



R3PACK – REDUCE, REUSE, RETHINK PACKAGING TOWARDS NOVEL FIBRE-BASED PACKAGING AND REUSE SCHEMES

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Guidelines for efficient environmental reuse scenarios

1. Methodology and Objective

This report adopts a comprehensive methodological approach articulated in three interconnected phases — *Market and Case Study Analysis*, *Comparative Environmental Assessment (LCA)*, and *Social Risks Assessment (S-LCA)* — which also structure the overall document. Each component contributes to building an integrated understanding of reusable packaging systems, assessing their operational feasibility, environmental performance, and social implications across the entire value chain.

a) Market and Case Study Analysis

The first section focuses on mapping existing reusable packaging models across various industrial sectors — including food and beverage, cosmetics, logistics, and e-commerce — and across different material types such as plastics, glass, metals, and composites. The analysis is based on an extensive desk research process, drawing upon academic literature, industry reports, policy documents, and corporate sustainability disclosures.

Through the comparative examination of international case studies, the research identifies key operational frameworks (e.g., B2B and B2C models, deposit-return schemes, refill-on-the-go systems, and take-back logistics). This enables the recognition of design trends, operational barriers, and factors influencing consumer acceptance.

The section concludes with a synthesis of insights into what works and what fails within current reuse systems, highlighting critical success factors and recurring challenges. These findings provide the contextual and empirical foundation for the subsequent analytical stages, ensuring that environmental and social assessments are grounded in realistic and relevant system configurations.

b) Environmental LCA Main Findings

The second part of the report is based on the main findings of the comparative assessment of the environmental performance of single-use and reusable packaging systems, conducted through a Life Cycle Assessment (LCA) in accordance with ISO 14040 and 14044 standards in D6.3b.

The analysis quantifies the environmental impacts associated with both models, covering the full life cycle — from raw material extraction to end-of-life management — and including



production, transport, cleaning, and use phases. A functional unit (e.g., delivery of a defined number of product units) is established to ensure comparability, and key indicators such as greenhouse gas emissions, energy demand, water consumption, and waste generation are assessed.

Special attention is given to determining *break-even points*, i.e., the number of reuse cycles required for a reusable system to outperform a single-use counterpart in environmental terms. Sensitivity analyses are carried out to explore the influence of critical variables such as transport distances, material choices, and return rates. The outcomes inform design priorities related to material optimisation, durability, and the efficiency of reverse logistics operations.

c) Social Risks Main Findings (S-LCA)

The third phase integrates the social dimension of sustainability through the main findings of the Social Risk Analysis carried out in the final part of D6.3b. This will ensure that design choices minimize not only environmental but also social risks along the value chain. The assessment is based on data from the Social Hotspots Database (SHDB v5) and follows the UNEP Guidelines for S-LCA (2020), maintaining consistency with the environmental LCA boundaries and system definition.

The S-LCA evaluates potential social risks associated with each stage of the packaging life cycle — from material extraction to processing, use, and end-of-life — across five key impact areas: Working Conditions, Human Rights, Health & Safety, Governance, and Community Well-being. Risks are classified into qualitative levels (low, medium, high), and the results are compared between single-use and reusable systems to identify hotspots and leverage points for improvement.

By combining these findings with the environmental outcomes, the analysis generates actionable design insights to enhance both environmental and social sustainability, promoting responsible sourcing, safe working conditions, and positive community impacts.

d) Integrated Design Guidelines for Reuse Packaging Systems

Building on the insights derived from the market mapping, environmental LCA, and S-LCA, the final phase translates analytical findings into integrated design guidelines for reusable packaging systems.

These guidelines combine environmental and social performance criteria with practical and operational considerations, offering a coherent framework for the design, implementation, and scaling of effective reuse systems. The focus is on material optimisation, durability, ease of cleaning, efficient reverse logistics, and user-centred design to foster consumer engagement and return efficiency.

The objective of this document is twofold:



- To identify and analyze best practices in the design of reusable packaging systems, collecting a set of case studies from both the literature and the market. This part focuses on design and material choices that characterize reusable packaging systems compared to single-use alternatives, with particular attention to their influence on consumer acceptance.
- To integrate and discuss the comparative environmental and social analyses developed in Deliverable D6.3b, highlighting the main findings and implications concerning the environmental performance of reusable versus single-use packaging systems.

By combining insights from design research and environmental and social risks assessment, this deliverable aims to provide an integrated understanding of how materials and packaging can be designed for reuse, balancing technical feasibility, environmental and social sustainability.

The outcomes of these activities will consist of a set of design strategies for reusable packaging, encompassing both technical-functional and aesthetic-sensorial aspects of materials that can enhance consumer acceptance and engagement with reuse systems.



2. Introduction

Packaging represents one of the most resource-intensive and waste-generating sectors in the European Union. In 2023, the EU-27 generated approximately 79.7 million tonnes of packaging waste, corresponding to 177.8 kg per inhabitant (Eurostat, 2025a). Of this total, the material composition was 40.4 % paper and cardboard, 19.8 % plastic, 18.8 % glass, 15.8 % wood, and 4.9 % metal (Recycling Magazine, 2025).

