for these systems	-	Can promote and help the organizations in the inclusion of people with special social conditions. Can be seen as an enabler to the integration of these people.
Governments	Can provide incentives for the newly hired people so that managers of the reusable system can succeed in the beginning of their activities	Can provide incentives for training people with special social conditions	-	-

Table 24: Social impacts on labour practices and decent work

Society

In this category, four main subcategories were analysed: (i) public commitments to sustainability issues; (ii) contribution to economic development; (iii) technology development and (iv) corruption. Firstly, reuse systems reduce the environmental impacts in all product groups, ranging from 64% less impact for E-commerce and up to 92% for HoReCa (food containers) and Large retail (household care). In addition, local businesses will decrease their waste generation by 78% (E-commerce) and up to 98% less waste in HoReCa (beverages). This will lead to a reduction on waste management costs not only for the municipalities, but also for its citizens.

These systems will also foster technology development, mostly in three main areas: washing systems (in order to reduce and have a more efficient consumption of water and energy); eco-design of reusable packaging and increasing the development of traceability systems, including the tracking devices and software (e.g., for apps). Finally, in all subcategories, since most of the production phase will be placed in Europe, there is more control of the entire system and it will decrease the risk of corruption (especially when compared to complex and international supply chains).

	Public commitments to sustainability issues	Contribution to economic development	Technology development	Corruption
Managers of the reuse system	This system will reduce by 75%, 92%, 92%, 64% the environmental impact on beverage containers, food containers, household care and e-commerce fashion, respectively	-	The introduction of reuse systems will potentiate the technology development in 3 main areas: Washing systems to reduce energy and water consumption; Eco-design of the reusable packaging; IT systems for traceability	Based on the Corruption Perceptions Index it is possible to see that having more activities done locally in Europe decreases the corruption risk
HoReCa/Retailers	HoReCa and Retailers will be promoting the reduction of waste by 98% in beverage containers, 97% in food containers, 96% for household care in retail, 78% e-commerce fashion respectively.	The introduction of sustainable systems improves the companies' image and therefore sales can rise.	The introduction of the reusable systems, promotes HoReCa/Retailers to improve their technology in terms of IT systems, updating some outdated systems and therefore improving efficiency in their businesses.	Based on the Corruption Perceptions Index it is possible to see that having more activities done locally in Europe decreases the corruption risk
Workers in the reuse system	-	More employees lead to more taxes paid and therefore economic growth.	Workers can be empowered to bring ideas and challenges for technology development	Based on the Corruption Perceptions Index it is possible to see that having more activities done locally in Europe decreases the corruption risk
Users	HoReCa and Retailers will be promoting the reduction of waste by 98% for beverage containers, 97% for food containers, 96% for household care, 78% e-commerce fashion.	-	-	-
Local community	-	The installation of facilities locally promotes the local communities' economic growth.	-	Based on the Corruption Perceptions Index it is possible to see that having more activities done locally in Europe decreases the corruption risk
Society	Society can be aware of the waste generated and therefore reduce their consumption in single-use systems	-	-	Based on the Corruption Perceptions Index it is possible to see that having more activities done locally in Europe decreases the corruption risk

NGOs	Can communicate this type of initiatives showing the potential of circular economy and reusable systems.	-	-	-
Governments	These systems reduce waste treatment needs, therefore contributing to the reduction of costs associated with waste management	The entrance in the market of new business brings economic growth to European Countries.	New technologies can be then transposed to other systems, leading to technology development in cross-sectorial systems	Based on the Corruption Perceptions Index it is possible to see that having more activities done locally in Europe decreases the corruption risk

Table 25: Social impacts on Society

Human Rights

The Human Rights category analyses basic human rights, child labour, fair salary and forced labour issues.
Since reuse systems operations will be mostly based in Europe, it is expected that all subcategories will be positively affected because there is a greater compliance with human rights and a larger control of abuse of these rights by local authorities.

