REUSABILITY BY DESIGN

2024 Update

RECOUP

Reusability by Design

Reusable plastic packaging design guidance for the value chain

RECOUP is the UK's leading independent authority and trusted voice on plastics resource efficiency and recycling. As a registered charity, our work is supported by members who share our commitments including a more sustainable use of plastics, increased plastics recycling, improved environmental performance and meeting legislative requirements. We achieve these by leading, advising, challenging, educating and connecting the whole value chain to keep plastics in a circular system that protects the environment, underpinned by evidence and knowledge.

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Executive Summary

This guidance document has been produced as part of project TRACE (Technology-enabled Reusable Assets for a Circular Economy); a UK Research & Innovation (UKRI) Smart Sustainable Plastic Packaging funded industrial research project.

The vision for project TRACE, was to explore how applying ultra-low-cost radio-frequency identification (RFID) technology to track reusable food-grade plastic packaging could encourage reuse and enable highly scalable infrastructure.

One of the aims of project TRACE was to develop reusable packaging design guidance, a part of the project which was lead by RECOUP and supported by Pragmatic and the University of Sheffield.

Reusable packaging represents a key element of achieving a circular economy. It has to not only meet the criteria of single-use packaging in terms of its capabilities to hold, protect, handle, deliver and present goods but needs to maintain these performance characteristics over a number of use cycles. Despite some of the challenges to the large-scale adoption of reusable packaging, this industry presents a huge market and resource efficiency opportunity. Converting just 20% of plastic packaging into reuse models is a business opportunity worth 10 billion US dollars[1]. Designing reusable packaging so that it meets the requirements of all stakeholders in the value chain is a key component of this.

This document seeks to provide guidance on areas for consideration for reusable plastic packaging design primarily for food and beverage markets. The guidance does not attempt to provide precise and constraining advice on reusable packaging design but aims to highlight the key areas for focus when considering adoption of reusable packaging and the requirements of all areas of the value chain to ensure that appropriate and sustainable choices are made in reusable packaging design and development.

Information to produce this guidance was gathered through a number of methods with both quantitative and qualitative data sourced through desk-based research, industry survey, value chain workshops, interviews, practical testing, and outputs from other work packages in the TRACE project.

When designing reusable packaging the needs of stakeholders throughout the supply chain must be considered, these include but are not limited to packaging manufacturers, brands, retailers, consumers, waste management companies and service providers.

A number of technical characteristics of the packaging must also be considered at the design stage, including material choice and durability, size and shape of packaging, visibility of the product, closure type, tamper evidence requirements and decoration. However, choices on these must be made in collaboration with an acknowledgement of consumer needs, food safety, washing and cleaning requirements, impact on transportation and also the design implications on end-of-life scenarios for the packaging when it leaks or leaves the reuse system. Any design should have an objective to reduce the environmental impact of the packaging in comparison to single-use alternatives but must also be mindful of costs to both the consumer and supply chain in doing so.

The design of reusable packaging cannot be considered in isolation by any stakeholder in the value chain nor in isolation from the reuse system in which the reusable packaging will function. Consideration of how elements such as standardisation and use of technology for reusable packaging throughout the supply chain will no doubt have a key role to play in the scale up of reuse. Collaboration among stakeholders will be vital to the success of scaling up reusable packaging systems.

1 Reuse- rethining packaging

Background

Project TRACE

This guidance document has been produced as part of project TRACE (Technology-enabled Reusable Assets for a Circular Economy); a UK Research & Innovation (UKRI) Smart Sustainable Plastic Packaging funded industrial research project lead by Pragmatic Semiconductor Limited. Project TRACE ran from early 2022 to July 2024 and this report has been produced as a result of a work package focussed on reusable packaging design.

Project TRACE aimed to address some of the challenges that currently prevent large-scale reuse. Work packaged covered the following:

- Understanding consumer perception and how best to encourage adoption.
- Developing reusable packaging design guidance.
- Enabling item-level traceability throughout the packaging lifecycle.
- Ensuring packaging remains safe and fit-for-purpose.
- Developing and demonstrating an end-to-end model for collection, sorting and washing infrastructure.
- Quantifying the overall environmental impact of moving from single-use to reusable packaging.

The core technology innovation is the use of Pragmatic's ultra-low-cost RFID tags to enable a packaging reuse model. These tags provide machine-readable unique codes that allow automated identification and tracking of individual items throughout multiple reuse cycles, generating rich data. These smart systems can support customer adoption and infrastructure implementation for optimal environmental impact. For example, the movement of assets within the system, number of cycles, packaging provenance and legislative reporting.

The intention is to update this document beyond the lifetime of the project as the understanding of the design requirements of reusable packaging develop.

TRACE project partners

Pragmatic is revolutionising semiconductor technology with flexible integrated circuits (FlexICs) that make it quick and easy to embed intelligence almost anywhere. Faster to produce than silicon chips, and significantly more cost-effective, FlexICs are thinner than a human hair and, invisibly embedded in objects, enable novel solutions that are simply not possible with conventional electronics.

The University of Sheffield is a research university in the Russel Group with a global reputation for excellence in research and teaching. The university is home to over 30,000 students and 7,000 members of staff across a broad range of academic disciplines and specialised research centres including the Advanced Manufacturing Research Centre (AMRC) and the Grantham Centre for Sustainable Futures. Through research, innovation and collaborative working, Sheffield is committed to finding solutions for worldwide social, environmental, and economic challenges.

AMRC Cymru is part of the University of Sheffield Advanced Manufacturing Research Centre and a member of the High-Value Manufacturing (HVM) Catapult, a consortium of leading manufacturing and process research centres backed by Innovate UK. The state-of-the-art centre, fully funded with £20m from the Welsh Government and managed by the University of Sheffield, focuses on advanced manufacturing sectors, including aerospace, food and drink and nuclear in the key research areas of future propulsion, sustainability and digital manufacturing.

RECOUP, is the UK's leading independent authority and trusted voice on plastics resource efficiency and recycling. As a registered charity, our work is supported by members who share our commitments including a more sustainable use of plastics, increased plastics recycling, improved environmental performance and meeting legislative requirements. We achieve these by leading, advising, challenging, educating and connecting the whole value chain to keep plastics in a circular system that protects the environment, underpinned by evidence and knowledge.

Ken Mills has 40 years' experience in the design, manufacture, and installation of numerous MRF facilities across the world. Ken Mills' tailored waste solutions help clients manage their waste and recycling operations more efficiently, enabling clients to minimise their environmental impact.

Funded and supported by

UK Research and Innovation

Purpose of document

This document seeks to provide guidance on areas for consideration for reusable plastic packaging design, taking into account research, industry and consumer views and practical testing. This report does not attempt to provide precise and constraining guidance on reusable packaging design but aims to ensure that all areas of the value chain are considered during the conceptual and design processes for reusable packaging. This document aims to highlight the key areas for focus when considering adoption of reusable packaging and the requirements of all areas of the value chain to ensure that appropriate and sustainable choices are made in reusable packaging design and development.

It is noted that continuing work will be required by many parties including designers, manufacturers, academia, service providers, retailers, brands, waste and resource management professionals and governments to address these developing challenges as we accelerate the transition towards a circular economy and the intent is that this guidance will be updated over time to reflect this. This document should therefore be considered only as a starting point for reusable packaging design guidelines.

Scope of document

This document has been produced following the below scope:

Rigid plastic packaging

While initial research was focussed on the general requirements of reusable packaging design, this guidance is concentrated on the use of plastics for the manufacture of reusable packaging. As a durable and versatile material plastic presents a unique opportunity for use in reusable packaging. The choice of any material must be made based on evidence and requirements of both the product and the packaging system. For the practical testing elements this work is focussed on the following polymers: PET, HDPE, PP, Tritan™ and PBT in rigid packaging formats.

Business-to-consumer food and drink packaging

While the focus of project TRACE and this document is on business-to-consumer reusable packaging, for fast moving consumer goods (FMCG), in particular food products, many of the learnings can be transferred to other product sectors. Food packaging has strict requirements in terms of its properties and characteristics related to materials used and safety and hygiene standards therefore packaging developed for these requirements will likely meet criteria for non-food products in many cases. Specific product requirements should always be considered during the packaging design process.

Value chain focus

This report has endeavoured to capture the viewpoints and considerations of the whole supply and value chain that is required for the success of reusable packaging and reusable packaging systems. In particular the views of the following stakeholders have been sought and insights from these are shared throughout the report:

- Packaging manufacturers
- Packer/fillers
- Brands
- Retailers
- Consumers
- Waste management companies
- Plastic reprocessors
- Service providers

Geographic focus

While RECOUP and the partners of the TRACE project are UK based, the requirements of reusable packaging and reusable packaging systems are a universal challenge. Some countries are more ahead in their reusable packaging journeys, and where applicable this experience has been incorporated into the report although the main findings are related to the UK market circumstances.

Radio-frequency identification (RFID)

The core technology innovation for project TRACE is the use of Pragmatic's ultra-low-cost integrated circuits that make it viable to add RFID tags to FMCG packaging. These tags provide machine-readable unique codes that allow automated identification and tracking of individual items throughout multiple reuse cycles. Rich data generated can support consumer adoption and infrastructure implementation for optimal environmental impact. Other track and trace systems are available such as QR or barcodes, but this guidance will focus predominantly on incorporating RFID technology as part of the design process.

While these guidelines provide information related to the incorporation of RFID tracing technology for reusable packaging, the majority of the guidelines are still of relevance to reusable packaging that is not technology enabled or utilises another form of technology.

Reuse definition

These guidelines align with the definition of reuse as stated by the Ellen MacArthur Foundation (EMF) in their circular economy glossary:

'The repeated use of a product or component for its intended purpose without significant modification. Small adjustments and cleaning of the component or product may be necessary to prepare for the next use.'[2]

[2] Finding a common language — the circular economy glossary

Reusable packaging design

This guidance focuses on reusable packaging design as opposed to reusable systems design. Although it recognised, and will be referred to throughout this report, that these two design areas are intrinsically linked and neither can be considered in isolation, this guidance will concentrate on the considerations for reusable packaging design only.

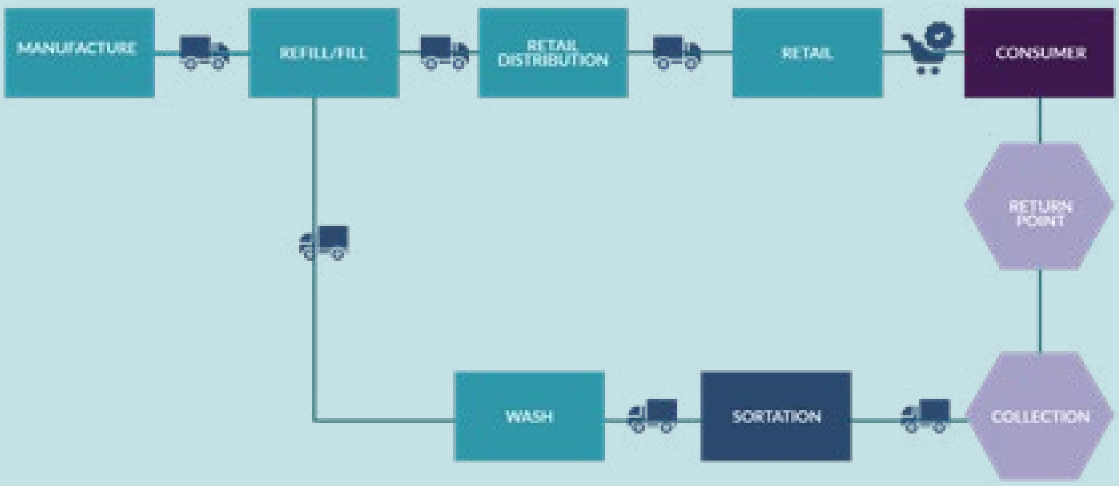
Reuse systems in scope

The research for project TRACE was primarily focussed on two types of system model (in-store return and delivery) for business-to-consumer reusable packaging, where the packaging is an asset of the reuse system and is not owned by the consumer as seen in some other reuse models. These models are outlined below.

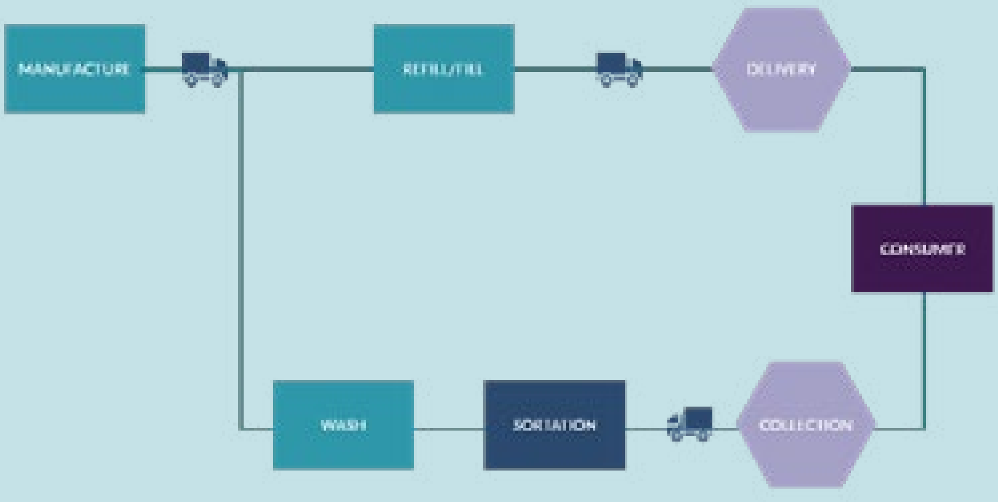
Under the EMF definitions[3] these models fit under the 'return from home' (picked up from home by a pickup service) or 'return on the go' (consumer returns packaging to store or a drop off point). These models are both focussed on a prefill system where the consumer is not required to fill the reusable packaging at point of purchase, the product is already contained within the packaging available on shelf or online. The return of the packaging could be via means such as return in store to smart bins, returned through delivery services of online purchases or mechanisms such as kerbside collection of reusable packaging.

[3] Reuse – rethinking packaging

In-store model: Product is sold via a retail store, customer purchases and consumes product, packaging is returned to in-store return point, packaging collected by local logistics/waste management organisation, packaging is sorted and washed, returned to supplier to be filled and then returned to retail store for sale.



Delivery Model: Consumer purchases product online, order is delivered by service provider, consumer consumes product, packaging is collected by service provider, sorting and washing at service provider, refilled and then placed back on sale.



These guidelines do not focus on packaging for refill applications where the packaging is owned and prepared by the consumer for reuse. Packaging formats for refill often have less design pressures as they do not need to be designed to tolerate the pressures of a reuse system including industrial transportation, washing and filling. RECOUP have produced a case study on refill packaging availability on the market, materials used, suitability for reuse and environmental claims. This can be accessed at www.recoup.org/our-work/reuse.

Ellen MacArthur Foundation business-to-consumer reuse models

Evidence Base

This document has been produced based on findings from:

Desk-based research
A desk-based review of guidelines, legislation and previous work completed in this area was undertaken.

Online survey
A survey was carried out, completed by over 120 participants from across the value chain. The survey was communicated primarily to the RECOUP membership base and via TRACE project partners, but also shared via numerous social media and external channels. The focus of the survey questions was to determine design priorities for different stakeholders in the supply chain.