Each EU citizen produced on average 35.3 kg of plastic packaging waste, of which only 14.8 kg was recycled, resulting in a 42.1 % recycling rate for plastic packaging (Eurostat, 2025). Despite gradual progress, packaging waste remains a major contributor to greenhouse gas emissions and marine litter across Europe (European Commission, 2025a).

In response, the European Commission has identified packaging as a priority stream within the EU Circular Economy Action Plan and the new Packaging and Packaging Waste Regulation (PPWR), aiming to ensure that all packaging placed on the EU market is reusable or recyclable by 2030 (European Commission, 2025b).

Two main strategies are currently under consideration to reduce the environmental burden of packaging:

- **The replacement of single-use plastic packaging with paper-based or other renewable-material alternatives;**
- **The transition toward reusable packaging systems that can circulate multiple times within the economy.**

Both approaches offer potential environmental and economic benefits. However, their effectiveness depends not only on technological and logistical feasibility but also on consumer perception and acceptance. Packaging design—its form, materials, sensorial attributes, and user experience—plays a critical role in determining the willingness of consumers to engage in reuse practices.

This deliverable therefore investigates how packaging and materials can be designed to support reuse. Through a review of literature and market case studies, complemented by the environmental comparative findings from Deliverable D6.3b, this work identifies key factors and design principles that can enhance the attractiveness, functionality, and sustainability of reusable packaging solutions.



3. Market and Case Study Analysis

The switch to reusable packaging is considered a promising path by the European Commission, as reaffirmed in the Packaging and Packaging Waste Regulation (PPWR), formally adopted in 2024 and entering into force in 2025. The Regulation establishes clear and binding reuse and refill targets for several packaging categories—such as beverages, take-away food, transport, and logistics packaging—and mandates that all packaging placed on the EU market must be recyclable by 2030, with a progressive integration of reusable solutions (European Commission, 2025a; Council of the European Union, 2024).

Reusable packaging may provide superior environmental performance for some impact categories compared to single-use alternatives. However, the actual outcome depends on numerous variables, including the selected material, number of reuse cycles, transport distances, and system management (Stefanini et al., 2021). Therefore, to draw robust conclusions, the application of Life Cycle Assessment (LCA) methodologies remains essential to quantify potential benefits and trade-offs.

Beyond the environmental dimension, return and refill models also represent an interesting economic opportunity. Estimates from the Ellen MacArthur Foundation (2019) suggest that converting just 20% of plastic packaging into reusable formats could unlock a USD 10 billion business opportunity globally, driven by efficiency gains, material savings, and new service models.

While economic and environmental aspects of reuse are widely discussed in literature, a less explored yet crucial dimension concerns consumer willingness to engage with reuse schemes and the factors influencing such participation. Research by Greenwood et al. (2021) identified key determinants of reuse acceptance, showing that material type, packaging format, durability, and ease of cleaning significantly influence consumers' willingness to return or refill packaging. Glass jars and bottles were preferred over flexible films or cans, especially when associated with appealing design and convenience.

Recent European surveys confirm this trend: despite a generally positive attitude toward reusable packaging (with over 75% of respondents expressing support), concerns related to hygiene, practicality, and lack of clear information remain major barriers (Stora Enso, 2023). These findings highlight the importance of design and communication strategies that can effectively address user perceptions and facilitate the large-scale adoption of reuse systems.

The research also pointed out that willingness to reuse is not associated with nature of the packaged product and consumers are more willing to participate in reuse programs they are already familiar with (e.g. reusable milk bottles) (Greenwood et al., 2021). This means that special attention should be given to packaging design, material selection and to changes that may occur after repeated reuse cycles.



4. Reusable packaging features and materials analysis

From previous consideration, an analysis of cases studies of reusable packaging systems has been set up. The analysis aims to investigate the design details and the material choices of existing reusable packaging.

Packaging reuse systems can be divided in four main broad categories described in “Reuse – Rethinking packaging” (EMF, 2019): Refill at home, Refill on the go, Return from home, Return on the go. The selected case studies mainly belong to the latter, since it is the selected model within the R3PACK project; however, the considerations that will be provided could remain – totally or partially – valid also for other reusable packaging. Case studies were collected both from literature and existing documents (Coelho et al., 2020; EMF, 2019) and desk research. Among the 43 selected case studies, the following types of packaging/packaged products were included: beverage bottles, drinking cups, grocery products, home care products, personal care products, takeaway food and transport packaging. For each case study, the listed elements were analyzed:

- Selected material(s) and material requirements
- Design elements and characteristics (eg. geometric details)
- Improved design VS single use: if reusable packaging design results to be more high-end, providing a better look, feel or improved functionality with respect to single-use alternatives (EMF, 2019)
- Aesthetic-sensorial attributes
- Design type (shared or ad hoc): if reusable packaging can be shared among different brands offering similar products or it is expressly designed for a specific company

Some of the results are shown in Fig. 1 and considerations related to the different aspects analyzed are reported in the following paragraphs.