	Basic Human Rights	**Child Labour**	**Fair Salary**	**Forced Labour**
Managers of the reuse system	Based on the Human Development Index (HDI) and the Global Slavery Index (GSI), it is possible to see that having more activities done locally in Europe increases the human rights compliance and do not promote human rights' abuse			
HoReCa/Retailers	Based on the Human Development Index (HDI) and the Global Slavery Index (GSI), it is possible to see that having more activities done locally in Europe increases the human rights compliance and do not promote human rights' abuse			
Workers in the reuse system	Based on the Human Development Index (HDI) and the Global Slavery Index (GSI), it is possible to see that having more activities done locally in Europe increases the human rights compliance and do not promote human rights' abuse			
Users	-			
Local community	Based on the Human Development Index (HDI) and the Global Slavery Index (GSI), it is possible to see that having more activities done locally in Europe increases the human rights compliance and do not promote human rights' abuse			
Society	Based on the Human Development Index (HDI) and the Global Slavery Index (GSI), it is possible to see that having more activities done locally in Europe increases the human rights compliance and do not promote human rights' abuse			

NGOs	-
Governments	Based on the Human Development Index (HDI) and the Global Slavery Index (GSI), it is possible to see that having more activities done locally in Europe increases the human rights compliance and do not promote human rights' abuse

Table 26: Impact analysis on Human Rights

Product responsibility

The last category regards health and safety issues, transparency and end of life responsibility. On the first topic, reuse packaging systems can guarantee that health and safety measures are being implemented and assured since the washing process is done centrally by a certified provider. In addition, traceability systems can support businesses with real-life control of the reusable packaging to manage and measure the environmental impacts of their operations. From the data collected, reuse packaging systems indeed present a better environmental performance: a reusable cup can be used 132 times; a food container or a reusable packaging for household care can be used up to 100 times and e-commerce packaging can circulate 30 times.

Finally, it is the businesses, NGOs, and governments' role to promote awareness and education actions to workers and users of the system. To workers, by sharing information about the environmental and social impacts of the sector they are working for and how they contribute to it. And, to users, by sharing information and data of their consumption impacts and how changing their behaviours can generate positive environmental benefits for them, for their community and for society.

	Health & Safety	Transparency	End of life responsibility
Managers of the reuse system	Ensured because they wash and refill the packaging (when needed)	With an IT system for traceability, it is possible to monitor real time the environmental impacts and to present this information to the other stakeholders	The reuse system will reuse 132, 100, 100, 30 times the same package for the beverage containers, food containers, household care and e-commerce fashion systems respectively
HoReCa/Retailers	Ensured because the packaging is centrally washed	With an IT system for traceability, it is possible to monitor real time the environmental impacts and to present this information to the other stakeholders	HoReCa and Retailers will be promoting the reduction of waste by 98% for beverages containers, 97% for food containers, 96% for household care, 78% e-commerce fashion respectively.
Workers in the reuse system	Ensured, since there is a standard production process	Educate workers about the environmental impacts of their activities and by how much they are contributing to the reduction of the environmental impact, motivating them in their activities.	-
Users	Ensured because they buy the product already packed	Users can have information on their impacts and therefore understand that behavioural changes bring benefits of the planet	HoReCa and Retailers will be promoting the reduction of waste by 98% for beverages containers, 97% for food

			containers, 96% for household care, 78% e-commerce fashion.
Local community	-	-	-
Society	-	Possibility of creating communication programs that create awareness and promote the use of reuse systems.	-
NGOs	-	Information available so that NGO can create promotion programs and governmental pressure to the adoption of this type of systems	-
Governments	Should create legislation that promotes the use of reuse systems	This information will pressure governments to give more incentives to the reuse systems	HoReCa and Retailers will be promoting the reduction of waste by 98% for beverage containers, 97% for food containers, 96% for household care, 78% e-commerce fashion.

Table 27: Impact analysis on Product Responsibility

4. Scale up potential in Europe

Based on the above environmental impact assessments and economic savings estimations, the potential impact of packaging reuse systems across Europe was estimated for each of the product categories, based on the three scenarios below:

	2027	2030
Scenario 1	10%	20%
Scenario 2	20%	50%
Scenario 3	50%	75%

Table 28: Scenarios for reusable packaging system targets

These scenarios were applied to a proportion of what was deemed addressable for each of the product groups to determine the potential number of packaging uses to replace (Table 29 and 30).