Workshops
Two virtual workshops were held with a mixture of attendees from brands, retailers, packaging manufacturers, service providers, waste management and academia. The focus of the workshops was to understand some of the benefits, barriers and challenges of reusable packaging design and to start to develop design briefs for some specific product categories, the outputs of which are shared in this report as design briefs.

Interviews
Interviews were held with organisations on the TRACE steering committee as well as other key stakeholders identified to gather further insights on the requirements of reusable packaging design.

Other TRACE work packages
Knowledge was also gathered from parallel TRACE work packages looking at areas such as sorting capabilities for packaging incorporating RFID and consumer acceptance of reusable packaging.

Practical testing
Insights from practical tests carried out by the University of Sheffield, including washing durability tests on packaging and materials as well as label/tag application tests contributed to this report with full details of these findings available in the Supplementary Technical Guidance to this document.

Introduction

Packaging is defined as any material used to hold, protect, handle, deliver and present goods as they travel through the supply chain. Single-use packaging, particularly single-use plastic (SUP) packaging, has become a well-used and recognised term, particularly over recent years with the recognition of the impact of increased resource usage and waste impact of single-use items on the environment.

While collection and recycling rates of single-use plastic packaging in the UK have continued to grow over recent decades[4] it can be argued that although we may be well on our way to transitioning from a linear to a recycling economy, we still have a long way to go to meet the requirements of a circular economy. A circular economy, as opposed to a linear economy, is one in which the value of resources are maintained and not lost from the system, this can be achieved in a number of ways such a repair, recycling or reuse of materials and products in order that they do not become waste.

Reuse represents a key element of achieving a circular economy and is defined as *'the repeated use of a product or component for its intended purpose without significant modification'*. In the context of reusable packaging this has to not only meet the criteria of single-use packaging in terms of its capabilities to hold, protect, handle, deliver and present goods but needs to maintain these performance characteristics over a number of use cycles. Despite some of the challenges in the large-scale adoption of reusable packaging, this industry presents a huge market and resource efficiency opportunity. Converting just 20% of plastic packaging into reuse models is a business opportunity worth 10 billion US dollars[5].

While a number of business-to-business reuse systems have been in place for some time, it is clear that business-to-consumer focused reuse systems will have a significant role to play in the future as progress is made to find long term solutions for resource efficiency and the circular economy. Whilst single-use packaging models are well developed, efficient reusable packaging systems are still in their infancy and there is work to be done to implement and exploit the best and most viable models. Many retailers and brands have attempted to implement reuse systems, but often struggle to scale because of the lack of commonly available infrastructure to make it financially and environmentally viable. It is important that these systems work at scale, adding layers of innovation where needed to improve the service as we move forward. It is also important to implement these types of system only when practical and genuinely the best option. Developments in this area must build on the benefits of the packaging and product delivery systems currently in operation and further build on resource efficiency and progress towards a circular economy. Reusable packaging in business-to-business environments such as pallets and crates has been adopted successfully for many years, however there are increased challenges and criteria to be addressed when looking at business-to-consumer adoption of reusable packaging and systems. Modern day demands of consumers such as convenience and speed to market of products requires new ways of thinking and innovation when it comes to delivering successful reuse systems.

In respect of the waste hierarchy, circular economy, and resource efficiency, reuse is the favoured option above recycling, recovery and disposal. By transitioning from single-use plastic packaging to reusable plastic packaging there is the potential to reduce the impact on the environment through extending the packaging's lifecycle leading to reduced resource consumption and delayed disposal and recycling of resources. However, any environmental savings need to be quantified through methods such as life cycle assessment to ensure the move to reusable packaging is for the right reasons and utilised for the right product categories. Environmental impact of the packaging will be directly influenced by factors such as material choice, number of reuse cycles achieved and the washing and logistic requirements of the reuse system. Reusable packaging should be designed in close alignment with the number of uses expected of the packaging to ensure the risk of under or over engineering the packaging design is mitigated.

The transition to reusable packaging systems will also require a shift in consumer behaviour. Consumers are used to their role in the packaging lifecycle to be disposal or segregation for recycling, single-use packaging has little to no value to consumers once products have been consumed. Not only will how the consumers interact with packaging be altered but there will also be a need to instil a value to the packaging and adopt new behaviours to return packaging to the reuse system. Whether this is a request to return packaging to retail stores or via a delivery/take back system it will require a change in behaviour. We have however seen some progress towards these types of behaviour with the introduction of carrier bag charges and front-of-store films and flexible recycling collection points. These schemes require voluntary uptake, how to incentivise reusable system uptake will be a major consideration.

[4] RECOUP The UK Household Plastic Packaging Collection Survey

[5] Reuse – rethinking packaging

Role of design & the value chain

The design of reusable packaging will have a key role to play in the scale up of the adoption of reuse systems. Design is an important lifecycle process whether the packaging is intended for single or reusable use applications. The packaging in either case must be designed to meet its primary requirement of protecting products throughout the supply chain, in the case of reusable packaging it must be designed to withstand multiple trips along the supply chain. Alongside these protection requirements packaging design also considers factors such as functionality, quality, protection of products, product promotion and information, efficiency and convenience of use, transport and cleaning efficiencies and recyclability.

Throughout the research it became increasingly apparent that reusable packaging must be defined and designed for the system in which it will operate. The two are intrinsically linked and it will be detrimental to the reuse system if considered in isolation. This guidance explores the role that design has to play in meeting the requirements of reusable packaging for all stakeholders in the value chain.

Outlined below are the main stakeholders in the reusable packaging value chain and their role.

Part of value chain	Role
Packaging Manufacturer	Undertakes the activity of turning raw material into a product, in this case packaging
Packer/Filler	Producer that puts products into packaging
Brand Owner	Person or company who sells commodities under a registered brand label
Retailer	Storage and sale of products. Potential return point
Consumer	Consumer of products and party responsible for return of packaging
Logistics services	Transportation of products and packaging throughout the supply chai
Service provider	Sort, quality check and clean returned packaging
Technology provider	Track, trace and collect data on reusable packaging
Waste management	Post-consumer collection sorting and recycling of waste

The main difference to stakeholders in the reusable packaging value chain in comparison to the single-use packaging value chain is the incorporation of service and technology providers. These parties have a crucial role to play in ensuring that reusable packaging is not only traced through the reuse system but that reusable packaging re-enters the system under strict hygiene controls and suitability for reuse.

While stakeholders in the value chain are focussed on different elements of the characteristics of reusable packaging, its performance and the system in which it operates, there are common themes around what are perceived as challenges to the success of reusable packaging. Design can play an important role in overcoming these challenges for the scale up of reusable packaging. Design of packaging is most often undertaken by stakeholders at the beginning of the packaging life cycle, namely the packaging manufacturers, at times with influence and input from brands and retailers and other stakeholders. Therefore consideration, and in the case of reusable packaging, collaboration, in relation to the design needs for the whole value chain must be considered by the parties responsible for the design.

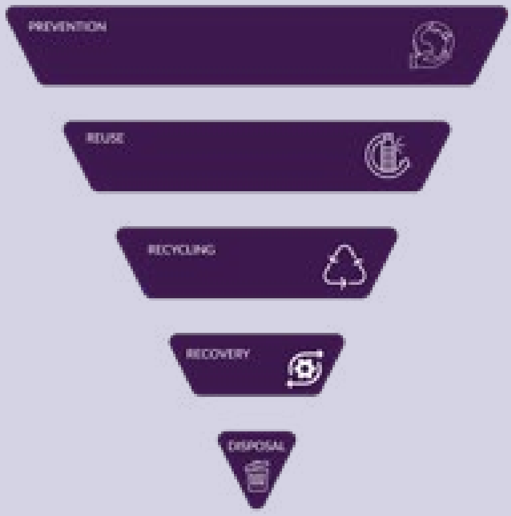
Challenges to overcome for reusable packaging and its design include:

Applicable legislation and voluntary commitments

The role of reusable packaging is touched on by a range of legislation, standards and voluntary commitments, however there is often a lack of detail and tangible targets for adoption or scaling of solutions. This section touches upon any areas where reusable packaging is a subject of discussion, particularly any elements that may have an impact on packaging design.

Waste Framework Directive

The Waste Framework Directive (WFD) defines waste as 'any substance or object which the holder discards or intends or is required to discard'. The basis of the WFD is the waste hierarchy which outlines preference for the management and disposal of waste from prevention of waste through to disposal. Preparing for reuse sits below prevention but above recycling in the order of preference. The updated Waste Framework Directive (WFD 2018/851)[6] implements the EU Circular Economy Package, and measures and regulates how products sold in the European Economic Area (EEA) are reused, repurposed, recycled or disposed of. Extended Producer Responsibility (EPR) schemes were introduced under this directive. With this, it is highlighted that the definition of an EPR scheme clarifies that producers of products are financially responsible for the management of the waste stage of a product's life cycle including separate collection, sorting and treatment operations, and can include contributing to waste prevention and to the products reusability and recyclability.



Waste Hierarchy

Within the Directive, Article 8a 4(b) states that Member States are to provide 'modulation' of financial contributions paid by the producers (modulated fees) where possible, taking into account product attributes such as durability, reparability, reusability and recyclability. This acts as an incentive for producers to design products that contribute to waste prevention and facilitate recycling.

Packaging & Packaging Waste Regulations (PPWR)[7]

The Packaging & Packaging Waste Regulations (PPWR) covers both packaging design and packaging waste management. The primary aim is to decrease volumes of packaging waste and also to remove barriers in the internal market to packaging design.

In late 2023, the EU agreed on a series of targets as part of the regulations. As well as focusing on recycled content in packaging, and overall recycling rates, it also included a number of reuse targets. These targets include:

- Alcoholic and non-alcoholic beverages including water and juices, but excluding milk, wine and some spirits, at least 10% reusable by 2030, 40% by 2040.
- Final distributors of beverages and takeaway food will have to offer consumers the option to bring their own reusable container for food collection. They will also be required to target 10% of products to be sold in reusable packaging formats by 2030.

Targets have also been introduced for transport and sales packaging and grouped packaging formats. While these regulations are not applicable to the UK they may still influence the market and future policy developments.

UK Plastic Packaging Tax[9]

The UK Plastic Packaging tax was introduced by HMRC on 1 April 2022 and dictates that any plastic packaging placed on the UK market that does not contain at least 30% recycled content will be subject to a tax. As of January 2024, this is charged at a rate of £210.82 per tonne. This is applied to any item of packaging whereby plastic is the main component by weight.

The plastics packaging tax makes specific reference to reusable packaging items that are out of scope of the tax, this includes:

- Drinks bottles designed for reuseFood storage boxes and containers designed to be reused, such as lunch boxes
- Reusable coffee cups

- Reusable dosage or measuring cups that are not used as a lid or cap, such as a dosage cup sold with washing powder
- Reusable medical sharps bin
- Reusable pan liners

Waste Electrical and Electronic Equipment (WEEE)

Waste electrical and electronic equipment is regulated to reduce the amount that is sent to landfill or for incineration. Reduction is achieved through various measures which encourage the recovery, reuse and recycling of products and components.

The Waste Electrical and Electronic Equipment Regulations 2013 (as amended) is the underpinning UK legislation for waste electrical and electronic goods.[10]

The regulation includes RFID, radio tracking devices, anti-theft devices and electronic tags for criminals. Exempt from the regulations are RFID security features that form part of the product's packaging. The Department for Business, Enery & Industrial Strategy (BEIS) has confirmed that RFID tags labels used on packaging such as cups and bowls would not be considered electrical and electronic equipment and therefore not considered to fall under the WEEE regulations.

Single-Use Plastic Legislation

In recent years, there has been development of Single-Use Plastic legislation across Europe. This has involved restrictions and bans placed on certain plastic products, including (but not limited to) plastic plates, bowls and trays, cutlery, balloon sticks, polystyrene food and drinks containers, and oxo-degradable plastic. These bans have the potential for incentivising the use of reusable alternatives, particularly for food and drink containers and cutlery, as well as potential material substitutions.

Voluntary commitments

The Ellen MacArthur Foundation – Global Commitment[11]

The Global Commitment is led by the Ellen MacArthur Foundation in collaboration with the UN Environment Programme. The Global Commitment has over 500 signatories which represent 20% of all plastic packaging produced globally with a common vision to:

- Eliminate the plastic items we don't need.
- Innovate so all plastics we do need are designed to be safely reused, recycled, or composted.
- Circulate everything we use to keep it in the economy and out of the environment.

WRAP UK Plastics Pact (UKPP)[12]

The UKPP is a voluntary commitment bringing together business from across the plastics value chain to tackle plastic waste. The UK Plastics Pact is led by WRAP, enabled by the Ellen MacArthur Foundation's New Plastics Economy initiative. The vision of the pact is 'A world where plastic is valued and doesn't pollute the environment'.

The UKPP has four targets to 2025, these are:

1. Eliminate problematic or unnecessary single-use packaging through redesign, innovation or alternative (reuse) delivery model.
2. 100% of plastics packaging to be reusable, recyclable or compostable.
3. 70% of plastics packaging effectively recycled or composted.
4. 30% average recycled content across all plastic packaging.

Arguably reusable packaging has a role to play in meeting all of these targets. While particularly prevalent to targets 1 and 2, the design of reusable packaging to address its potential to be recycled and the incorporation of recycled content will also address targets 3 and 4.

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[6] The Updated Waste Framework Directive (WFD 2018/851)
[7] Packaging waste (europa.eu)
[8] European Green Deal: Putting an end to wasteful packaging (europa.eu)
[9] Plastic Packaging Tax - GOV.UK (www.gov.uk)
[10] Regulations: Waste Electrical and Electronic Equipment (WEEE) - GOV.UK (www.gov.uk)
[11] The Global Commitment and Circular Economy for Plastic Use
[12] The UK Plastics Pact | WRAP

Durability & Material Choice

Packaging durability

In most cases single-use plastic packaging has been optimally designed with the appropriate level of durability to survive one journey through the supply chain while still carrying out its primary function of protecting goods.

When we consider the requirements of reusable packaging, durability needs to be a key consideration as the packaging will be required to be designed to go through the reuse system multiple times while experiencing the stresses of activities such as industrial washing, multiple trips down filling lines and numerous transportation journeys.

> ***Highly durable differentiates reusable packaging from single-use.***
> ***Survey respondent***

Reusable packaging not being durable enough to withstand multiple use cycles was identified as a challenge to reusable packaging adoption by 32% of survey respondents and was identified as an extremely important design characteristic by 81% of respondents.

Some of the key design considerations for durability identified through the research included:

Durability design requirements for reusable packaging
Durable when dropped or mishandled – shatter proof
Does not display signs of wear or degrading appearance
Robust enough for cleaning requirements
No warping of containers through heat exposure
Durability of branding/labelling/technology assets
Packaging maintains quality over time

One of the key questions for durability of reusable packaging is when does a piece of plastic packaging transition from single-use to being multiple-use and fitting the definition of reusable? This is a difficult question to give a specific answer to and throughout discussions with industry stakeholders we found various opinions on this topic. Opinions ranged from thoughts that some single-use packaging formats used on the market today could potentially, with little to no redesign, be utilised by a reuse system. Others were of the opinion that by definition reusable packaging can only achieve the robustness required by the supply chain through being heavier and stronger than single-use packaging.