Case study

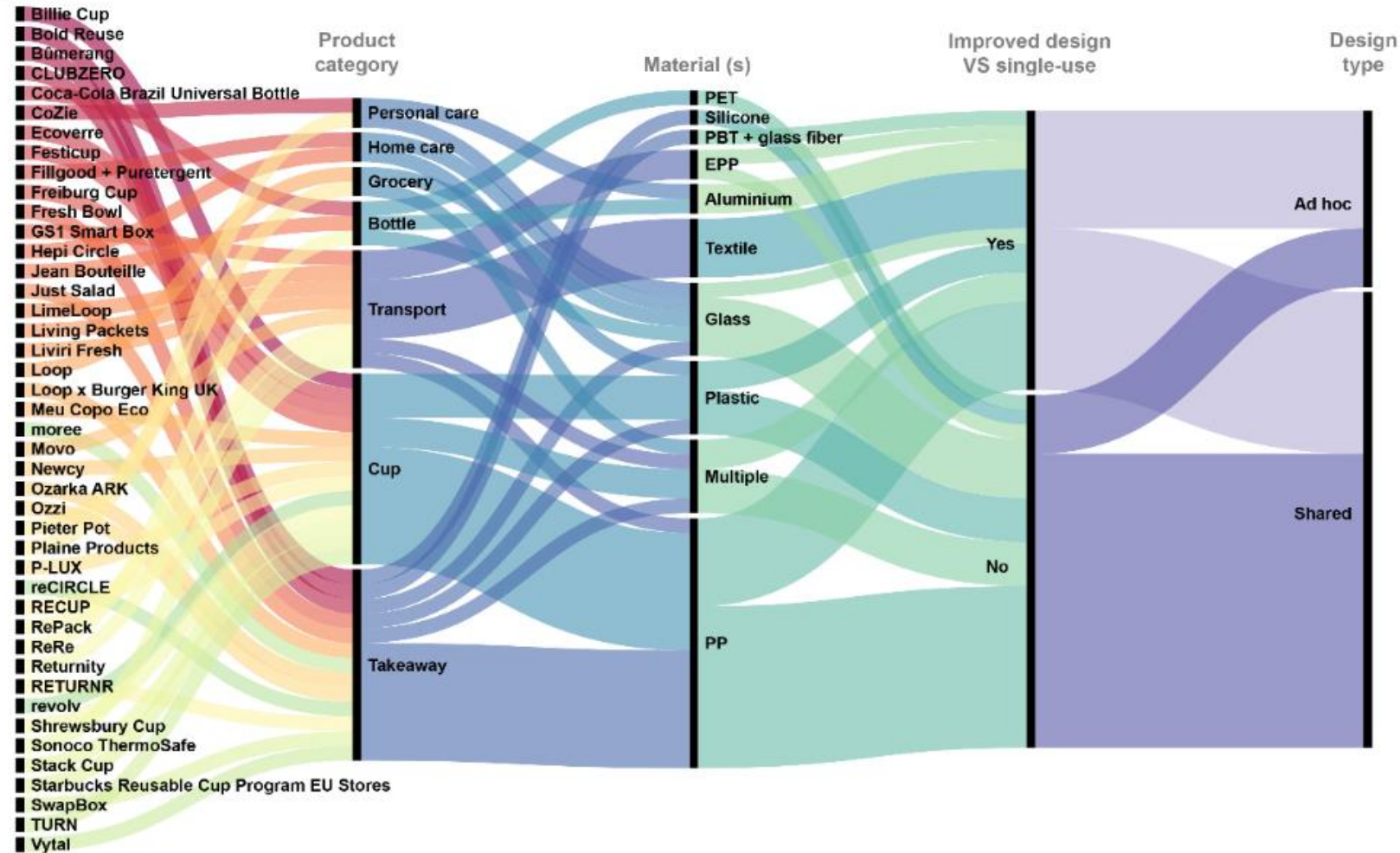


Fig 1 Reusable packaging analysis results visualization

a) Selected material(s) and material requirements

Material selection is a core step in the packaging design process and has a fundamental influence on the impact of the packaging itself (Zhu, 2022): in particular, when designing reusable packaging, the selected material has a considerable influence on the properties of the packaging itself, on how it interacts with food, on how this is perceived by users and, consequently, on the success of the entire reuse system and on the users' willingness to take part in these schemes. The analyzed case studies show a variety of materials used : plastics, glass, metals, textiles etc. Among them, polypropylene (PP) is the most widespread, used in almost 40% of cases. As shown in Fig. 1, PP along with other plastics, is mainly used in two product categories, i.e. cups and takeaway packaging. The reason behind these choices is clear: plastics are the materials that best manage to meet the essential requirements for these product types: lightness, impact resistance, resistance to temperatures, water, and detergents used in the washing phases.

However, PP also presents limitations that are relevant in reuse systems. Several studies show that PP can retain odours and volatile compounds, even after repeated washing. Strangl et al. (2021) demonstrated that post-consumer PP packaging retains odour-active compounds and that standard washing cycles (including at 80 °C) reduce but do not eliminate odours completely. These characteristics—linked to the partial sorption and release of volatiles—can limit consumer acceptance in long-term reuse applications.