Product category	Packaging units and CAGR	Assumption	References
HoReCa: Food containers	19 202 168 063 units in 2019 CAGR 4%	Packaging tones of take-away food containers consumed in Germany Germany population represents 18.58% of European population in 2019 50gr per container	[39]
HoReCa: Beverage container	33 752 272 626 units in 2019 CAGR 3%	Packaging units of beverage containers consumed in Germany Germany population represents 18.58% of European population in 2019	[39]
E-commerce: Fashion	10 000 000 000 in 2020 CAGR 15%	One packaging per order was considered	[40]
Large retail: household care	19 500 000 000 in 2019 CAGCR 2.3%	Packaging units in EU+EFTA+UK in 2019 80% Sustainable Charter representation	[41] [42]

Table 29: Packaging units consumed in Europe in each of the product groups

	Assumption	References
HoReCa: Food & Beverage containers	Population in urban areas	74,73% [343]
E-commerce: Fashion	Intra-European e-commerce orders of fashion items	32% [44]
Large retail: household care	Liquid laundry detergents and fabric conditioners	24,83% [45]

Table 30: Assumptions for European scale up of each of the product groups

Having this into account, in the subsequent sections, the potential environmental and economic impacts across all product groups are presented.

For ease of representation, equivalences were established for the total impact of each of the environmental criterion for each scenario in the two years of the targets based on the below equivalences:

Criteria	Description	Units
Waste to landfill (kg)	Full truck load 8T	8000 [46]
Energy (MJ)	Average energy consumption per household per year	13320 [47]
Water consumed (m3)	Olympic pool	2500 [48]
Materials (kg)	Full truck load 8T	8000 [46]
Climate change (kg CO2-eq)	Carbon dioxide absorbed per year by a mature tree	21,8 [49]

Table 31: Environmental criteria impact equivalence units

HoReCa: Food containers

The table (next page) represents the potential impact of a scale up of reusable food containers in Europe for each of the three scale up scenarios on the main environmental impact criteria in the original units and economic savings for the retailer.

	Scenario 1		Scenario 2		Scenario 3	
Years	**2027**	**2030**	**2027**	**2030**	**2027**	**2030**
Reusable targets	**10%**	**20%**	**20%**	**50%**	**50%**	**75%**
Waste to landfill (kg)	1,885,072	4,297,064	3,770,144	10,742,661	9,425,359	16,113,991
Energy (MJ)	246,886,757	562,783,988	493,773,514	1,406,959,970	1,234,433,784	2,110,439,956
Water consumed (m3)	1,134,238,449	2,585,522,392	2,268,476,899	6,463,805,980	5,671,192,247	9,695,708,970
Materials (kg)	307,382,234	700,684,808	614,764,469	1,751,712,019	1,536,911,171	2,627,568,028
Climate change (kg CO2-eq)	270,801,422	617,298,012	541,602,843	1,543,245,029	1,354,007,108	2,314,867,543
Savings (€)	€926,495,444	€2,111,967,476	€1,852,990,887	€5,279,918,691	€4,632,477,218	€7,919,878,036

Table 32: Environmental impact for main criteria and economic savings for the retailer for scale up scenarios for food containers

Table 33 shows a representation of the estimation of the environmental impact criteria.

		Scenario 1		Scenario 2		Scenario 3	
Criteria	**Equivalence**	**2027**	**2030**	**2027**	**2030**	**2027**	**2030**
Waste to landfill	Full truck load 8T	240	537	479	1,343	1,198	2,014
Energy	Average energy consumption per household per year	21,937	42,251	43,873	105,628	109,683	158,441
Water consumed	Olympic pools	567,364	1,034,209	1,134,728	2,585, 5222	2,836,820	3,878,284
Materials	Full truck load 8T	40,480	87,586	80,960	218,964	202,400	328,446
Climate change	Carbon dioxide absorbed per year by a mature tree	13,289,956	28,316, 423	26,579,912	70,791, 056	66,449,779	106,186, 585

Table 33: Environmental impact for main criteria equivalence for scale up scenarios for food containers

HoReCa: Beverage containers

The table below represents the potential impact of a scale up of reusable beverage containers in Europe for each of the three scale up scenarios on the main environmental impact criteria in the original units and economic savings for the retailer.