As with the majority of considerations for reusable packaging design the durability requirements will be dependent on a number of factors including the level of product protection required and reuse system requirements. One of the primary factors that will influence packaging durability is material choice alongside the wall thickness of any packaging format, this is explored further in the next section. The consumer perception of durability and the requirements of this are explored later in the document.

Material choice

Material choice for reusable packaging can be a contentious subject. A shift towards increased uptake of reusable packaging, should be made with the intention to reduce resource consumption and keep materials in the circular economy for longer and thereby reduce environmental impacts. However, some shifts in material choice for reusable packaging have been made to be able to label products as ‘plastic free’, which can appear as greenwashing without evidence that environmental impact has been improved as part of the transition away from plastics. The impact of any material used for reusable packaging should be considered from a life cycle perspective taking into account factors such as total material use, realistic reuse rates and also end-of-life management. By viewing any proposed transition from this holistic standpoint will ensure that the overall aim of reducing environmental impact through the introduction of reusable packaging is prioritised. Environmental impact of reusable packaging is is discussed later in the guidance.

This focus of this report is primarily guidance for the use of plastics in reusable packaging design. Despite plastic having received bad publicity for pollution problems and resource use, these are mismanagement issues rather than material ones. Lightweight and durable, with a range of barrier properties for water, light and oxygen, suitable for use in a range of temperatures from oven to freezer, including microwave, offering versatile visual characteristics, rigid and flexible options, with established reprocessing routes – plastic is an excellent choice for reusable packaging. These properties form a solid foundation for functional packaging that is easy to use throughout the supply chain and helps deliver environmental benefits for the whole reusable packaging system.

Certain areas discussed throughout this guidance are applicable to reusable packaging manufactured in any material, for example the branding and consumer challenges, however in this next section of the report we will focus on how plastic as a material is viewed and performs in relation to reusable packaging.

Material choice design considerations

Design priorities related to, or influenced by, material choice featured highly in the top 10 design priorities for reusable packaging as identified by the survey and highlighted below:

1. **Recyclability** after the pack can no longer be reused
2. **Durability** (packaging can withstand multiple use cycles without losing its properties)
3. Hygiene guarantee (customer can check that the container was cleaned in accordance with regulations)
4. Logistics (cube utilization, stackability etc)
5. **Compatibility with current manufacturing systems**
6. Brand information visibility e.g., labelling
7. **Product protection** (e.g., damage, shelf-life)
8. Traceability provided via RFID tag/app
9. **Product is visible** (transparent packaging)
10. **Packaging appearance**

All of the above characteristics can be influenced through material choices for reusable packaging. Some of the key challenges identified link directly to these priorities, the need for material choice to fit with existing manufacturing lines and to achieve robustness through multiple use cycles.

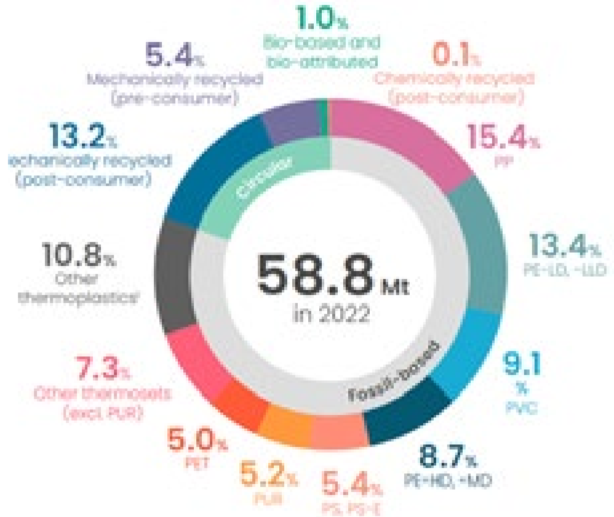
Other design considerations highlighted through research related to material choice are detailed in the table below.

Characteristic	Packaging material choice requirements
Resource efficiency	Optimised weight while maintaining durability Consideration of renewable or recycled content
Outer surface performance	Capability for printing/decorating/labelling Resistance to scratching or wear from phases of reuse system
Functional performance	Can retain product shelf-life Withstands hot wash and commercial detergents Not easily stained Shatterproof Displays minimal signs of wear Keeps shape
Visual appearance	Preference for clear material to provide cleaning assurance although coloured better for highly staining products Appearance does not degrade through multiple use cycles
End-of-life	Recyclable Mono-material preferred

Polymer options for reusable packaging

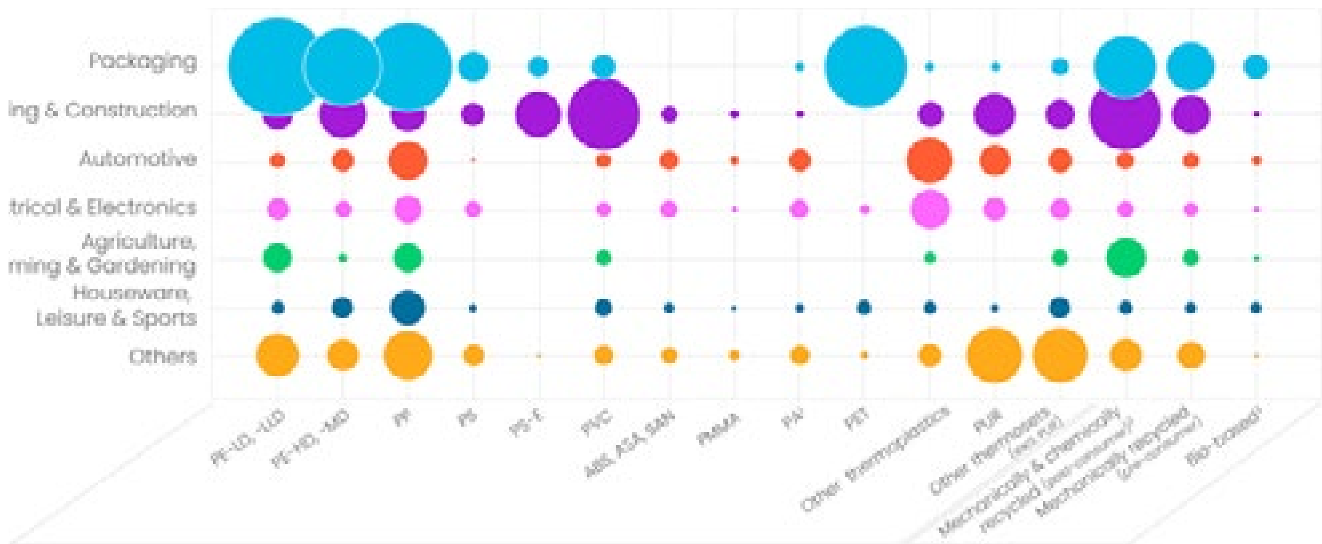
European plastic production in 2022, as reported by Plastics Europe[13], was 58.8 Mt, 80.3% of this was fossil-based plastic, 13.2% post-consumer recycled plastics, 5.4% pre-consumer recycled plastics, 1.0% bio-based or bio-attributed plastics and 0.1% chemically recycled plastics. Of this 58.8 Mt the distribution across plastic types is shown in the chart below, 39% of which was attributable to packaging applications.

European plastics converters demand per material type and sector is shown below. For packaging the main polymers used are Polyethylene (High Density (HDPE), Medium Density (MDPE), Low Density (LDPE and Linear Low Density (LLDPE)), Polypropylene and Polyethylene Terephthalate.



European plastics production by type[13]

Data Sources: Conversio Market & Strategy GmbH and nova-Institute Sources: Conversio Market & Strategy GmbH, nova-Institute, Polyglobe database by Kunststoff Information Verlagsgesellschaft mbH, Eurostat (European Statistical Office).
The above data are rounded estimations.
Polymers that are not used in the conversion of plastic parts and products (i.e. for textiles, adhesives, sealants, coatings, etc.) are not included.
*Including plastics production from polymerisation and production of mechanically recycled plastics 1. Includes PBT, PEEK, PEI, POM, PPA, PSU/PES/PPSU, PTFE, PVDF and other thermoplastics not listed separately.



European plastics converters demand by application and type[13]

Source: Conversio Market & Strategy GmbH based on the input of the Plastics Europe Market Research Group (PEMRG). The above data are rounded estimations. Demand data are built on estimations of quantities bought by European converters, including imports. Demand for recycled plastics and bio-based/bio-attributed plastics is not included. Polymers that are not used in the conversion of plastic parts and products (i.e. for textiles, adhesives, sealants, coatings, etc.) are not included.

The survey and practical testing for this project focuses on five main polymer types:

- High Density Polyethylene (HDPE)
- Polypropylene (PP)
- Polyethylene Terephthalate (PET)
- Tritan™
- Polybutylene Terephthalate (PBT)

A brief overview of each of these polymers' typical applications, characteristics and limitations for use in packaging are shown in the table below. Practical testing of these materials to provide insights on factors such as packaging durability (with and without RFID labelling) and methods of RFID tag application, staining and scratching were undertaken by the University of Sheffield as part of project TRACE and is available online in the Supplementary Technical Guidance to Reuseability by Design.

Polymer choice for reusable packaging is not limited to these five materials. These materials were chosen as they either fit the criteria of commonly used polymers within single-use packaging (Plastics Europe data) in the case of HDPE, PP and PET or have been proven to work in other reuse applications in the case of Tritan™ and PBT.

An overview of currently available reuse schemes for cup, bowl and tray formats suggests that the majority of them are manufactured from PP, followed by a small representation of PET, PBT, HDPE and Tritan™. Polymers such as polystyrene (PS), expanded polystyrene (EPS) and poly vinyl chloride (PVC) are the focus of a number of voluntary agreements (as outlined in the introduction) to be reduced in their applications for packaging, hence this report does not focus on these materials.

[13] Plastics - the Facts 2023 • Plastics Europe

Polymer	Typical packaging applications	Manufacturing processes commonly used	Characteristics	Limitations	Recyclable via current infrastructure
Polypropylene (PP)	Food and non-food pots, tubs, trays, pails etc.	Injection moulding Blow moulding Thermoforming	Rigid Opaque/transparent Good stability at high temperatures Excellent resistance to acids & alcohols Melting point 135-165 (dependant on homo or co polymer) Good resistance to environmental stress cracking	Sensitive to microbial attacks such as bacteria and mould Limited resistance to aromatic and halogenated hydrocarbons and oxidising agents Poor resistance to UV and scratches	Yes
Polyethylene Terephthalate (PET)	Food and non-food pots, tubs, trays, jars and bottles	Blow moulding Injection moulding Thermoforming	Strong and lightweight Good gas and moisture barrier properties Suitable for transparent applications Shatter resistant Excellent resistance to alcohols, oils, grease and diluted acids	Amorphous PET has low heat tolerance	Yes
Polybutylene Terephthalate (PBT)	Consumer goods	Injection moulding	Engineering plastic Excellent stain resistance High strength, toughness and stiffness Good durability under thermal stress and harsh chemical environments Good UV resistance Low moisture absorption	High mould shrinkage Poor resistance to hydrolysis (sensitive to hot water) Prone to warping due to high differential shrinkage	No

Polymer	Typical packaging applications	Manufacturing processes commonly used	Characteristics	Limitations	Recyclable via current infrastructure
Polyethylene (High Density) (HDPE)	Jerrycans, chemical drums, personal and healthcare bottles, milk bottles	Easy to process by most methods; used particularly for injection and blow moulding	Translucent/waxy appearance Weatherproof Good low temperature resistance Good chemical resistance High tensile strength Excellent moisture barrier properties Melting point 120-140 ˚C	Poor UV and low heat resistance Susceptible to stress cracking High mould shrinkage Poor resistance to hydrocarbons Lower stiffness than PP	Yes
Tritan™[14]	Water bottles, cosmetic packaging	Injection moulding Injection stretch blow moulding	Excellent stain resistance Impact and shatter resistant Transparent High chemical resistance Excellent resistance to washing	None found in literature search	No

(Sources of information: Interviews, Selection Guides: Polymers & Plastics (specialchem.com); Thermoplastics (bpf.co.uk))

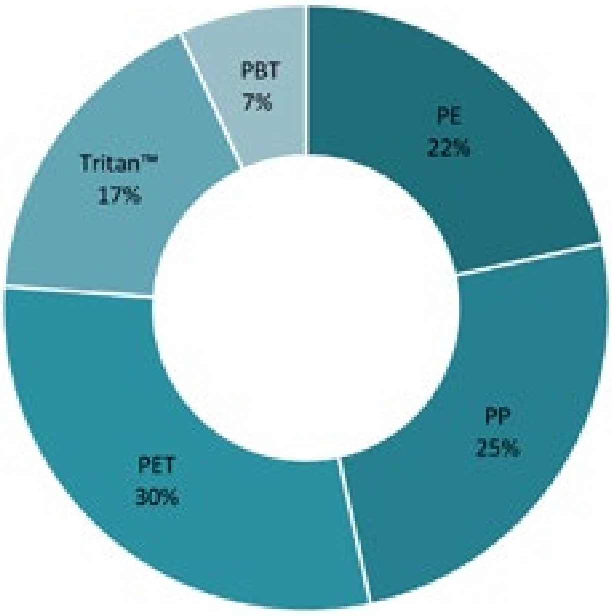
[14] Eastman Tritan Copolyester | Overview

Polymer suitability for reusable packaging

As mentioned in the previous section, five polymers were chosen to focus on for research and practical testing for reusable packaging applications.

Initial research into material choice through the industry survey asked participants to choose which polymers they believed are the most suitable for the application of reusable packaging. Survey participants were given the choice of the five polymers previously mentioned; PE, PP, PET, Tritan™ and PBT as well as an option to choose 'other' and specify the polymer type. Participants were permitted to pick as many polymer options as they deemed appropriate.

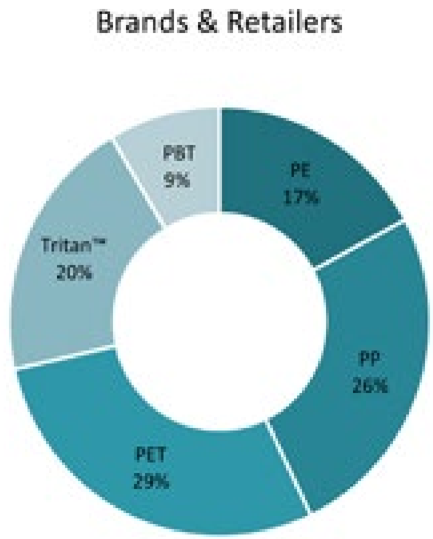
Results, shown below, for all participants of the survey showed a preference for PET, followed by PP and PE as material choices for reusable packaging. This is unsurprising as they are among the most well-known and available polymers, although Tritan™ and PBT, which are less commonly used polymers with lower availability for packaging were still deemed suitable choices by a number of survey participants.