In this regard, it should be noted that certain widely used polymers may be unsuitable for reusable packaging due to the possible migration of chemicals. This is the case of polycarbonate (PC), that may release BPA (Bisphenol A), a substance that shows endocrine-disrupting effects (EFSA). Consequently, companies have formulated new polymers such as Eastman's Tritan™; this co-polyester has been approved by FDA, and studies in literature have proven the absence of BPA water contamination in Tritan™-made reusable water bottles (Cooper et al. 2011) and the lack of effects of concern on the endocrine system caused by Tritan™ monomers (Osimitz et al., 2012). Furthermore, Tritan™ is particularly suitable for reuse for other reasons: it is characterized by greater thermal dimensional stability, compared to traditional co-polyesters, and by a chemical resistance superior to that of polycarbonate, which makes it resistant to repeated washing cycles. Tritan™ hardness and transparency make it aesthetically and perceptually suitable for replacing glass and ceramics: for this reason, it was selected by Elium Studio for the design of the first range of McDonald's reusable tableware, deployed in all French restaurants since 2023 (Fig. 2).

Nevertheless, Tritan™ presents some practical limitations for circularity. While Eastman has developed Tritan Renew¹™ (containing recycled material), Europe currently lacks a dedicated recycling stream for Tritan or similar co-polyesters. Available recycling reports highlight that advanced recycling technologies enabling such recovery are not yet widespread in Europe (Plastics Recyclers Europe, 2024). This limits the end-of-life circularity of Tritan-based reusable packaging.

¹ More info on: <https://www.eastman.com/en/products/brands/tritan/about/renew>





Fig. 2: McDonald's reusable tableware by Elium Studio

Glass, as reported in the literature (Greenwood et al., 2021), is well-perceived by consumers for reusable packaging, but, as a drawback, it is way heavier and more fragile compared to plastics, making it less attractive for the above-mentioned product categories. In fact, by analyzing the case studies, glass is used for other applications such as home care, personal care, and grocery products, where shock-proofness and lightness are less relevant.

Across Europe, glass reuse is gaining momentum: companies like Verallia² are implementing regional reuse systems in France, Germany, Spain, and Italy, while FEVE³ highlights reusable glass as a key strategy for reducing the carbon footprint of packaging. Moreover, the New Reuse Alliance⁴ emphasizes the need to strengthen EU-level targets for reusable glass, and Zero Waste Europe's first European Reuse Barometer⁵ confirms the growth of reuse solutions with high return rates.

Analyzing reusable transport packaging through the lens of materials is possible to find significant differences compared to single-use alternatives in which extensive use of paper and cardboard is made, often recycled and easily recyclable. In reusable packaging systems for e-commerce, on the other hand, solutions made of fabric such as LimeLoop, Movo, RePack and Returnity are on the rise. The selected fabrics show the following characteristics: they are equipped with waterproof treatments and, in 75% of analyzed cases, they are made of recycled fibres. Textile packaging also shows the notable advantage of being foldable, requiring very little space once empty, thus facilitating return operations.

² Verallia: <https://www.verallia.com/en/communique-de-presse/verallia-steps-up-glass-reuse-projects-in-europe>

³ Report available at (see page 34): <https://feve.org/wp-content/uploads/2024/10/FEVE-Decarbonisation-Report-2024-1.pdf>

⁴ Available at: https://drive.google.com/file/d/1ui0CjI5WNY1TtqADnnpnEJrYap_y-cLD7/view?pli=1

⁵ Available at: https://drive.google.com/file/d/1ui0CjI5WNY1TtqADnnpnEJrYap_y-cLD7/view



Packaging for fragile products and/or those that require temperature control such as Living Packets and Liviri Fresh, the material choice is directed on foams like EPP (Expanded Polypropylene), which combines very low density, impact resistance and thermal insulation.

Another particularly interesting material for reusable packaging is aluminum which combines lightness and resistance to repeated washings; it is especially used in bottles and jars for grocery and personal care (e.g. ReRe and Plain Products).

Companies such as Loop, Revolv and TURN offer reusable packaging as a service, available in different sizes and in multiple materials to match different needs.

From this analysis it clearly emerges that the type of material varies considerably according to the intended use of the packaging: materials selection, therefore, must be carried out after establishing the functional requirements and constraints, prioritizing them based on the objectives. However, functional requirements may not be enough to ensure consumers acceptance: for example, plastics can guarantee proper durability for multiple uses, but users' perception of the look of these materials after several cycles can raise issues; in fact, scratches and wear on polymer-based packaging may affect perceived hygiene and safety. The same is not valid if we consider returnable glass, where visible wear does not generate concerns (Bucknall, D. G., 2020). This differentiated perception of the various materials used in the reuse schemes is closely related to the previous experience of the users, being glass traditionally used in returnable containers. This would not discourage the use of plastics, but it is rather a suggestion to keep these elements in mind when designing with these materials, selecting polymers that are more wear-resistant, avoiding those that may be subjected to changes in appearance if exposed to certain use conditions and those that may retain odours and other contaminants, etc.

b) Other factors influencing materials' selection

An interesting relation to investigate – beyond the results of the case study analysis – is the one between packaging materials and perceived environmental friendliness. Herbes et al. pointed out that the results vary considerably among different countries: in Germany, the packaging options perceived as most environmentally friendly are based on reusable materials; while in France and the United States, the highest ranking goes to packaging based on recyclable materials. These results can be explained by the fact that Germans are more used to Deposit Return System (DRS), while people more accustomed to recycling systems perceive recyclable material as more sustainable.