	Scenario 1		Scenario 2		Scenario 3	
Years	**2027**	**2030**	**2027**	**2030**	**2027**	**2030**
Reusable targets	**10%**	**20%**	**20%**	**50%**	**50%**	**75%**
Waste to landfill (kg)	1,602,817	3,512,794	3,205,633	8,781,986	8,014,083	13,172,979
Energy (MJ)	3,496,290,991	7,662,604,979	6,992,581,981	19,156,512,446	17,481,454,953	28,734,768,670
Water consumed (m3)	174,446,796	382,324,267	348,893,593	955,810,668	872,233,982	1,433,716,002
Materials (kg)	4,625,321,463	10,137,031,317	9,250,642,925	25,342,578,293	23,126,607,313	38,013,867,440
Climate change (kg CO2-eq)	199,549,217	437,339,693	399,098,435	1,093,349,231	997,746,087	1,640,023,847
Savings (€)	€928,746,402	€2,035,476,116	€1,857,492,804	€5,088,690,290	€4,643,732,011	€7,633,035,434

Table 34: Environmental impact for main criteria and economic savings for the retailer for scale up scenarios for beverage containers

Table 35 shows a representation of the estimation of the environmental impact criteria.

		Scenario 1		Scenario 2		Scenario 3	
Criteria	**Equivalence**	**2027**	**2030**	**2027**	**2030**	**2027**	**2030**
Waste to landfill	Full truck load 8T	200	439	401	1,098	1,002	1,647
Energy	Average energy consumption per household per year	262,484	575,271	524,969	1,438,177	1,312,422	2,157,265
Water consumed	Olympic pools	69,779	152,930	139,557	382,324	348,894	573,486
Materials	Full truck load 8T	578,165	1,267,129	1,156,330	3,167,822	2,890,826	4,751,733
Climate change	Carbon dioxide absorbed per year by a mature tree	9,153,634	20,061,454	18,307,268	50,153,634	45,768,169	75,230,452

Table 35: Environmental impact for main criteria equivalence for scale up scenarios for beverage containers

E-commerce: Fashion

The table below represents the potential impact of a scale up of reusable e-commerce fashion packaging in Europe for each of the three scale up scenarios on the main environmental impact criteria in the original units and economic savings for the retailer.

	Scenario 1		Scenario 2		Scenario 3	
Years	**2027**	**2030**	**2027**	**2030**	**2027**	**2030**
Reusable targets	**10%**	**20%**	**20%**	**50%**	**50%**	**75%**
Waste to landfill (kg)	110,827	372,774	221,653	931,936	554,133	1,397,904
Energy (MJ)	37,672,698	126,715,347	75,345,396	316,788,368	188,363,491	475,182,552
Water consumed (m3)	119,030,284	400,368,555	238,060,567	1,000,921,388	595,151,418	1,501,382,082
Materials (kg)	29,853,725	100,415,562	59,707,450	251,038,904	149,268,625	376,558,356
Climate change (kg CO2-eq)	50,989,240	171,506,675	101,978,479	428,766,688	254,946,198	643,150,032

Table 36: Environmental impact for main criteria and economic savings for the retailer for scale up scenarios for e-commerce packaging

Table 37 shows a representation of the estimation of the environmental impact criteria.

		Scenario 1		Scenario 2		Scenario 3	
Criteria	**Equivalence**	**2027**	**2030**	**2027**	**2030**	**2027**	**2030**
Waste to landfill	Full truck load 8T	14	47	28	116	69	175
Energy	Average energy consumption per household per year	2,828	9,513	5,657	23,783	14,141	35,674
Water consumed	Olympic pools	47,612	160,147	95,224	400,369	238,061	600,553
Materials	Full truck load 8T	3,732	12,552	7,463	31,380	18,659	47,070
Climate change	Carbon dioxide absorbed per year by a mature tree	2,338,956	7,867,279	4,677,912	19,668,197	11,694,780	29,502,295

Table 37: Environmental impact for main criteria on equivalence for scale up scenarios for e-commerce packaging

Large Retail: Household care

The table below represents the potential impact of a scale up of reusable household care packaging in Europe for each of the three scale up scenarios on the main environmental impact criteria in the original units and economic savings for the retailer.

	Scenario 1		Scenario 2		Scenario 3	
Years	**2027**	**2030**	**2027**	**2030**	**2027**	**2030**
Reusable targets	**10%**	**20%**	**20%**	**50%**	**50%**	**75%**
Waste to landfill (kg)	153,473	328,617	306,947	821,543	767,367	1,232,314
Energy (MJ)	206,525,496	442,212,048	413,050,992	1,105,530,120	1,032,627,480	1,658,295,180
Water consumed (m3)	301,624,766	645,838,446	603,249,531	1,614,596,115	1,508,123,829	2,421,894,172
Materials (kg)	100,268,882	214,695,562	200,537,763	536,738,906	501,344,408	805,108,358
Climate change (kg CO2-eq)	119,976,640	256,893,781	239,953,279	642,234,453	599,883,199	963,351,679
Savings (€)	€150,160,100	€321,522,556	€300,320,200	€803,806,390	€750,800,500	€1,205,709,585

Table 38: Environmental impact for main criteria and economic savings for the retailer for scale up scenarios for household care packaging

Table 39 shows a representation of the estimation of the environmental impact criteria.