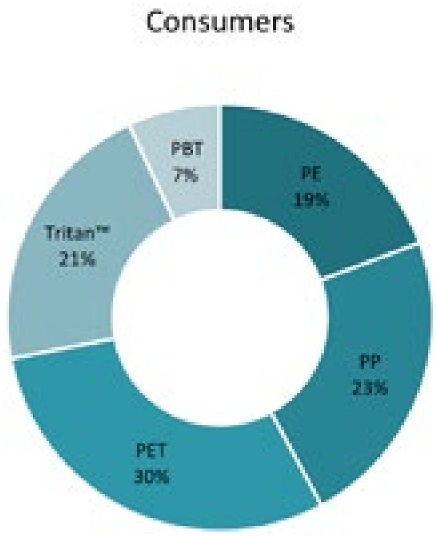


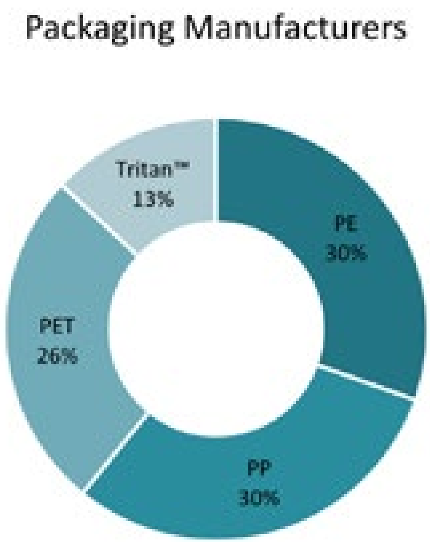
Survey responses for material choice for reusable packaging

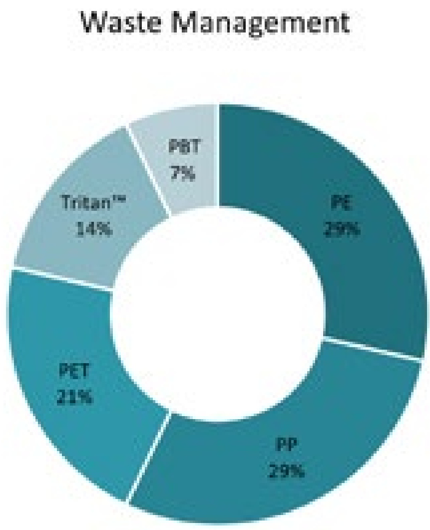
Some slight variations in polymer choice were seen when the results were looked at by how the participants defined the sector they represented. A similar trend can be seen across the sectors in that PET, PE and PP, although at varying percentages, are seen as the most applicable polymers for reusable packaging. Tritan™ was recognised by all sectors as being a suitable material for reusable packaging although at a lower percentage than the more commonly known polymers which could be a reflection of how recognised it is among stakeholders. While the results indicated that PBT was deemed as the least suitable polymer for reusable packaging applications, interestingly none of the packaging manufacturers chose this material as suitable for reusable packaging applications. The reasons for this are not entirely clear although throughout the research it was found that the use of PBT in packaging is scarce and the material itself can be hard to procure.

Survey results for the waste management sector were also noteworthy as they didn't correlate with what was heard in interviews about material choice. During interviews the message from waste management was that it didn't necessarily matter what material the packaging was made from (as they are not looking at it from a product protection viewpoint) but the end-of-life stance is to focus on economies of scale, the more there is demand for a material the more viable it becomes to collect and recycle it. The choice of polymer suitability is therefore dependent on market needs for this sector. PE, PP and PET have defined recycling routes and end markets, so it is no surprise that these are the top choices of the waste management sector. In contrast, Tritan™ and PBT do not have defined collection, sorting or recycling infrastructure in place and little to no demand for end markets.









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Discussions during workshops and interviews provided some further insights into the views on the different polymers:

Polymer	Positives	Limitations
PE	None mentioned	Very little gas barrier
PP	Reusable PP packaging can still be fairly 'light weight' Can be made in to clamshell format Good for hinges Can be made almost clear with clarifiers Heat resistant A good balance of durability and cost	Will stain from some foods No food grade mechanically recycled material available
PET	Can be produced as heavier weight container	Susceptible to surface scratching Susceptible to solvents Sensitive to heat deformation when washing
Tritan™	More durable than PET for clear applications and doesn't scratch as much	No recycling infrastructure Costly
PBT	None mentioned	Lack of availability

A key topic frequently mentioned throughout all streams of research was the recyclability of reusable packaging. While the intention is that reusable packaging remains in the reuse system for as long as possible and achives a high number of reuses, there will come a time that for any number of reasons the packaging will be unitnentionally or intentionally removed from the system. This may be due to a fault with the packaging, it no longer meets quality standards or the consumer disposes of it incorrectly.

At this point the reusable packaging becomes a waste stream and material choice has a direct impact on whether the packaging will be considered recyclable or not. Recyclability of reusable packaging was identified as one of the top design priorities in the survey, with 88% of respondents identifying it as extremely important. Throughout further research it was mentioned numerous times that reusable packaging should follow similar guidelines to single-use packaging by being manufactured from mono-material composition and with a commonly recyclable polymer.

In contrast to this the question of whether we could justify the usage of polymers that are not widely recyclable in established waste streams if they perform better and for longer was debated also. These topics are dicussed further in the end-of-life and environmental impact sections of this guidance.

Options for recycled plastic content[15]

The option to include recycled or renewable content within plastic packaging can be another way by which environmental impact can be reduced and also assists towards voluntary commitments and regulatory requirements.

There are restrictions on the use of recycled materials and how they can be used for different applications, especially when it comes to food-grade (or food contact) packaging. To meet food-grade standards, recycled and virgin plastics must meet certain criteria.

This creates an additional challenge when it comes to supply and demand, requiring certain levels of recycling and processing to ensure they meet the applicable legislative standards. As such, costs and availability are affected, and economics come into play as to how viable recycled content in food-grade is in comparison to virgin polymer, particularly when also considering the perceived differences in quality.

Furthermore, with the introduction of legislation such as HMRC's UK Plastic Packaging Tax, availability of this material is further impacted by non-food grade applications using food-grade standard material to meet the 30% threshold, leaving less material for food-grade applications, and thus increasing its cost further.

It is estimated that there are 102,000t of plastic reprocessing capacity to produce food-grade flake and pellet that can be used in food-grade plastic packaging, in the UK.

Food-grade considerations and outline estimates for each polymer are detailed in the table below.

[15] UK Plastic Packaging Sorting & Reprocessing Infrastructure, RECOUP

[16] Tritan Renew | Sustainability Without Compromise | Eastman

Polymer	Availability of food-grade recycled material
PE	• Mechanically recycled food-grade material available. • There is an estimated 32,000 tonnes capacity in the UK to manufacture food-grade HDPE plastic packaging.
PP	• No mechanically recycled food-grade material available. • The European Food Safety Authority (EFSA) requires 99% of the recycled feedstock to come from food contact products. This is not currently possible because of the mixed composition of food and non-food-grade PP packaging feedstock processed at both MRFs and PRFs. • Advanced recycling options are available for recycled PP although availability is currently limited as most production is at a pilot level scale.
PET	• Mechanically recycled food-grade material available. • There is an estimated 70,000 tonnes capacity in the UK to manufacture food-grade PET plastic packaging.
Tritan™	• No mechanical food-grade material available. • Advanced recycled options available for Tritan™[16]
PBT	• No information found in research

Durability and material choice design considerations summary

Durability - shatter proof, robust for supply chain, maintains quality over time.

Material choice needs to be based on the requirements of the product and supply chain.

Widely recyclable material - Preferable end-of-life route is recycling.

Recycled content can be used (dependant on polymer choice) to reduce environmental impact of packaging.

Packaging Format & Functions

We have all become accustomed to the variety of single-use plastic packaging shapes, formats and sizes adorned across supermarket shelves; pots, tubs, trays, bottles, pouches to name but a few. All available in a range of polymers, sizes and shapes with varying decoration techniques.

When it comes to reusable packaging what visual design changes are needed, if any, when it comes to considering packaging specifications?

Throughout the research there was a general consensus that reusable packaging needs to differentiate itself from single-use packaging through its appearance, if it looks too similar to single-use items consumers may confuse it as being disposable. However, there is a balance to be found, for systems that require the packaging to be returned for reuse as there is a risk that if the packaging is overengineered beyond its functional requirements then it not only increases cost to the supply chain and consumer but could also disincentivise return of packaging if it looks more 'luxury' and could be used for home storage needs.

> ***Reusable packaging can't be overengineered to look beautiful and lovely if there is a massive price tag on it.***
> ***Workshop attendee***

Alongside the size, shape and appearance of the packaging, it will also need to be designed to meet the requirements of product protection which can differ greatly between categories.

This section explores some of these requirements further.

Packaging size and shape

Differentiation through size and shape was an area of discussion throughout research, although the majority view was that reusable packaging should look like existing packaging formats for single-use albeit with some changes needed to properties for increased durability etc. Not only would this mean minimal change for consumers but would also be beneficial to the supply chain, particularly for any changes required to filling lines or logistic requirements.

> ***Any change might need to be done in stages with legacy shapes retained and any changes made through material or properties for reuse so it is not too big a change for the consumer.***
> ***Workshop attendee***

Shape is key for the washing stage of the lifecycle for reusable packaging, this is discussed in further detail later in the guidance. For example, containers with a narrow neck may inhibit the ability to clean the inside of the packaging, making the washing step less effective. Shape of the packaging neck, particularly in the design of reusable bottles or jars, must be a key consideration and aligned with washing processes within the system.

Product visibility

The survey asked how important it is that the product contained within the packaging, without defining whether this is a specific food or non-food product, is visible to the consumer i.e., in transparent packaging. Responses indicated this was considered important by just over half of respondents and was a topic with divided responses throughout the rest of the research.

It was found that the perceived need for transparency of the packaging was directly related to the product in question. Fruit and vegetables, alongside bakery products, were sectors that when explored, the need for consumers to be able to see the product when making purchases was deemed important. Where products are highly sensitive to damage and highly perishable, such as a products like berries, it was felt the consumer would need to have visibility in order to provide the confidence and trust of the quality of product being purchased. It was also felt that transparent packaging could provide additional benefits such as providing reassurance of washing processes and the cleanliness of packaging.

Opaque and coloured packaging became more of a preference for products that don't require consumer visibility, where packaging may be more vulnerable to factors such as staining due to containing products such as tomatoes, turmeric etc and also easier to incorporate recycled content into the packaging. The transparency or colour of the packaging also becomes a key factor at end-of-life.

Closures

A closure can be defined as a mechanism by which to close or seal packaging. Closures not only protect products but should also offer the consumer an easy-to-use function to dispense or access products.

Single-use packaging inherently has a single-use closure, although there is a case to say that a number of closures used for single-use packaging are multi-use, e.g. caps on bottles. When we think about the design of reusable packaging does the closure also need to be reusable or is there a place for single-use closures?

The survey asked, 'For the packaging to go through multiple use cycles, what packaging format do you find the most appropriate; packaging with a sealable closure (both reusable), one-piece system (closure attached to the packaging) or reusable packaging with a single use closure'.

The results found that 84% of respondents believed a reusable closure and packaging body to be the most appropriate solution for closures for reusable packaging with the majority of these responses indicating that the closure should be separate to the body of the packaging. 16% of respondents believed that the most appropriate solution would be a single-use closure on the reusable packaging.

From further discussions around this topic a number of challenges became clear:

- Closures (dependant on size and shape) can be difficult to clean or lead to water entrapment.
- Tamper evidence in single-use packaging is often linked to the closure (e.g., beverage bottle seals), how would this work with reusable closures?
- If the packaging body and closure are not attached, then tracking and tracing them through the supply chain as one pack could be limited if not returned together.

The type of closure is not just dependant on the packaging size and shape but also the product it contains and the requirements of the supply chain. A good example of this is the fruit and vegetable sector which predominantly currently uses heat sealed film lids on punnets, although previous to this used rigid plastic lids. The move was made for a number of reasons such as reducing the overall packaging weight in relation to the product requirements, easing transportation and automation of supply chains. While this is the best fit for the current supply chain there is no reason that this packaging type could not go back to rigid lids if the benefits were there.

Recommendations for closures for reusable packaging:

- If the closure is designed to be single use, then it is recommended that there is an established recycling stream for this item.
- Reusable closures will need to ensure that they are suitable for the washing phase.
- If closure is separate to packaging body and intended for reuse, a means by which to track and trace its use would be required in a large-scale system.

Tamper-evident packaging

Tamper-evident packaging is packaging that has indicators or barriers to opening, that if missing or damaged when the consumer comes to purchase or use the product could indicate that the product has been tampered with at some point in the supply chain. Examples of tamper evident packaging include shrink bands around lids and caps, button top security lids, tamper-evident tapes and labelling.

While there is no legislation that food or drink needs to be contained in tamper evident packaging, it is often expected by the consumer and ensures product protection and safety throughout the supply chain.

Reusable packaging designs will also need to include tamper evidence where it is required by products and expected by the consumer, although how this is implemented will need to be considered as part of the overall packaging design. Introducing tamper evidence as a reusable feature of the packaging is a challenge, tamper evidence by definition is only used once as once tampered with or the product used it becomes obsolete.

Tamper evidence needs to enable refilling with minimum effort.
Workshop attendee

While tamper evidence was an emotive issue when it did come up in research it was not mentioned a high number of times in comparison to other areas. In our research limited suggestions were made for the use of tamper evidence for reusable packaging. Potential options include:

- Incorporating tamper evidence into a single-use lid or in the case of some products a film seal lid
- Using a label/sticker as tamper evidence
- Using a shrink sleeve as tamper evidence

In the spirit of reusable packaging, ideally any functional requirement such as incorporating tamper evidence would also be reusable and not produce waste in every reuse cycle. However, it is acknowledged that without innovative design this could be a hard concept to achieve. If a single-use item is used for tamper evidence, then best practice would be to ensure that this is at least recyclable.

Packaging format and functions design considerations summary

Packaging should replicate existing formats, sizes and shapes but with increased durability.

Impact of shape and size on the supply chain is a key consideration e.g. filling, cleaning and logistics.

The consumer may want to be able to see some products within the packaging, for example to check for freshness.

Reusable closures with a reusable body is a preference although this needs to be suitable for the whole supply chain.

Tamper-evident packaging requirements need to be considered depending on product category.

Decoration & Branding

Packaging decoration

Decoration of packaging can be what makes it stand out on-shelf and is the means by which to communicate about the product to consumers. Decoration can be achieved in a number of ways from labelling, shrink sleeve to direct printing on the packaging. Decoration of packaging has a number of functions, to provide communications linked to:

- Product identification
- Product information e.g., ingredients, size, weight, instructions to use
- Promotion of products
- Any legal requirements
- Recycling information

In the survey, participants were asked to rate their priorities for visual components of the design of reusable packaging and 'brand information visibility e.g., labelling'. This was rated as either extremely or moderately important by 81% of respondents. This indicates that decoration is important as part of packaging design and closely linked to product branding (which is discussed further in the next section).

The main finding when decoration was mentioned was that the recommended way to achieve this for reuse systems would be to use temporary labels that remain securely on the packaging throughout its use but can be washed off or easily removed at certain points within the life cycle where a new label can be attached. By doing this the packaging is not restricted to one product or one brand and can be used for multiple different applications as long as safety standards are upheld. An example of a system where this is already applied is the German DRS system for water which uses standardised packaging with single-use labels that are applied each use cycle dependant on the product they are refilled with. This method would become particularly applicable if standardisation of packaging is utilised to upscale the adoption of reusable packaging.