In the context of the R3PACK project, the chosen reuse model "Return On the Go" also influences the material selection phase: when, after a number of cycles, the end-of-life phase of a packaging occurs, it will be managed by the collectors and not by the users, whose duty is just to return the empty container to the drop-off points. Therefore, this can be a great opportunity to explore novel sustainable materials whose origin guarantees lower impacts (recycled, scrap-based, bio-based, etc.). It's less relevant to select materials that are recyclable



in established streams: in fact, if ad-hoc recycling processes are required, collectors will be able to guarantee closed loops, since they know the exact composition of their products.

Regardless of the selected material, to facilitate recycling processes – whether in existing flows or with ad hoc procedures – it is useful to follow the mono-material strategy, i.e. each component of the packaging is made with a single material.

c) Design aspects

Designing reusable packaging requires redefining the priority of the different ecodesign strategies (Vezzoli et al., 2008) with respect to single-use packaging. For the latter, it is fundamental to minimize materials consumption and optimize the renewability and recyclability of the resources. For reusable packaging, instead, the focus is optimizing products' lifespan, by facilitating the reuse by simplifying and minimizing all the operations needed to rehabilitate the packaging for a new cycle e.g. washing, disassembly, reassembly, etc.; nonetheless, optimizing the logistics and impacts of all these activities is essential. This can be achieved through specific packaging design features that have been identified in case studies analysis.

Reusable packaging must guarantee durability for several cycles, and this has a twofold consequence: firstly, the cost of each piece must be divided by the number of reuse cycles. As a result, a single pack can show a higher unit cost. Secondly, reuse implies designing considering all the hygiene-related aspects and allowing repeated uses.

1. Improved Design and Enhanced Perceived Quality

The first aspect, in many cases, results in an **improved design** of the reusable solutions compared to single use: almost half of the case studies show a premium look or higher functionality. A clear example can be the reusable burgers, sides and cold drinks packaging developed by Loop for Burger King®. Traditional paper-based sandwich wrappings and disposable cups are replaced by reusable plastic shells and cups. This reusable pack is physically and perceptively sturdier than single-use ones. (Fig. 3).





Fig. 3: Burger King reusable packaging system by Loop (left) current single-use paper-based (right)



Many plastic-based takeaway containers and cups show higher wall thickness in order to enhance overall durability: this is the case of SwapBox and Vytal (Fig. 4).



Fig. 4: SwapBox and Vytal reusable containers for takeaway

Finally, one of the clearest cases of improved design is Returnr; this Melbourne-based start-up offers a very wide range of modular product sets for takeaway with an extremely high-end design: insulated stainless steel cups and bowls can be combined with additional plastic containers and transparent Tritan plastic lids fitted with sealing gaskets (Fig. 5); it is evident that these containers offer functional properties that are difficult to replicate in disposable packaging.



Fig. 5: Returnr modular canisters

2. Design for Washability and Hygiene

The second, above-mentioned, key factor to consider in reusable packaging is connected to hygiene-related aspects and elements that allow the feasibility of reuse. Some design features which will be described below can be useful to address these points.



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Among the analyzed case studies, especially those dedicated to food packaging are provided with **rounded corners** and the **geometries are free of recesses** and sharp details in which residues could accumulate. Just Salad reusable bowl (Fig. 6) is an example of this extremely smooth and edge-free design that is extremely useful to make washing operations easier.



Fig. 6: Just Salad reusable bowls

3. Design for Stackability and Space Optimization

Another key aspect to consider in packaging design to foster reuse operations and limit their impact is the **reduction of the volume** occupied by **empty containers** in the return phases. This goal, in turn, can be achieved through a careful definition of the geometries: a common solution is to design the containers to be stackable such as Ozarka Ark (Fig. 7).



Fig. 7: Ozarka Ark stackable food containers

4. Design for Compactability (Folding, Flexible Materials)

Otherwise, it is possible to define a compactable packaging architecture: The Box by Living Packets (Fig. 8), for example, has been engineered to be folded; the initial capacity of 32 litres can be reduced to 2 litres thanks to a special mechanism that makes it suitable for different storage needs and decreases the volume once empty.



Fig. 8: Living Packets The Box foldable transport packaging

Finally – as mentioned in the previous section dedicated to materials – another possibility to make the packaging compactable consists in selecting intrinsically foldable materials, such as fabrics.

5. Reversible Closure Systems for Reuse

A feature that distinguishes the design of disposable packaging from reusable packaging is the **closure system**: single-use packs are often provided with non-reversible closures (e.g. peelable lids, heat-sealings, etc.); this type of closure is not suitable for reusable packaging, where the reversibility of the system is instead a priority: in the analyzed case studies screw-caps are the most used for bottles and jars (e.g. ReRe, Plain Products, Fillgood, Fresh Bowl), pressure-caps are widespread among bowls, cups and trays (e.g. reCIRCLE, Bûmerang), while Velcro and zip closures are the most common in e-commerce transport packaging (e.g. Movo, Returnity).