		Scenario 1		Scenario 2		Scenario 3	
Criteria	**Equivalence**	**2027**	**2030**	**2027**	**2030**	**2027**	**2030**
Waste to landfill	Full truck load 8T	19	41	38	103	96	154
Energy	Average energy consumption per household per year	15,505	33,199	31,010	82,998	77,525	124,497
Water consumed	Olympic pools	120,650	258,335	241,300	645,838	603,250	968,758
Materials	Full truck load 8T	12,534	26,837	25,067	67,092	62,668	100,639
Climate change	Carbon dioxide absorbed per year by a mature tree	5,503,516	11,784,118	11,007,031	29,460,296	27,517,578	44,190,444

Table 39: Environmental impact for main criteria on equivalence for scale up scenarios for household care packaging

The job creation potential was also assessed for the three scale up scenarios across all product categories.

	Scenario 1		Scenario 2		Scenario 3	
	2027	**2030**	**2027**	**2030**	**2027**	**2030**
Job creation	93	245	185	613	462	920

Table 40: Estimation of job creation potential for scale up scenarios for all product groups

5. Study limitations

The authors of this study tried to elaborate the most complete and informative document taking in consideration the scope and objectives set out. However, the study presents different limitations which are described below for transparency purposes.

Due to the lack of data at the time of performing the prioritisation of product groups for the different criteria used distributed for each product group within each channel, the classification was performed taking mostly into consideration the knowledge of the consultants. Although this is a limitation of the study, the application of a multicriteria decision analysis made the process systematic and therefore more reliable.

A simplified quantitative study was used to estimate the potential of improvement of the reusable systems at environmental, economic and social level. Where possible, data used was based on published LCAs from reusable packaging systems currently in operation and done by known organizations and following equivalent methods (i.e., Cup Club and Hipli). Although precision and consistency were pursued as much as possible, several assumptions were made because data was either confidential, inconsistent or unavailable.

The study focused on analysing the worst-case scenario for the reuse system and the best case for the single-use system, in order to ensure that where positive results arose, it meant that with a higher level of certainty it could be affirmed that reuse systems are a promising solution.

Data on packaging units consumed in each product group is not readily available (a European level), so assumptions had to be made based on the best data proxy.

Economic data was harder to assess and modulate as i) some systems have very small, non-scaled operations, or are wary of sharing data on business-critical processes such as reverse logistics and cleaning costs; ii) there were no examples to base data on (i.e., household care). This may impact the results and make less positive business cases in some product groups.

Investment was not taken into consideration in the assessment of the business case for reuse as neither was the investment in single-use packaging (such as moulding and blowing equipment).

The economic impact for incentives for return (deposit or reward) were not considered in the design of the systems as there are different alternatives available, and who incurs the cost (retailer/ manufacturer, reusable system provider). Although deposits are mainly used to ensure the packaging is returned to the system by the user, retailers/manufacturers may incur costs in the processing of electronic transactions, which may be avoided with a digital wallet system. Moreover, reward is often implemented as a discount on a subsequent purchase, driving loyalty and additional sales which would have to be accounted for. Nonetheless, there is a need for incentives for all actors of the value chain to design successful systems.

Needless to say, although European averages were used, there are sometimes significant differences in terms of population density, warehousing space cost, or even wages that have an impact in the business and environmental case of reuse systems in certain settings or member states.

A sensitivity analysis of the LCAs was not conducted in this study. When implementing reusable packaging systems, undertaking sensitivity analysis can support decision-making in terms of determining thresholds that should be met to ensure reusable systems are made environmentally friendly.