It was also mentioned that as with closures and tamper evidence, any single-use items that are used in the reusable packaging system such as labels, should be recyclable once they reach the end of their use.

There was also a common theme that any kind of decoration should be minimal, which includes the use of labelling, in order to reduce any waste from the reuse system in line with its ambitions to reduce environmental impact. Alternatives were proposed such as the use of decoration techniques like washable inks and label-free packaging with branding achieved through methods such as packaging shape or embossing and information communication through technological methods e.g., QR or RFID.

Branding

Branding is defined as 'the activity of giving a particular name and image to goods and services so that people will be attracted to them and want to buy them.'[17] Branding is used as a marketing tool to create awareness and appeal for a product. Through branding companies aim to achieve brand value through customer loyalty and trust.

Branding for packaging is an important part of product marketing as it is the component of a product that the customer will first come in to contact with and is the means by which to communicate the product messaging. Branding options related to packaging design include colour of the packaging, decoration incorporating company font style and logo, and shape of packaging.

An example of where packaging design has supported branding in achieving its aim is the Coca-Cola bottle, the shape of this products packaging can be recognised globally, even without the brand name and colours communicated on the bottle. A 1949 study indicated that less than 1% of Americans could not identify a Coca-Cola bottle from just its shape, which indicates just how successful this branding was and still is[18].

The History of the Coca-Cola Contour Bottle [18]

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[17] Oxford English Dictionary

[18] The History of the Coca-Cola Contour Bottle - News & Articles (coca-colacompany.com)

When asked if reusable packaging could help to improve brand image, 91% of survey respondents either agreed or strongly agreed with this statement. 100% of respondents that identified themselves as either representing brands or retailers agreed or strongly agreed with this statement which shows the value of reusable packaging, if introduced correctly, could have on brand image and therefore brand value. In terms of brand visibility on packaging, 80% of respondents cited this as extremely or moderately important (87% for brand and retailer specific responses), which indicates again how valued branding is to packaging and marketing of products and therefore must be a key consideration for reusable packaging design.

From research, the strong message came across is that branding needs to become more agile and adapt to changing supply chains, particularly as we move towards increased reuse. It was suggested that to achieve this agility the following should be considered:

- Branding on one component of packaging with other elements standardised
- Minimalistic branding to allow for large efficient systems
- Utilise benefits of digital branding
- Branding still needs to remain obvious and durable but be replaceable/removeable e.g., use of temporary labelling

> *Branding is vital, but needs to be removable.*
> *Survey respondent*

It is clear to see the importance placed on branding of packaging, in some cases, such as the Coca-Cola bottle, the bottle is the brand. However, for reusable packaging, there will need to be incorporation of agility and innovative marketing methods adopted when it comes to branding if scalable reuse systems are to be achieved.

Decoration and branding design considerations summary

Temporary labels may be the best way to decorate reusable packaging which can be removed each cycle.

Decoration should be minimal.

Branding is important but needs to be more agile.

Innovative methods for branding should be explored.

Role of Standardisation

The subject of branding links directly to the topic of standardisation which is a highly discussed topic when it comes to the scaling up of reusable packaging. Standardisation of packaging would mean that the shape and sizes of packaging formats for various products would conform to a set standard and be used across the whole industry. For example, reusable packaging for beverages would only be sold in set sizes and bottle formats so that all products available on-shelf and online were sold in the same packaging independent of which brand or retailer they were sold by. This is already happening for some single-use packaging formats we see on shelves today, for example milk bottles and tinned goods which are a standard shape and size across different brands and retailers. Branding could be incorporated through temporary labelling or other methods discussed in the previous section. Standardisation would require collaboration not only between all stakeholders in the value chain but also amongst organisations within the same market sectors.

> ***We need to work with multiple stakeholders to develop reusable packaging systems that can be adopted as industry standards to ease implementation and the return/cleaning infrastructure.***
> ***Survey respondent***

There are a number of benefits to standardising reusable packaging design. Standardised packaging could:

- Increase cleaning efficiencies at scale of same packaging formats
- Reduce allergen and cross contamination risks if utilised by certain product sectors
- Return logistics – quicker return cycles and smaller pooling volumes
- Aid consumer adoption and building trust – same packaging/system across brands/retailers could increase number of reuses as its easier to navigate the standardised system
- Lower investment requirements for different packaging types and formats for different schemes
- Achieve an economy of scale – sufficient volumes needed to make large scale reusable packaging uptake financially feasible and scalable
- Reduce cost of packaging manufacture

While standardisation would remove some of the challenges related to the scaling up of reusable packaging and its associated systems there are some barriers to be overcome to achieve this.

As discussed in the previous section, branding is used to differentiate products and to build customer loyalty and trust in products. Standardisation would limit the possibilities when it comes to certain aspects of branding such as packaging shape. However, there are a number of other ways in which differentiation for branding purposes could still be achieved through packaging decoration (labelling, sleeving, direct print etc).

Other barriers to overcome to achieve standardisation include a lack of novelty for the consumer in using reuse systems if all product categories utilise the same packaging formats and designing packaging that meets the needs of a variety of products in terms of factors such as product protection, size requirements etc within the 'standard' range of formats. Not to mention the barrier of the co-ordination and collaboration that would be required by the whole supply chain in order to adopt standardisation.

One area in particular that could support the use of standardisation is the increase in online shopping which has a completely different user experience to in-store. Consumers purchase goods based on information held on a webpage which will include product specific information and is highly likely to incorporate imagery which will allow for marketing information and branding. Therefore, branding does not need to be achieved through the appearance of the packaging as the consumer will already have made their purchasing choice. With the rise in online shopping and deliveries this could be an opportunity for standardised reusable packaging to be implemented at scale.

Consumer Requirements

Much of the research and focus on reusable packaging has been on the consumer interactions and behaviours when adopting these systems. The question is how much of the uptake of or interaction with reusable packaging is influenced by packaging design?

The consumer perception of plastic was a concern raised throughout the research and how consumers would react to reusable plastic packaging. It is perceived that consumers do not value plastic as much as they do other materials and that this option would not be considered 'environmentally friendly'. However reusable formats of packaging such as refillable water bottles, lunch boxes and food container storage boxes such as Tupperware are already prolific in consumers lives albeit more for refill at home or refill on the go rather than return models. This suggests that consumer perception could be altered, for example with a consumer education and communications piece alongside the reuse system.

One of the perceptions from industry that came through in the research is that 'customers really enjoy seeing reusable formats on the market' and there is a 'novelty' and 'sense of delight' when encountering such systems. This suggests in the current market reuse is still considered a novelty although consumers do show keenness to adopt.

> ***Reusable packaging needs to go above and beyond single-use packaging, customer delight and functional elements combination is key.***
> ***Workshop attendee***

From an industry perspective one of the top challenges identified in the survey to the adoption of reusable packaging, cited by 79% of respondents, was difficulty to predict and maintain the customer uptake and reuse rate. This indicates the level of risk the industry can see in introducing these systems and the need for them to meet the needs of the customers in order to be successful and make an environmental impact while being economically viable.

There was a recognition in the survey that reusable packaging can help to attract new customer segments (72% either agreed or strongly agreed with this statement) and also meet existing customer demands (72% also either agreed or strongly agreed with this statement).

When responding to the survey, 35% of respondents chose their primary self-identification as 'consumers', rather than representing other areas of the supply chain (brand, retailer, waste management provider, packaging manufacturer, recycler/reprocessor, service provider or other). While we could all classify ourselves as consumers of packaging, the survey was shared predominantly by TRACE project partners and through the RECOUP network so these results could be seen as being more skewed towards an eco-conscious community rather than a broad perspective of consumer views.

Some of the key design considerations in relation to the consumer identified through the research could be broadly split in to two categories: packaging appearance and the consumer experience of using the packaging.

Packaging appearance	Packaging use experience
Appearance of being clean and new	Inclusive design e.g., opening suitable for elderly
Looks good to display at home	Similar or superior experience compared to single-use
Ergonomic design	Packaging nudges consumer to follow intended reuse route
Appearance similar to single use packaging formats	Consideration of consumer time when interacting with reusable packaging. Easy to use/empty
Visibility of some products, particularly fresh products e.g., fruit, vegetables, bakery	Easy to store and transport for return
No marks or discolouration	No extra cost, no extra effort – convenience is key
	Reassurance of pack cleanliness/hygiene

As part of project TRACE, the University of Sheffield carried out some research with consumers on the barriers to consumer uptake of reuse systems, digital reuse systems in particular. Although this research was not focussed on the design of the packaging within the reuse system, some findings of interest were observed in the responses. These findings are summarised below. Full article with research details and findings is available via open access - see reference.

Participants were presented with three different scenarios:

1. Returning reusable containers from home
2. Returning reusable containers in-store
3. Returning reusable containers on-the-go (i.e., if they bought a bottled drink when out and about).

After each scenario, participants were asked a number of questions about what would make it easy to use reusable containers in that context, what would make it difficult, what concerns they had and if they had any other comments to add.

All responses were open-ended, the main responses that linked to packaging design are detailed below. Specifically, participants suggested that reusable containers need to be:

- Easy to store – e.g., stackable
- Easy to differentiate from single-use containers e.g, a different colour
- Strong, sturdy and good quality
- Light weight for easy transportation
- Have good functionality – e.g, easy to open/close[19]

A Hubbub survey[19] of over 2000 consumers found that packaging not looking and/or being clean and hygienic, having to carry and return packaging to store and that packaging might be scratched or damaged as key factors that might put them off using a reusable packaging system. IGD consumer research[20] found similar patterns, barriers to uptake included hygiene, effort, home storage space and quality.

> ***Reusables must slot in easily to consumers lifestyle.***
> ***Survey respondent***

This is an area that will need ongoing work to really understand the detail of how design characteristics for reusable packaging can influence consumer uptake. What consumers say when asked about a topic compared to what they actually do in reality can be different things. That is not to say that barriers and concerns highlighted should be ignored when designing reusable packaging but that they may need further investigation to really understand how the consumer will interact with and accept the scale up of reusable packaging systems. Further academic work such as that carried out by Baird et al[21] which used computer based tasks to gain an understanding of how willing people are to use reusable packaging, particularly as it starts to show signs of use, could be utilised to assess how packaging design affects peoples willingness to reuse to gain a further understanding of consumer design needs.

Striking a balance

One of the key themes that came through in the research was how 'attractive' and 'novel' to make reusable packaging design in comparison to single-use packaging. There was a recognition that to some extent reusable packaging needs to have some differential characteristics to single-use packaging so as not to confuse consumers, although this could be as simple as increased durability, but there was also the recognition that for ease of adoption there should be a level of similarity for consumers to their experiences with single-use packaging for both the design of the packaging and how the consumer interacts with the reuse system.

For a reuse system where success is achieving a high return rate, where do you strike a balance between the attractiveness of the packaging to encourage uptake but for it not to be too attractive that the consumer does not return the packaging to the system and uses it for alternative purposes within the home. Consideration of a deposit or incentive scheme may be required alongside appropriate packaging design to ensure adequate return rates are achieved.

Of course, the concept of how attractive and novel the packaging is to the consumer will be directly related to the product that is being sold in the packaging and must be considered on a product specific basis. For example, when purchasing everyday groceries such as fruit and vegetables, packaging is not expected to be attractive, it expected to be functional. However, when purchasing premium goods or those that are targeted at gifting such as chocolates then the expectation on the design of packaging becomes greater. For reusable packaging this is something that will need to be considered on a product-by-product basis and links directly with numerous other design factors such as material choice, visual appearance and branding of packaging and of course packaging cost.

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[19] Understanding Consumer's Willingness to Engage with Digital Reuse Systems

[19] Reuse systems unpackaged, Hubbub

[20] How to help consumers adopt reusable packaging, IGD

[21] This has already been used!

Consumer interaction with technology as part of packaging design

When it comes to the inclusion of technology as part of reusable packaging design (e.g., QR, RFID, NFC etc) that is aimed to be used by the consumer, how this is incorporated into the packaging design is integral.

If the consumer is required to interact with the technology, for example to find out more about product information or as part of the return process for the packaging then it needs to be visible to the consumer or at least indicated on the packaging where the touchpoint with the technology is. If the technology needs to be visible but remain with the packaging, then design needs to incorporate tamper proofness. In some instances for single-use packaging, particularly where shrink sleeves are used, consumers are asked to remove labels before placing the packaging for recycling collection, it would therefore need to be clearly communicated to the consumer that technology incorporated in to a visible part of the packaging such as labels should not be removed at any point. If the consumer is not required to interact with any technology incorporated with the reusable packaging and this is more a requirement of the supply chain then research suggested it would be better to embed or hide this function from the consumer. If the technology needs to be visible but remain with the packaging, then design needs to incorporate tamper proofness.

There is still research required in relation to how consumers interact with technology to overcome some of the barriers and challenges to adoption of technology used in this capacity. Some of these barriers include consumer concern over what is being tracked and if this is linked to personal information and inclusivity for consumers that are not technology confident or able.

> *How can information accessible via tag be communicated to customers who don't want/cannot engage with technology?*
> *Workshop attendee*

To read more about the incorporation of technology in to the design of reusable packaging, particularly RFID, then more information can be found in traceability and tracking technologies section of this guidance.

A detailed overview of how tracking technologies are currently used in reuse models for food and drink and how consumers interact with them, completed by the University of Sheffield, can be found in the Appendix.

Consumer requirements design considerations summary

Familiar and recognisable design for everyday products but still distinguishable from single-use.

Novel designs can be explored for premium/innovative segments.

Packaging weight not considerably higher than single-use packaging.

Design for ease of storage at home before return e.g., stackable, nestable when empty.

If technology is included as part of the packaging design, then if and how the consumer needs to interact with this needs to form part of the design process.

Material/packaging colour/visibility of product to be considered at design stage to ensure a positive impact on consumer confidence around cleanliness and hygiene of used packaging.

Food Safety

Cleaning and preparation for reuse is the distinctive step that differentiates reusable packaging system from single-use. There is no surprise that design requirements and concerns associated with hygiene and food safety issues are a top priority and were one of the most mentioned categories by survey and workshop respondents. 30% of survey respondents considered compliance with Health and Safety Regulations as a challenge to the adoption of reusable packaging.

Being able to provide a hygiene guarantee to users that packaging has been cleaned to sufficient standards and ensuring that the packaging is durable enough to withstand processes such as washing rated extremely highly in the survey as important design considerations.

Design consideration	Identified by survey respondents as important
Hygiene guarantee (customer can check that container was cleaned in accordance with regulations)	90%
Durability (packaging can withstand multiple use cycles without losing its properties)	95%

Research on consumer behaviour also shows that hygiene is one of the top concerns for the consumer (38% of respondents recognising hygiene as a concern) and it is suggested that robust washing procedures and good communication can be used to mitigate this concern.[22]

*"**Food safety** is the strategies and activities aimed to protect foods from biological, chemical, physical, and allergenic hazards that may occur during all stages of production, distribution, and consumption"*[23]

*"**Food hygiene** refers particularly to the practices that prevent microbial contamination of food at all points along the chain from farm to table."*[24]

*"**Cleanliness** is the state of being clean, or the act of keeping things clean"*[25]

Food safety is a regulated area and reusable packaging is required to meet the relevant standards and pass certification where applicable. The role of design is to ensure that technical characteristics match the requirements of the food hygiene practice. Reusable packaging cannot permit chemical migration, causing a taste, flavour or composition change. Microbiological, physical contamination and physical hazards also need to be minimised via design when possible.