6. Shared vs. Brand-Specific Designs

The last investigated aspect in the case studies concerns their **design type**, distinguishing reusable packaging that can be shared among different brands offering the same or similar products from those that are expressly designed for a specific company (ad hoc design): almost 3 out of 4 packaging design can be shared. This is particularly valid for those third-party



companies that offer packaging as a service, for example, the ones that offer cups for events (e.g. Ecoverre) or packaging platform for FMGC (eg. ReRe). In some cases, shared packaging can be treated with reluctance by brands, especially by those whose brand-specific packs are particularly significant in witnessing the brand image. Especially in cases where the brand identity cannot be conveyed by the product design, it is important to ensure brand recognition in other ways: for example, the various services that offer reusable cups allow customization with prints or engravings. It is clear that, if the product is customized, it will be possible to use a shared design, but that specific product won't be suitable for sharing among other brands. Anyway, to foster the implementation of reusable packaging systems it will be important to reach a certain degree of standardization to enable pooling systems. Standardized packaging also offers significant operational advantages: by reducing variability in formats and components, it simplifies collection, washing, redistribution and storage, thereby improving the overall efficiency of the reverse logistics chain

A practical example of this approach is offered by the R3PACK project, where sector-wide standardization efforts led to the development of shared packaging formats co-created by multiple industrial actors. The reusable salad tray (Fig. 9), jointly developed by Sodebo, Florale and LSDH, represents a format that can circulate across brands within the same product category, optimising reuse cycles and simplifying return logistics for retailers and washing operators. Likewise, the 500 g dairy pot (Fig 10), co-designed by Eurial and Schreiber, demonstrates how competitors can converge on a common packaging architecture that fulfills functional requirements while enabling pooling and operational efficiency along the entire reuse chain.



Fig. 9: Shared packaging format for salad trays_ R3PACK Case



Fig. 10: Shared packaging format for 500 g dairy pot_R3PACK Case

7. Trackability, Digital Information and User Guidance

Finally, to enable a reusable packaging system is important to consider trackability and information: this aspect in the case studies is addressed in different ways, by providing barcodes, QR codes, RFID tags, etc. These systems are useful to collect, store and access information related to the product life cycle. Furthermore, digital media are extremely useful to provide information on how the reuse system works: clear communication of the required steps of a return scheme can help users not to be discouraged by the behaviour required which, in many cases is the obstacle in engaging reuse (Babader, 2015).

5. Outcomes for reusable packaging design

a) Materials selection

The following suggestions can be useful to identify and combine different material-related requirements, to select a proper material that makes packaging technically suitable for reuse, but also perceptually accepted by users:

- Identify **constraints and requirements** for the material and define their **priority** for the type of packaging
- Consider **functional requirements**: e.g. water and chemicals resistance, shock proofness, lightness, thermal insulation, expected shelf-life of the packaged product, minimum n° of reuse cycles, etc.
- Consider **aesthetic-perceptive requirements**: e.g. scratch resistance, odor/color retention, overall appearance over time, etc.



- Consider **environmental requirements**: e.g. feedstock origin, process-related impacts, recyclability, etc.

b) Packaging design

The following design strategies can foster both a better functioning of reuse schemes and superior consumers acceptance of reusable packaging:

- Improve product design vs single-use:
 - opt for a **more durable design**: e.g. increase wall thicknesses; provide more effective and reversible closure systems
 - opt for a **more refined design**: e.g. increase packaging performances (sealing, protection, insulation); provide more recognizable shapes and details to express the brand's identity
- Design to **enhance washing operations**: e.g. avoid recesses and sharp details; give preference to smooth geometries and rounded corners
- **Optimize volume reduction for empty containers**: e.g. design for stackability, compactibility, foldability
- Consider a **shared design among brands**: standardization increases the volumes of the shared pack in circulation, making economies of scale possible and, at the same time, allows for an increase in the number of drop-off points, simplifying return operations for users
- Allow **customization**: e.g. provide possibilities to express brand identity through prints or engravings; consider brand-specific packaging design for large batch sizes, etc.
- Optimize **recyclability at end-of-life**: e.g. give preference to mono-material packaging components, facilitate the disassembly of incompatible materials for recycling, etc.
- Allow **trackability**: provide barcodes, QR codes, RFID tags or other tools collect, store and access information related to the product life cycle.
- Provide **instructions on the reuse scheme** steps: e.g. make information accessible through digital media on the packaging.

6. Environmental LCA Main Findings

The comparative environmental analysis aimed to assess the performance of reusable versus single-use packaging systems, considering the full life cycle of the packaging, from material production to end-of-life.

The analysis focused on identifying the environmental break-even point — the number of reuse cycles required for a reusable system to achieve equivalent or better performance than a single-use counterpart.



The functional unit (FU) was defined as 100 g of packaged product, ensuring comparability across product types and formats.

In this deliverable, the LCA results are discussed at a general level, without a detailed discussion of each environmental indicator. The focus is therefore on the overall interpretation of results through the aggregated single score, which allows for a clear and synthetic comparison between single-use and reusable systems. This approach is intended to highlight overall trends and relative performance, while the detailed indicator-based analysis will be addressed in subsequent, dedicated deliverables.