Appendix

Ecoinvent references for the LCA model	
Polypropylene	Polypropylene, granulate {GLO}| market for | Cut-off, U
Low density polyethylene	Polyethylene, linear low density, granulate {GLO}| market for | Cut-off, U
Injection moulding	Injection moulding {RER}| processing | Cut-off, U
Truck	Transport, freight, lorry, unspecified {RER}| transport, freight, lorry, all sizes, EURO6 to generic market for | Cut-off, U
Electricity	Electricity, medium voltage {RER}| market group for | Cut-off, U
Tap water	Tap water {RER}| market group for | Cut-off, U
Detergent	Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Cut-off, U
Recycling	Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Cut-off, U
Landfill	Waste plastic, mixture {CH}| treatment of, sanitary landfill | Cut-off, U
Incineration	Waste plastic, mixture {CH}| treatment of, municipal incineration | Cut-off, U
Paper board & Corrugated sleeve	Solid bleached board {GLO}| market for | Cut-off, U
Polystyrene	Polystyrene, general purpose {GLO}| market for | Cut-off, U
Calendering (Corpo)	Paper, wood containing, supercalendered {RER}| paper production, wood containing, supercalendered | Cut-off, U

Table 40: EcoInvent references for the LCA model for beverages

Ecoinvent references for the LCA model	
Polypropylene	Polypropylene, granulate {GLO}| market for | Cut-off, U
Extrusion	Extrusion, plastic film {RoW}| extrusion, plastic film | Cut-off, U
Thermoforming	Thermoforming of plastic sheets {RoW}| processing | Cut-off, U
Truck	Transport, freight, lorry, unspecified {RoW}| transport, freight, lorry, all sizes, EURO6 to generic market for | Cut-off, U
Ship (Shanghai to Rotterdam)	Transport, freight, sea, container ship {GLO}| transport, freight, sea, container ship | Cut-off, U
Electricity	Electricity, medium voltage {RER}| market group for | Cut-off, U
Tap water	Tap water {RER}| market group for | Cut-off, U

Detergent	Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Cut-off, U
Recycling	Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Cut-off, U
Landfill	Waste plastic, mixture {CH}| treatment of, sanitary landfill | Cut-off, U
Incineration	Waste plastic, mixture {CH}| treatment of, municipal incineration | Cut-off, U

Table 41: EcoInvent references for the LCA model for food containers

Ecoinvent references for the LCA model	
HDPE	Polyethylene, high density, granulate {GLO}| market for | Cut-off, U
Blow Moulding	Blow moulding {RER}| blow moulding | Cut-off, U
Truck	Transport, freight, lorry, unspecified {RER}| transport, freight, lorry, all sizes, EURO6 to generic market for | Cut-off, U
Electricity	Electricity, medium voltage {RER}| market group for | Cut-off, U
Tap water	Tap water {RER}| market group for | Cut-off, U
Detergent	Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Cut-off, U
Truck	Transport, freight, lorry, unspecified {RER}| transport, freight, lorry, all sizes, EURO6 to generic market for | Cut-off, U
Recycling	Mixed plastics (waste treatment) {GLO}| recycling of mixed plastics | Cut-off, U
Landfill	Waste plastic, mixture {CH}| treatment of, sanitary landfill | Cut-off, U
Incineration	Waste plastic, mixture {CH}| treatment of, municipal incineration | Cut-off, U

Table 42: Ecoinvent references for the LCA model for household care

Ecoinvent references for the LCA model	
Polypropylene	Polypropylene, granulate {GLO}| market for | Cut-off, U
Polyester	Fibre, polyester {GLO}| market for fibre, polyester | Cut-off, U
Nylon	Nylon 6 {RoW}| market for nylon 6 | Cut-off, U
Extrusion	Extrusion, plastic film {RoW}| extrusion, plastic film | Cut-off, U
Sewing	Fibre, cotton {GLO}| market for fibre, cotton | Cut-off, U
Ship	Transport, freight, sea, container ship {GLO}| transport, freight, sea, container ship | Cut-off, U
Truck	Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified | Cut-off, U

Light commercial vehicle	Transport, freight, light commercial vehicle {RER}| market group for transport, freight, light commercial vehicle | Cut-off, U
Álcool	Ethanol, without water, in 99,7% solution state, from ethylene {RER}| market for ethanol, without water, in 99,7% solution state, from ethylene | Cut-off, U
Landfill	Waste plastic, mixture {CH}| treatment of, sanitary landfill | Cut-off, U
Incineration	Waste plastic, mixture {CH}| treatment of, municipal incineration | Cut-off, U
LDPE	Polyethylene, low density, granulate {GLO}| market for | Cut-off, U

Table 43: Ecoinvent references for the LCA model for e-commerce fashion

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