This section will look at some of the important points for food safety and hygiene and consider how design decisions can help to optimise reusable packaging functionality during these processes. For a comprehensive review of safety guidelines for reusable packaging please refer to the document by World Economic Forum, Consumers beyond Waste Safety Guidelines for Reuse.[26]

Food contact material requirements

Polymer choice for food contact application:
Apart from the physical and mechanical suitability of the polymer for the reuse application, if the reuse system is aimed for food or beverage products, the material must comply with food contact legislation.

*"**Food Contact Materials (FCMs)** are materials and articles that come into contact with food during its production, processing, storage, preparation or serving."*[27]

Primary food contact material legislation for GB is listed below:

- Retained Regulation (EC) No 1935/2004[28], as amended applies to all materials in contact with food.
- Retained Regulation (EU) No 10/2011[29], as amended, sometimes known as the PIM (Plastics Implementation Measure). Only applies to plastic
- Retained Regulation (EC) No 2023/2006[30], as amended Good Manufacturing Practice applies to all materials in contact with food

[22] https://www.hubbub.org.uk/reuse-systems-unpacked
[23] https://www.researchgate.net/profile/Fahmi-Abu-Al-Rub/publication/342182975_Food_Safety_Hazards/links/5ee7b57992851ce9e7e3f342/Food-Safety-Hazards.pdf#page=13
[24] https://www.open.edu/openlearncreate/mod/oucontent/view.php?id=193&printable=1
[25] https://dictionary.cambridge.org/dictionary/english/cleanliness
[26] https://weforum.ent.box.com/s/6f5192886e94cq5bluk68ltm8shjgwkn
[27] https://www.food.gov.uk/business-guidance/regulated-products/food-contact-materials-guidance
[28] https://www.legislation.gov.uk/eur/2004/1935/contents
[29] https://www.legislation.gov.uk/eur/2011/10/annex/I
[30] https://www.legislation.gov.uk/eur/2006/2023/adopted

If packaging is equipped with tracing technology such as RFID tags, there might be a need to refer to the specific guidance from the Food Standards Agency on food contact materials authorisation.[31]

There are 332 monomers approved for food contact application by Retained Regulation (EU) No 10/2011. While this demonstrates a wide variety of possible material solutions for reusable packaging, and creates an opportunity for innovation, novel materials may need to be authorised and also carefully considered in terms of their suitability for other parts of the supply chain to ensure that benefits of less common polymers overcome challenges such as the lack of availability of recycling at the end-of-life. Widely used and time-tested materials such as PET, PP, PE often provide sufficient material characteristics for the application.

Recycled content

Retained regulation (EC) No 282/2008 on recycled plastics[32] is applicable to the food contact material with recycled content in Great Britain according to Food Standards Agency.

The EU version of this Regulation was recently repealed and is no longer in force in EU Member States. It was replaced by Commission Regulation (EU) 2022/1616[33] on recycled plastic materials and articles intended to come into contact with foods which entered into force on 10th October 2022.

More information regarding European requirements can be found on the EC food safety website.[34]

Labelling and printing

Labels and printed media often play a crucial role in providing information such as batch traceability, best before dates and allergen information across the supply chain and to consumers, therefore their suitability for reusable applications must be considered alongside food safety and discussed with relevant stakeholders, such as label suppliers.

There are generally two ways to approach labelling reusable packaging:

1. Permanent label that will only be removed at the end-of-life after a certain number of reuse cycles have been achieved and packaging is no longer useful
2. Temporary single-use label that is removed after each reuse cycle and replaced

For both applications it is necessary to work closely with label, ink and adhesive suppliers to make sure that all components are safe for food contact and don't present any risks to human health in reuse applications.

For the permanent label scenario, it is necessary to test that all labelling materials can withstand washing conditions without losing its properties and without leaching any of the components over time; meet packing and storage conditions (sterilisation procedure, chilled/ frozen); are durable during transportation and explore how they can be removed for recycling at the end-of-life or their potential impact on recycling processes.
The suitable labelling solutions will depend on factors such as type of product, type of reusable packaging system, washing procedure and end-of-life scenario.

Some industry guidance such as The European Printing Ink Association's (EuPIA) 'Guideline on Printing Inks applied to Food Contact Materials'[35] can assist on the initial steps of packaging design.

Packaging surface adapted to the function: durable, no water entrapment, easy to reapply label, not easily stained, or option to being reskinned. Workshop attendee.

Polymer composition and properties suitable for multiple uses and compatible with the product

When making a design decision about reusable packaging, it is crucial not to look at the packaging in isolation but apply a systemic approach and consider product, packaging, processes and the environment as part of the system to assure quality and safety.

Different materials will have different advantages for different products, storage and washing conditions and will behave differently in multiple use cycles. When making a choice about polymers, additives and material properties it is important to address the specifics of multiple uses with polymer formulation scientists and packaging technologists.

- **Surface**
  The surface of the reusable packaging has more complex requirements than single-use packaging and suitable finish and colour solutions must be chosen to meet the demands of the application. Will the surface be exposed to excessive scratching during use (for example packaging used for hard, dry goods or designed for the consumption of food with cutlery)? Could interaction with salts and water during cleaning cause break down of the material, pitting the surface and creating area which can potentially harbour microorganisms?If yes, how this can be mitigated?

31 Food contact materials authorisation guidance | Food Standards Agency
32 https://www.legislation.gov.uk/eur/2008/282
33 Commission Regulation (EU) 2022/1616
34 https://food.ec.europa.eu/safety/chemical-safety/food-contact-materials/plastic-recycling_en
35 https://www.eupia.org/wp-content/uploads/2022/09/2020-12-22_EuPIA_Guideline_on_Printing_Inks_applied_to_Food_Contact_Materials.pdf

- **Staining and taint**
  Staining and taint are the complex issues that might severely affect the acceptance of reusable packaging by the consumer and retail. Is the product likely to stain (curry, tomato, coffee) or taint the surface? Is the container likely to be heated in a microwave (this can have a major impact on the intensity of the stain)? Could cleaning solution taint the material? If yes, how can this be mitigated? For example, would material like Tritan™, that is less susceptible to staining be more suitable for this application?

- **Migration of the plastic components**
  Reuse cycles will expose reusable packaging to mechanical interactions, higher temperatures, moist environments, temperature changes, prolonged exposure to UV lights, and also lengthier interactions with product and servicing chemicals (cleaning liquids, adhesive compounds) compared to single- use packaging. Polymer and packaging specialists will be able to help and assess suitability of formulations for the specific reuse applications to make sure only components with required stability are used. This discussion must take place at the very early design stage.

Quality standards in the industry

BRC Global Standard for Packaging Materials[36] is widely used in food industry to guarantee the safety and the quality of the packaging.

"British Retail Consortium is a membership-based organisation representing over 200 major retailers. BRC (British Retail Consortium) Global is an independent food safety accreditation. Supermarkets and large organisations recognise it as proof that high food safety standards are in place and that a food company is safe to supply."

The Standard provides a framework specifying:

- Product safety
- Quality
- Operational criteria necessary to protect the consumer and fulfil the legal requirements

Reusable packaging will have to go through the procedures set up by the standard multiple times. If the packaging is intended to be implemented within the framework of this standard, then it is necessary to revise the controls in place and make sure that design doesn't create barriers to performing these procedures efficiently.

Other standards often used are FSSC 22000[37] (Food Safety System Certification) and IFS[38] (International Featured Standards). Cleaning procedures and equipment related to packaging are described in these standards.

Mitigation of food safety hazard risks via design

*"A **food safety hazard** is an agent or condition that could potentially cause an adverse human health effect."[39]*

Different life cycle stages will present different levels of hazards risks, which will have to be managed by relevant tools such as Hazard Analysis and Critical Control Point (HACCP) plans.[40]

1. **Consumer use.** Risks due to unintended or intended misuse of the container. This is the stage with highest uncertainty.
2. **Collection and transportation.** Risks due to exposure to contaminated packaging, careless handling, unsuitable transportation conditions. HACCP plan in place can help to manage these risks.
3. **Supply chain**. Risks due to exposure to food safety hazards, unsuitable handling, and storage conditions etc. HACCP plan in place can help to manage these risks.

> ***I wouldn't consider reuse to be higher risk; if the business followed a suitable Hazard Analysis and Critical Control Point plan end to end. But it would be a flag to have a closer look.***
> ***(Health and Safety body, H1)(Ellsworth-Krebs et al., 2022)***

There are three main food safety hazards that must be considered throughout the reusable packaging lifecycle. Understandably, these hazards cannot be eliminated solely by design however it is important to consider them as minimising them is a substantial part of a successful reuse system.

1. **Physical contamination**
   The particles of product, dirt, elements of broken packaging and other materials remaining on the packaging after use and during processing present the risk of physical contamination.

   Design mitigation: surface finish that repels dirt and avoids design elements that can trap and accumulate physical contamination.

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[36] https://www.brcgs.com/store/global-standard-packaging-materials-issue-6/p-723/
[37] https://www.fssc.com/schemes/fssc-22000/
[38] https://www.ifs-certification.com/index.php/en/standards/4128-ifs-food-standard-en
[39] https://www.sciencedirect.com/science/article/pii/B9780124200845000019
[40] https://www.food.gov.uk/business-guidance/hazard-analysis-and-critical-control-point-haccp

2. **Chemical contamination**
Chemical cross-contamination is one of the major concerns raised in relation to the consumer use stage of reusable packaging. In the current reuse systems, there are specific equipment such as electronic nose/sniffer used to test for a variety of substances such as:

    - Petrochemicals
    - Urine, biological liquids
    - Additives, UV stabilizers and antioxidants degradation products, oligomers
    - Flavour, aroma and odour compounds

    While this equipment can identify most typical contaminants there is still a challenge to detect novel or non-typical contamination.

    Design mitigation: standardised packaging for different product categories. Design can stimulate the consumer to use certain formats for certain product applications only. For example, the commonly used format of the typical milk bottle is widely recognised for single-use packaging and if used in a reuse system would likely communicate to the consumer the intended reuse for milk products. It is therefore important to avoid unnecessary experiments with the shapes and formats for certain products to maximise cross industry standardisation.

3. **Microbiological contamination**
Tests that are performed on reusable packaging before being released to the next reuse cycle will vary depending on the packaging format, product type and cleaning system in place. There are currently no standardised tests requirements. Some of the common tests for microbiological contamination might include testing for:

    - TVC (total viable count), Enterococcus
    - Yeast/Mould
    - Salmonella
    - ATP (adenosine triphosphate)

    Design mitigation: The risk of microbiological contamination can be reduced by minimising areas where potential growing mediums can be accumulated. Making sure reusable packaging is designed with minimal surface elements and in shapes that aid emptying and drying can help to mitigate microbiological risks.

The main contamination risk for reusable packaging is unknown substances introduced during the use and logistics stages. It is relatively easy to have controls in place when it is known what contaminants to test for, testing for unknown contaminants is very complicated.

Allergens

Allergens are one of the serious risk factors for reusable packaging contamination. Allergen management is a complicated process and there are no reuse specific requirements or rules.

First of all, thorough cleaning procedures have to be in place. Allergens can only be physically removed by cleaning, and cannot be managed by thermal, high-pressure processing or other means. Risk of cross contamination during cleaning process also needs to be minimised. Specialist companies can help with validation: developing washing procedures to make sure that potential contaminants such as microbial/allergens are removed. By complying with these protocols packaging providers can make sure that they have the right measures in place.

Secondly, standardisation can play a role in risk reduction. When the same packaging is used for different types of products, especially if they contain allergens, they could potentially cross-contaminate each other. If packaging is standardised for a particular type of product, for example, only bottles of certain shape and colour are used for dairy products, this could minimise cross-contamination risks in the reuse system. Tracing technology can also provide additional guarantees along the supply chain, which can be close to ‘batch traceability’ of single-use packaging.

And thirdly, reusable packaging has to be labelled clearly and according to legal requirements applicable depending on application. For example, guidance on allergen labelling for prepacked food for direct sale (The Food Information Regulations (2014)[41], Prepacked for direct sale amendment[42]) advices on relevant labelling for prefilled reusable packaging. According to these requirements the name of the food and an ingridients list including allergenic ingridients must be on the packaging or attached to the packaging of prepacked for direct sale food. At the same time, there is a movement away from excessive use of precautionary allergen labels, for allergens that are unintentionally present due to contamination by application of scientifically proven allergen threshold limits, so relevant food safety guidance needs to be monitored and approved innovative control processes can be explored. Allergen labelling requirements will differ depending on reuse scenario, and could be less strict for non-prepacked food.

While allergen risks cannot be managed solely by packaging design it can be useful to consider these requirements.

[41] https://www.food.gov.uk/business-guidance/allergen-labelling-for-food-manufacturers
[42] https://www.food.gov.uk/business-guidance/introduction-to-allergen-labelling-changes-ppds

Checklist for consideration of food safety concerns

Food safety concern	Design
Food contact	Materials from Retained Regulation (EC) No 1935/2004 list, following GMP Retained Regulation (EC) No 2023/2006
Recycled content	Following EC282/2008 regulations
Surface Staining	Product/Material compatibility
Surface scratching, microplastic	Product/Material compatibility
Allergen risk	Traceability Cleaning protocols validated using appropriate allergen test Standardisation of packaging types for particular product application Electronic nose/sniffer validation
Chemical contamination	Migration analysis Product formulation (e.g., avoiding additives not suitable for reuse)
Microbiological hazards	Clean surfaces and lines, no lips, ridges, holes – no "bug traps"
Cleanliness, hygiene	Compatibility with temperatures, detergents and pressures required for washing Closures and formats that ease cleaning and cleaning control e.g., wide neck, clear bottle.
Cross-contamination	Standardisation across product lines, product -material compatibility Design that encourages reuse for the same application (same food category) via shape, labelling etc.
Labels and adhesives	Option 1: Labels/adhesives/ inks that are easily removed before washing Option 2: permanently attached labels and adhesives, food contact approved and safe in terms of leaving residue on the packaging surface.
Shelf life	Chilled/heated – can withstand needed storage conditions Suitable sealing and gas barrier properties

Cleaning & Preparation for Reuse

Cleaning and preparation for reuse is one of the significant differences between single-use and reusable packaging. Stages of the cleaning process might include:

- Collection and sorting of the packaging
- Visual contamination and damage checks, decommissioning of no longer suitable or contaminated items
- Removing labels/decoration if single-use measures have been adopted for these
- Washing according to the relevant protocol
- Drying
- Quality assurance. Checking for residual contamination and hygiene/microbiological tests
- Preparation for reuse (palletising etc.)

Washing procedure and requirements

While there are standard requirements for the cleanliness of packaging before it is filled/packed with product, washing methods and protocols to achieve the necessary state will vary depending on the following:

1. Type and characteristic of the product, e.g., oily substances and loose fruit have different washing and sanitising requirements
2. Material of the container - temperature range and detergent concentration will need to be adjusted according to material properties
3. Washing facilities
4. Reuse system type and contamination risks - traceable packaging in a closed-loop system might require less stringent protocols than a return or refill system where part of the packaging journey is happening in the consumer's home

To make sure that the cleaning and washing protocol is adequate to the potential risk it has to undergo the validation process that is offered by specialised agencies.