7. Key Results

The study compared 20 representative product-packaging systems (dairy, beverages, meat, condiments, snacks, etc.), analyzing environmental trade-offs between *State of Art (SoA)* for single-use formats and reusable alternatives.

- The material and production phase dominates the overall impact profile, accounting for over 80% of total impacts and resource use across all cases.
- Weight-to-content ratio emerged as a critical performance driver: systems with low product density or poor filling efficiency showed disproportionately higher impacts per functional unit.
- Reuse effectiveness strongly depends on the number of achieved reuse cycles — within the certified minimum materials and product lifespan
- Single-use components (e.g., disposable caps or films) significantly increase the total footprint, even when the main body is reusable.
- Return rate (RR) proved to be a decisive factor: scenarios with RR below 60% are difficult to reach environmental break-even.
- Packaging weight optimization was consistently associated with lower impacts, highlighting the relevance of structural and geometric efficiency.
- Systems employing mono-material and recyclable solutions with high recycled content demonstrated clear advantages at the end-of-life stage and in material recovery potential.



8. Material-Specific Findings

a) Polypropylene (PP) — Trays, Cups, Buckets

- Positive performance for compact containers used for dense products (e.g., yogurt)
- Negative outcomes for lightweight or sparse products (e.g., snacks, chips) due to poor mass-to-packaging ratio.
- If evaluated with reusable lids the impacts can be reduced significantly.

b) Glass — Bottles and Jars

- Mixed performance depending on the comparison baseline:
 - Negative when replacing PET/HDPE single-use packaging
 - Positive when compared with single-use glass

c) EPS, PET, HDPE

- Direct substitution with PP reusable designs is often not beneficial due to increased mass and different densities.

9. Social Risks Results

The social analysis aimed to evaluate the potential social risks associated with alternative packaging systems compared to the current state-of-the-art single-use systems. The study followed the *Guidelines for Social Life Cycle Assessment of Products and Organizations* (UNEP, 2020), using the *Social Hotspots Database (SHDB, v.5)* as implemented in *SimaPro v.9.6*.

Social risks were assessed across five main categories — Working Conditions, Health and Safety, Human Rights, Governance, and Community — covering 30 subcategories and 160 social indicators (Bennema et al., 2022). All results were normalized to the project’s functional unit:

“The packaging required to contain, protect, and preserve 100 g of food throughout the expected shelf life.”

Representative packaging typologies were selected for the analysis to capture different material families and system configurations (plastic-based, paper-based, and glass-based).



10. Social Risks Main Findings (S-LCA)

Having held the production countries constant, the analysis is diversified based on the materials treated. The main conclusions of the analysis are presented below:

- Plastic-based reusable systems (e.g., PP trays and buckets, IDs 02-r, 04-r, 10-r1) showed the lowest overall social risks after two or more reuse cycles, mainly due to stable supply chains and moderate sectoral risks.
- Paper-based alternatives (e.g., 04-s, 10_1) exhibited higher social risk potentials, driven probably by greater exposure to low-wage regions and weak labour law enforcement within pulp and paper production sectors.
- Glass-based reuse systems (e.g., 11-r, 17-r) presented mixed outcomes: despite risk reduction over multiple cycles, initial risk levels remain high due to the energy- and cost-intensive nature of glass manufacturing and heavier transport loads.
- For ID 17-r, where the same glass jar is reused, social risk improves substantially after the first cycle, indicating the relevance of long product lifespan and the need of closed-loop reuse schemes.

Overall, the analysis confirms that plastic-based reuse systems currently offer the most balanced social performance, while paper and glass require stronger risk management through responsible sourcing and labour certification and systemic optimization.

11. Cross-Interpretation with Environmental LCA

For all packaging types, the material production stage dominates the overall social risk profile, typically accounting for over 80% of the potential impacts. In contrast, logistics, washing, and return processes contribute marginally (< 10%), despite their central role in the reuse infrastructure. This finding aligns with the environmental LCA results, where material selection and weight were also found to be the primary drivers of overall impact.

When comparing the social and environmental results, the following synergies and trade-offs emerge:

- **Synergies:**
 - Plastic reuse systems (PP buckets, trays, and lids) perform consistently well across *both* environmental and social dimensions once reuse cycles are considered.
 - Reduction in material intensity (through light weighting or optimizing the packaging/food) lowers both environmental burdens and the embedded social risk.



- **Trade-offs:**
 - Paper-based single-use substitutions, while often environmentally favourable for carbon footprint, may increase social risks probably due to sourcing from low-regulation contexts (e.g. forestry and pulping sectors).
 - Glass-based reuse improves social outcomes over time but starts from a higher baseline risk.

12. Overall Synthesis

The comparative analyses carried out within this deliverable — combining environmental (LCA), social (S-LCA), and design-based assessments — demonstrate that reusable packaging systems can offer significant sustainability gains, if design, material, and operational parameters are optimized.

The environmental cross-analysis revealed that only half of the tested packaging systems achieved a net improvement over their single-use counterparts at realistic return rates (64.6–85.5%). The key determinant of performance was the weight-to-content ratio, closely followed by material choice and return rate efficiency.