The information box on the right provides an overview of the washing conditions to indicate what reusable packaging needs to be compatible with. Some standard washing protocols, for example, for used tableware in catering, can be used as guidance; it is recommended to ensure that these processes are adequate for the product-container system and contamination risk.

From a hygiene point of view, dishwashers provide more reliable protection from pathogens. Handwashing can also be appropriate, providing the suitable systems are in use.

Environmental impact and costs must be considered while designing packaging with a particular washing method. For example, even though handwashing can seem to be the gentlest method for the container itself, its environmental and labour costs can make a whole reuse system inefficient.

Domestic dishwashers:
30-60˚C , wash cycle 30-90 minutes
Detergents suitable for domestic dish-washers

Industrial dishwashers:
Wash cycle for 3 to 5 minutes.
Temperatures over 80˚C
Aggressive (highly alkaline) detergents at higher concentrations, specialist rinsing agents to rinse off and dry washed items
Higher water pressures

Handwashing:
Temperature less than 60˚C , household dishwashing liquid

> *The domestic and commercial dishwasher results, as in the Return and Refill cases, show that the commercial dishwasher has a lower energy and water use per wash. Handwashing is likely to increase greenhouse gas emissions and water consumption relative to using a dishwasher, though since there is wide variation in the energy and water use of this process this result should be treated as indicative.*
> *(Greenwood et al., 2021)*

Typical washing requirements - temperature, detergent, time		
Typical temperature range for washing reusable packaging: A stadard temeperature for the wash cycle is ranging from 49 to 60 ˚C. Maximum temperature between 82-88˚C (ususally for the rinse cycle) is determined by the stability of alkaline detergent. Minimum temperature required for pathogen control is 70˚C.	**The detergent used in industrial washing:** Commercial strength alkaline detergent is usually used. The main ingredient is sodium hydroxide (caustic soda), pH14.	**Typical stages of washing process:** Wash - detergent Rinse - rinse aid Disinfect - disinfectant Dry - additional drying step is vital for plastic packaging due to low heat retention and surface properties.

Sample sterilisation protocol for PET refillable bottles used by the Cooperative of the German Mineral Water companies (GDB):

- 1.5 to 2 per cent caustic soda
- Heated to 60 °C
- Submerged for 10 mins[43]

During washing procedures packaging will interact with high pressure cleaning jets and should be designed to withstand that. Items that are lightweight might need to be provided with additional equipment e.g. bespoke racks, baskets, trays or basket accessories to make sure they stay in place during washing processes and are cleaned effectively.

Packaging also has to fit in the dishwashing trays effectively, and in the secondary packaging in which it is being delivered to the washing facility. Secondary packaging must be designed to protect logistic crew and vehicles from potential contamination prior to washing.

A systemic design approach will maximise automation during cleaning helping to reduce cost.

Working in collaboration with washing providers to design the packaging system so that it can run smoothly, efficiently, and economically through the washing process is key.

> *Sturdy packaging that does not break or crush in system cleaning jets.*
> *Workshop attendee*

Design considerations for washing process:

- No lips, ridges, holes or ‘bug traps’
- Avoid uneven surfaces and unnecessary asymmetric parts
- Internal parts easy to clean - round, open shapes
- Seals, labels and inks easy to remove or can withstand multiple washing cycles
- Minimise and rethink the types of adhesives used
- Clear containers can aid cleanliness monitoring and contamination detection for some products, e.g., beverage bottles. For tray format, there is no strong preference as the coloured surface can help to mask stains while not creating additional obstacles for visual product evaluation by consumers (can be done via top) or clean check before reuse
- Safe for multiple uses
- Standardised packaging formats for efficient washing processes
- Looks clean for the customer, with inbuilt cleaning indicators if possible

[43] https://petcore-europe.org/news-events/438-pet-%E2%80%93-from-recycling-champion-to-recycling-and-reuse-champion-state-of-

Cleaning, hygiene, food safety design considerations summary

To ensure adequate design for the reuse system in consideration of food safety and hygiene, reusable packaging should be designed so it:

Can withstand required wash and rinse temperatures

Can withstand multiple detergent contact

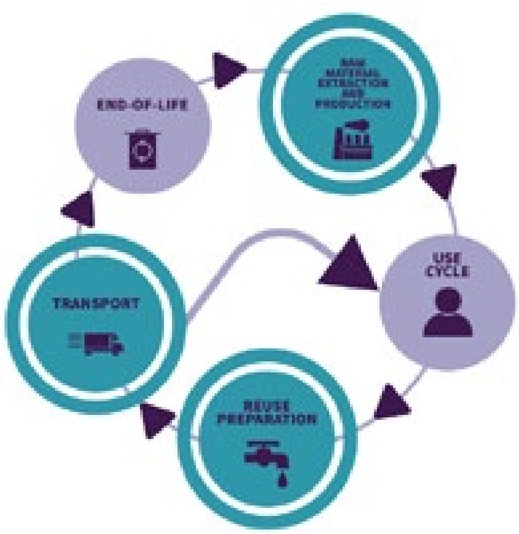
Is suitable for interaction with cleaning equipment: consider - standardised, allocation in the cleaning tray, robust/heavy enough to stay in place under cleaning jet -high pressure, wide, easy-to-clean closure area

It is suitable for interaction with intended product multiple times

Avoids the following deign characteristics: lips, ridges, holes, and anything where contaminants/ moisture can accumulate

Transport & Logistics

79% of survey respondents identified logistics characteristics as an important design consideration, highlighting this area as a central component of the reuse system. Reverse logistics is one of the main differences between single-use and reuse and often the most challenging element of the system, having a significant impact on efficiency, environmental impact, and costs. While transportation challenges often need to be mitigated on the reuse system level via optimising transport distances, creating a network of the collection and servicing points, choice of transport mode (e.g. cyclo-logistic, electric vehicles) and fuel and brand collaboration, there are packaging design features that can help to inrease the efficiencies of the system in particular packaging weight and volume, material used, formats with inbuilt nestability/collapsible and standardised.[44]



Transport is one of the environmental hotspots of a reuse system

To achieve optimal design for transportation and logistics it is important to find a balance between two main requirements of the packaging at this life cycle stage. Firstly, packaging has to fulfil its main purpose – to provide product protection and guarantee safe delivery of food items. Main design consideration relevant to this purpose are listed in the right column of the table below.

> ***Packaging and collection point integration. Co-design of crates and cups make logistics easier.***
> ***Workshop attendee***

Secondly, high economic and environmental costs of logistics and transportation in reusable packaging dictate the need to have design mitigation in place for these, which is reflected in the left column of the table below.

Design decisions about packaging format, material, size, shape, and durability needs to be discussed with the logistic and transportation partners at early stages to understand the specifics of particular transportation systems and product requirements. For example, for stackable/squared shape bottles, cleaning of the squared shapes and shapes with corners is harder as is the manufacturing process. However, would logistic benefits outweigh the difficulties with manufacturing and cleaning for the product and system packaging is designed for? This would have to be considered on a case-by-case basis.

[44] https://zerowasteeurope.eu/library/reusable-vs-single-use-packaging-a-review-of-environmental-impact/

Environmental impact and costs	Product protection and safety
Lightweight, material efficient	Durable to withstand movement and handling: consider impact, puncture, surface friction with product
Protect product from damage and losses	Protect product damage and losses -cushioning, protective structures
Stackable/foldable/nestable	Stackable
No closures if possible	Durable closures that won't open easily
Shape: optimised for maximum cube utilisation, avoid shipping air, 'square bottles'	Shape: optimised for the product properties
Optimised for storage when empty	
Optimised for display	
Standardised, integrated with secondary, tertiary packaging and servicing equipment such as washing trays	Optimised for the product
Automation and technology utilisation for increased efficiency	Automation and technology utilisation for traceability and contamination prevention
Labelling minimised, digitalised, automated	Marked with any necessary information, such as the contents of the package, the destination, and the handling instruction

Transport and logistics design considerations summary

Nestable, stackable, foldable.

Integrated system of primary, secondary and tertiary packaging.

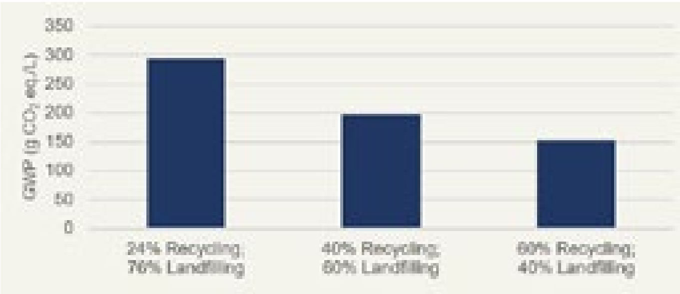
Integrated design of the return point and packaging (e.g. return bin).

Lightweight.

End-of-life

Although reusable packaging is intended to stay in circulation for as long as possible, at some point the packaging will leak from the system for any number of reasons such as the consumer not returning it or the packaging no longer meeting the quality requirements of the system. To become a truly circular solution the material has to be captured at the end-of-life and recycled for further use.

According to the Zero Waste Europe Reusable Packaging LCA[45], the end-of-life scenario affects the environmental performance of the reusable system.



GWP of 0,5L PET bottles considering different end-of-life scenarios. Source: ZWE -Reloop Report

The survey and workshops highlighted the importance of end-of-life: terms such as end-of-life, recyclability and recycled content were the most mentioned among all design priorities.

Recyclability was identified as a top design priority in the survey, with a strong agreement across all the supply chain players.

	Extremely Important
Recyclability after it can no longer be reused	**88%**
Durability (packaging can withstand multiple use cycles without losing its properties)	81%
Hygiene guarantee (customer can check that container was cleaned in accordance with regulations)	71%
Brand information visibility, e.g., labelling	46%
Improved product protection (e.g., damage, shelf-life)	44%
Logistics (cube utilisation, stackability)	56%
Compatibility with current manufacturing systems	50%
Traceability provided via RFID tag/app	42%
Product is visible (transparent packaging)	22%
Packaging appearance e.g., more luxurious / modern compared to single-use	17%

While recyclability is not a top contributor to reusable packaging environmental impact (production and service use have the major impact), and also does not affect the cost and performance of the system as such, there are several factors why recyclability is so high on the priority list.

One of the main drivers for the retailers to move to reusable packaging is waste and material use reduction. And while every cycle of reusable packaging serves this purpose, it can still become waste or litter at the end of its reuse life. The return rate is often unpredictable especially at the early stages of reuse systems as customers can dispose of reusable packaging out of habit or unintentionally and therefore packaging can be redirected to the waste management stream before it has reached the end of its actual service life. Providing customers with packaging that can be recycled via familiar routes is a recommended strategic decision for this scenario. Inbuilt recyclability also makes sense from a systemic change point of view: when reusable packaging will be available at scale (e.g. with favourable policy and economic climate), the amount of reusable items will unavoidably increase in the waste stream and it is important that they are designed for the current waste management system from the beginning.

Reusable packaging can enter into the waste management system either via a service provider e.g., disposed of during reuse preparation as no longer suitable for reuse or via the consumer placing the packaging for kerbside collection.

The service provider disposal route can present higher value material as it is sorted, has relatively low risk of cross contamination and is ready to be reprocessed compared to the packaging going through the household recycling stream with other materials. Closed – loop collection helps to mitigate some of the cross-contamination challenges of co-mingled waste management: with no segregation of food contact material and non-food grade materials, there is a risk for the plastics to absorb the potential contaminants during transportation and sorting, limiting its further use in food applications.[46]

Designing packaging for closed loop recycling only, comes with number of limitations starting from capturing containers at the end-of-life for recycling via specialised systems, storing until the required number are collected for efficient reprocessing, and having a stable supply of material - all adding another limiting factor to scaling up. This scenario relies on a high return rate and consumer

[45] https://zerowasteeurope.eu/wp-content/uploads/2020/12/zwe_reloop_report_reusable-vs-single-use-packaging-a-review-of-environmental-impact_en.pdf.pdf_v2.pdf

[46] https://www.sciencedirect.com/science/article/pii/

participation, which cannot always be guaranteed. If the reusable packaging is not captured by the system, it should still be designed to be suitable for the kerbside collection, sorting and recycling processes.

To be processed as a separate waste stream, via current systems, reusable packaging would require sufficient volumes and be easily recognisable otherwise it is not commercially viable for the waste management companies to invest into additional infrastructure requirements. New technologies such as artificial intelligence (AI) enabled sorting can offer new opportunities for separating reusable packaging as a material stream and increase chances of recycling for food grade applications.

Potential recyclability challenges for the reusable packaging

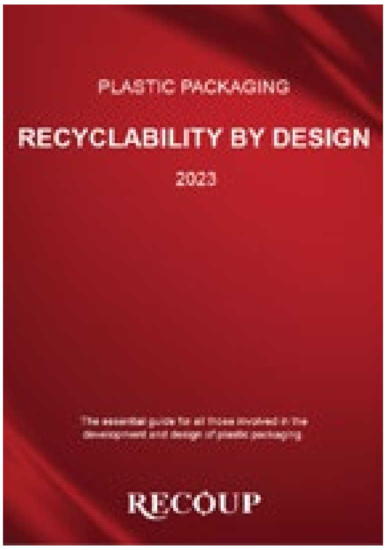
1) **Weight.** Slight increase in durability and wall thickness won't affect the recyclability and sortability of the items via existing MRF facilities, however items with significantly increased durability might not be captured with the same efficiency, be too heavy for air -jets, and create difficulties if prepared for reprocessing together with single-use items even of the same polymer. For example, Terracycle offers a separate collection and processing of reusable drink bottles and food storage containers.[47]
2) **Wear.** Reasonable levels of wear won't affect the recyclability of the packaging. It will also still be suitable for identification with NIR equipment, used for polymer sorting. Some polymer properties can be affected by multiple wash cycles, e.g. hydrophobicity of PP[48], but there should not be any significant changes that affect recyclability.
3) **Staining**. More contaminated products are at risk of being missed by optical sorting and ending up in the residual line. This will depend on the level and location of stains and will require further testing for a more concrete understanding.
4) **Recyclability of technological assets**. Please see RFID section.

Priorities for recyclability

1) Use of mono-material or mixed material of the same type is preferable.
2) If mixed material is used, it is important to make sure they can be easily separated.
3) Use of currently widely recyclable polymer with proven end markets.
4) Use of unpigmented polymers as these have the highest recycling value, and the widest variety of end uses.
5) Additional requirements can be applicable if reusable packaging is intended for recycling for food contact applications. This can include elements of traceability, use of the correct quality processes, and choosing the formulation (e.g., additives) that is compatible with food-grade recycling processes.

> *Food grade flake required at the end-of-life.*
> *Survey respondent*

Comprehensive information about recyclability requirements for different polymers and packaging formats, covering areas such as barriers, coating, colours, additives, closures, decoration (sleeves, labels and inks) and a variety of other topics are available in the RECOUP Recyclability by Design guidance[49]. This guidance is an industry recognised practical guide to plastic packaging recyclability, based on extensive experience, research and consultations, which is updated annually to reflect on newest developments.