The social assessment, conducted according to the UNEP 2020 and ISO 14075:2024 guidelines, confirmed that material sourcing and manufacturing stages dominate the social risk profile. Systems based on polypropylene (PP) and other polyolefins consistently exhibit lower overall social risk compared to paper and glass alternatives, due to better-regulated production chains and higher reuse efficiency.

From a design and consumer perspective, acceptance and usability remain crucial enabling factors. Reuse systems will only achieve their expected environmental and social benefits if consumers perceive them as convenient, safe, and hygienic.

Therefore, successful “design for reuse” requires integrating LCA-derived performance thresholds, S-LCA social safeguards, and user-centred design attributes into a unified framework.



13. Integrated Design Guidelines for Reuse Packaging Systems

The following table summarises the key design principles and monitoring priorities emerging from the comparative LCA and S-LCA analyses, literature review, and case studies. These guidelines represent the critical levers to enhance the environmental and social performance of reusable packaging systems and ensure their long-term effectiveness.

Particular attention should be paid to:

- Applying iterative LCA and S-LCA from the earliest design stages, ensuring continuous monitoring of environmental and social performance and enabling the early identification of potential trade-offs.
- This process should be supported by collecting and working closely with primary data from suppliers and producers to increase data reliability and contextual relevance.
- Designing for high return rates (above 60%), as consumer participation and logistical efficiency are essential to achieving environmental break-even.
- Managing risks in materials sourcing through certified and responsible supply chains, thereby ensuring low-impact raw material procurement and ethical production practices.
- Considering product category and filling characteristics, which critically influence the technical feasibility, material selection, and overall efficiency of reuse applications.

Effectiveness was assessed by identifying the life cycle stages most affected by each guideline. Based on the comparative results, the stages have been prioritised according to their overall significance across the analysed packaging types. According to the results, resources extraction and manufacturing dominates the environmental profile for all packaging types, typically accounting for over 80% of total impacts. Conversely, logistics, washing, and return operations—though central to reuse infrastructure—contribute less than 10% to the overall footprint. Therefore, in the analysed system, the materials selection and design phase remain the most critical intervention point for improving sustainability performance of reusable packaging systems.



Table 1: Integrated Design Guidelines for Reuse Packaging Systems

Section	Design Guideline	Evidence / Source	Life Cycle stages	Effectiveness
Efficient pack/content ratio	Select food categories with a low rate of volume/mass or adopt food filling optimization (stakability – dried foods)	D6.3b	All	High
	Apply lightweighting through structural optimization	D6.3b (ID10_1: –2 g = BE)	All	high
	Decision rule: roll-out if Break Even point is reached $\leq$ 5 cycles @ RR $\geq$ 70%	D6.3b sensitivity	All	high
	Limit glass to closed-loop circuits or where reuse already exists	D6.3b (IDs 11–13,16–20); S-LCA	All	high
	Replace disposable caps/lids with reusable or shared ones	D6.3b (caps = 25–30% impact); EMF 2019	Production - End-of-life	Medium-low
Maximize Return Rate – Avoid Production	Implement deposit–refund or incentive/penalty schemes	EMF 2019; Loop, Vytal	Production-End of Life	High
	Use materials optimized for technical and aesthetic durability to washing conditions and through cycles (anti-scratch, anti-UV coatings)	Cooper et al.; case studies (Tritan)	Production - End-of-life	medium
	Provide clear on-pack and digital return/use instructions	PPWR; Vytal case	Production-End of Life	medium
	Integrate digital traceability to manage the return (QR/Rfid)	SHDB; EMF; case studies	All – except transports and washing	low



Efficiency on operations	Prioritize nearby sourcing and production	S-LCA (geographical impacts); SHDB	Transports – Production	medium
	Optimize washing (low-temp, closed-loop systems)	LCA phase contrib.; S-LCA (worker safety)	Washing	Low
	Design for stackability or foldability to reduce empty transport	D6.3b (stackable gains); case studies (Living Packets)	Transports	Low
	Design for easy cleanability: smooth shapes, no recesses	Greenwood et al. 2021; case studies	Use - Washing	low
	Standardize formats across coherent product categories (pay attention to food volume). Use removable sleeves or engravings for shared branding	EMF; D6.3b	Production – Transports - Washing	medium
	Prioritize materials with high recycled content	D6.3b	End of Life – Material extraction	medium
	Prioritize mono-material, recyclable materials and end-of life design	D6.3b LCA (IDs 02,04); S-LCA; EMF 2019	End-of life	low



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Case Studies and Market Examples

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Eastman Tritan™ – https://www.eastman.com/Brands/Eastman_Tritan/Pages/Overview.aspx

Elium Studio – <https://elium.studio/project/mcdonalds-re-use/>

Fillgood – <https://www.fillgood.co>

Fresh Bowl – <https://www.myfreshbowl.com>

LimeLoop – <https://www.thelimeloop.com>

Living Packets – <https://livingpackets.com/the-box>

Loop – <https://loopstore.com>

Loop for Burger King® – <https://explorelloop.com/BurgerKingUK>

Movo – <https://www.movopack.com>

Ozarka Ark – <https://ozarka.nl/ark-reusable/?lang=en>

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