Recyclability by Design 2023 by RECOUP

[47] https://www.terracycle.com/en-GB/brigades/sistema-uk#@54.39586446195522:-.83447377734376zoom:5
[48] https://www.tandfonline.com/doi/abs/10.1080/02652030110071309
[49] https://www.recoup.org/p/430/recoup-reports-packaging-recyclability-design-

Communication of recyclability and end-of-life

It is recommended that reusable packaging has a clear indication of when it reaches end-of-life.[50] This can be achieved by implementing on packaging signaling of completed reuse cycles, either manual or using technology such as RFID. At the same time, research shows that consumers and retail staff are usually quite good at inspecting reusable packaging for acceptability for further use, and that packaging is usually considered unusable before actual end of service life.[51] When the decision is made that the packaging is no longer going to be in circulation, packaging should have appropriate recycling information.

Consumer research conducted by Tesco[52] showed that customers consider recyclable and reusable packaging as similar concepts which can cause confusion and disposal of the reuse packaging via recycling routes instead of returning for reuse. This can be avoided by using easily recognisable and standardised reuse specific designs alongside communication. Recognisable design will aid the sorting processes MRF's should reusable packaging end up in the recycling waste stream.

Easily recognisable labeling such as that offered by OPRL[53] can help consumers to identify reusable packaging and avoid early disposal.

OPRL Refill and Return labels

[50] https://weforum.ent.box.com/s/6f5192886e94cq5bluk68ltm8shjgwkn
[51] https://www.sciencedirect.com/science/article/pii/S0959652622019254
[52] https://www.tescoplc.com/media/759307/tesco-reuse-report.pdf
[53] https://oprl.org.uk/wp-content/uploads/2022/06/OPRL-Launches-Refillable-Packaging-Labels.pdf

End-of-life design considerations summary

Mono-material, commonly recycled polymer, recycled content.

Labels are made from the same polymer as packaging, labels that can be removed easily.

Format and composition compatible with current MRF and reprocessing facilities.

Clear information on the packaging about disposal or reuse process.

Sustainable recovery of RFID at the end-of-life.

Traceability & Tracking Technologies

Traceability of reusable packaging was identified as one of the top three challenges to the adoption reusable packaging in the survey.

Customer uptake/reuse rate is difficult to predict and maintain	79%
Reusable packaging is costly to implement (for the business)	60%
Traceability of reusable packaging is limited, creating the risk of packaging contamination or leaks into the environment	59%
Reusable packaging is not durable enough to withstand multiple use cycles	32%
It is hard to comply with Health and Safety regulations	30%
The environmental benefits of reusable packaging are questionable	28%
Reusable packaging does not offer enough options for brand differentiation	14%

Throughout reusable packaging development, different tracking technologies have been tried and tested. Radio Frequency Identification (RFID) (including Near Field Communications NFC) and barcodes (including QR codes) are the two main types of technologies currently used.

Barcodes represent data in a visual, machine-readable format. One-dimensional barcodes use parallel lines and spaces of varying widths and sizes and are readable by special optical scanners. Two-dimensional barcodes use rectangles, dots, hexagons and other patterns called a matrix. QR code is a type of two-dimensional barcode. QR codes can be read by a smartphone equipped with a suitable camera and software.

RFID is a technology that uses radio waves to passively identify a tagged object. RFID tags are comprised of an integrated circuit, an antenna and a substrate. The RFID tag holds identifying information in unique machine-readable codes. Tags allow automated tracking of individual items throughout multiple reuse cycles. Multiple RFID tags can be read almost simultaneously. RFID tags do not need to be within the line of sight of the reader so that they may be embedded in the tracked object.

Modern RFID tags can be thin, flexible, shock and heat resistant, use various substrates, have customisable functionality, low costs, and be compatible with high-speed packaging and labelling production lines. They are widely used by multiple industries, including retail and are approved for application in the food industry. Tags can be passive, active or battery-assisted passive depending on the power source used by an integrated circuit. Tags can also be classified by frequency. There are three frequency ranges in which they operate: low frequency, high frequency and ultra-high frequency. These three ranges are used for different types of applications.

NFC is a high-frequency RFID, operating at 13.56 MHz frequency. Being a global communication standard (certified by ISO), working only at one frequency and being able to be read by most smartphones makes NFC suitable for various applications. In the case of reusable packaging applications NFC is particularly useful where additional consumer engagement is required with the system.

UHF (Ultra-High Frequency) RFID is the most common type of RFID tag and operates in the frequency band 860MHz -960MHz. UHF RFID tags have a longer distance read-range than NFC, readers can capture tag data from a distance of several metres which makes them suitable for activities such as stock management for large volumes of items. This capability makes UHF RFID particularly suitable for reusable packaging systems with high volumes, enabling fast and efficient inventory management.

RFID technology is a valuable addition to reusable packaging, helping to overcome barriers such as traceability and hygiene concerns and providing additional benefits to consumers and brands. RFID technology can collect rich data about the movement of assets within the system, the number of cycles, packaging provenance and legislative reporting, supporting consumer adoption and infrastructure implementation for optimal environmental impact.

Digital watermarks allow information to be included into digital media, such as image or video. These watermarks are readable by a specialised reading device, and some can be read by smartphones.

Technologies such as RFID and QR codes can also incorporate sensors (e.g., temperature cold chain guarantee) to provide further supply chain visibility and safety.

How items can be tracked by technology

A detailed overview of how tracking technologies are currently used in reuse models for food and drink completed by the University of Sheffield can be found in the Appendix. The review analysed 62 reuse schemes utilising different tracking technologies and highlighted the similarities and differences across these schemes.

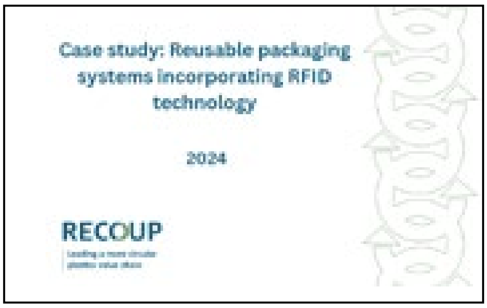
The rest of this section will discuss design considerations for RFID/NFC technology applications for reusable packaging.

Key areas where RFID tag can assist wider adoption of reusable packaging according to the survey and workshop findings were:

Role of RFID tags in life cycle

- Communication of the packaging journey
- Confirmation of cleaning status and food safety
- Information about number of reuses – 'badge of honour'
- Supply chain collaboration
- End-of-life capturing, sorting and processing

As part of project TRACE, RECOUP produced a Case study examining reusable packaging systems incorporating



RFID technology. The Case Study explored how RFID technology is applied and utilised in currently available reuse systems. This document can be accessed online via https://www.recoup.org/our-work/reuse/

RFID application design considerations

Tag application method

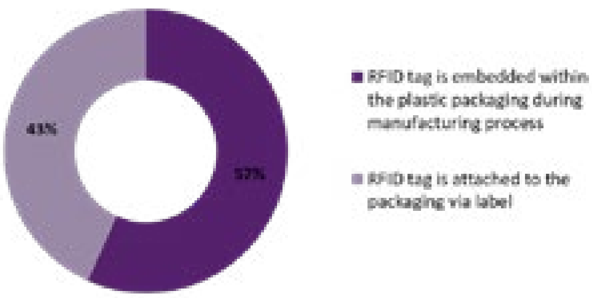
RFID tags are applied to the packaging mainly via labels or embedded in the plastic. Alternatively, overmoulding, printing and incorporation of RFID element into the removable part of reusable packaging has also been tested by various packaging and tehcnology providers.

The pros and cons of RFID tag application via label and via embedding are outlined in the table below.

Pragmatic RFID tags

	Labelling	Embedding in the plastic
Pros	• Easy and economical to apply to various packaging formats. • Labels can be replaced if the tag is not functioning. • Modern adhesive technologies can be used to ensure tags clearly float off during the recycling process, making the tag removable for plastic reprocessing. • Future development of customised adhesives provides a possibility to remove the label from the packaging under specific conditions for either repair or end-of-life but make the tag securely stay on the pack during use cycles.	• RFID tag is protected during washing, refilling, transportation, and sorting. • Packaging content is protected from interaction with the tag and adhesives. • The RFID tag cannot be accidently removed by consumers or throughout the supply chain.
Cons	• Tag is more exposed and can be damaged during washing, transportation, and user interactions. • Application of the tag has to align with food contact safety regulation, only pre-approved adhesives for reusable food packaging applications can be used.	• Failure of the tag can make the whole container unusable for some methods of embedding. • The embedded tag may affect the recycling process. • Compatible only with certain moulding processes and can add an additional step during the manufacturing process. • Depending on the containers polymer melting point and tag substrate, the tag might need to be encapsulated in a different polymer to protect it during the embedding process.

From survey respondents who chose between tag application via labelling vs embedding, 57% indicated that preferable application of the tag would be via embedding during the manufacturing process. However, there was a preference towards label application among stakeholders from the packaging manufacturing sector.



Location on the pack (visibility)

A number of factors influence the location on the packaging where RFID tags can be applied, these are:

- Tag application method
- How the tag will need to be read by technology and consumers throughout the use cycle
- Sorting technology
- Existing labelling requirements
- Packaging dimensions, surface characteristics, and shape

From survey respondents who chose between visible and hidden tag application, 62% indicated that the preferable application of the tag is when the RFID is hidden. However, there was a clear preference towards visible tag in the waste management and recycling category.

The concerns regarding visible tag application were associated with the space available on the packaging and possible removal or damage by consumers or handlers throughout the supply chain.

At the same time, having the tag hidden can raise consumer concerns about being tracked, make it difficult to identify RFID tagged packaging during recycling and sorting, and complicate the process if consumers or service providers need to interact with the technology.

> ***Preferable way of tag incorporation depends on the level of consumer interaction and type of data recorded by the tag. If consumer needs to engage with the tag, then tag needs to be visible, if tag only serving the system and supply chain – embedded, hidden.***
> ***Workshop attendee***

Recyclability and sustainability of RFID tags

The benefits of application of tracking technology to reusable packaging needs to always be weighed against potential environmental and other impacts. While production of the tag, application of the tag to the packaging, production and setting of tag reading equipment and removal or processing of tags at the end-of-life is expected to increase environmental footprint of the packaging system, at the same time, data collected by the tag can offer increased system efficiencies of the higher scale such as energy savings, transportation reduction, optimised reuse rate, increased material circularity at end-of-life, balancing out the burden of the additional component to the packaging. RFID can enable the system to scale by providing increased automation at various stages.

Cup Club (now CLUBZERØ) analysed the environmental impact of PP injection moulded reusable cups with PE lids and RFID tags through 132 life cycles using LCA methodology. Environmental contribution of RFID was found to be nearly negligible in most of the 18 analysed impact categories including Global Warming Potential, reaching approximately 1-3 % in only four impact categories (freshwater ecotoxicity, marine ecotoxicity, human non-carcinogenic ecotoxicity, mineral resource scarcity). [54] [55]

LCA studies of RFID enabled return systems for grocery shopping completed as part of project TRACE demostrated similar findings: inclusion of RFID technology contributed to less than 1% of the overall global warming potential of the system.

Recyclability and recoverability of the tags and packaging with tags

The preferable option is for tags to be separated and collected for future reuse if still functional or recycled if not. In terms of RFID tag recycling, separate recovery of metal elements of the tags present higher value compared to the scenario when tags are recycled with the packaging they were servicing.[56]

There are two pathways for tag removal from the packaging which can be considered: removal using state-of-art technology or manual removal.

Manual removal of the tags is expected not to be a financially and timely feasible option unless tags are high value and destined for reuse. Using the right adhesives applied to the RFID label has demonstrated that at least 5-10 reuses can be achieved[57], which is important to maintain traceability required for reuse application. The newest development of customised adhesive technologies can also allow tags to cleanly float off during the recycling process so tags can be separated from the plastic containers.

Currently some smaller scale tagged packaging providers utilise the manual removal of the embedded tags before recycling as an interim solution within closed-loop collection, however this will not be possible once reuse systems reach a certain scale.

According to the report by RAND, use of technology instead of manual sorting to separate the tags is also associated with challenges. Technology to separate the tags is expensive at this stage of development. Achieving necessary volumes to create a valuable recycling stream for which recyclers can consider implementing additional equipment is difficult as modern RFID tags are lightweight.

Practical information on recycling of RFID enabled packaging is limited. Theoretical estimations suggest that presence of the tags in plastic can be a barrier for closed-loop recycling at the current technology levels, therefore recycling pathways have to be considered on a case-by-case basis during the packaging and tag design process.

> ***As RFID tags can be considered problematic in plastics recycling, the production of RFID concentrates designated for plastic recycling is hardly an option. Furthermore, it is noteworthy that early-stage studies have found that besides the main elements listed above other elements (e.g. Ti, Cr, Sb, Sn and W) are detectable. Flame retardants or pigments used in the plastic parts, such as potassium or bromine, may also be carried into the recycling or disposal processes and are seen as environmentally critical in polymer recycling (Schniderlitsch et al., 2012)***

[54] https://drive.google.com/file/d/1C5Qzx31HQnVPg-EyglzR3PRDteQH5SfK/view?pli=1
[55] https://www.rand.org/pubs/technical_reports/TR1283.html
[56] https://www.rand.org/pubs/technical_reports/TR1283.html
[57] César Aliaga, Beatriz Ferreira, Mercedes Hortal, María Ángeles Pancorbo, José Manuel López, Francisco Javier Navas (2011): Influence of RFID tags on recyclability of plastic packaging

Trials of recycling of HDPE containers with tags attached via labels showed that some of the tag elements were captured via introduction of additional screening during the extrusion process. Material properties after pelletising did not differ significantly from material recycled without tag presence. However, the trial ended at the pellet production stage and potential issues producing packaging out of the recycled material would provide a more systemic picture of results.[58]

On-going experimental work on the recyclability of RFID tags attached via labels to PET containers showed some promising successes. PET bottles with RFID tags attached via labels were flaked and then extruded. The process of extrusion was unaffected by the presence of the tags and did not require any additional equipment adjustments. The mechanical and thermal properties of the recyclate was compared to that of virgin PET and no notable differences were recorded. The main challenge presented was visually observable pieces of aluminium, which can potentially affect visual and mechanical characteristics of the products made of the recyclate so further testing is required.

Chemical depolymerisation of PET with RFID tags demonstrated that the process of depolymerisation was similar to the process for material without the tags and allowed to recover metals and obtain BHET monomer with 90% conversion rate.[59]

For the scenario of RFID tags processed separately from the packaging they serve, depolymerisation of the tags also went successfully allowing not only recovery of the polymer but the metal compnents of antennae and IC as well.

Chemical recycling can offer recovery opportunities for the embedded tags which requires further research and testing.

There are clear opportunities for the successful reuse and recovery of RFID tags providing the existence of relevant infrastructure and sorting technology are in place. However, the establishment of these processes will require sufficient volumes and initial investment.

Alternatively, if RFID tags are not collected for recycling, and the amount of tagged items ending up going to incineration or landfill grows, this can not only result in a loss of valuable resource but also increase the amount of contamination (such as heavy metals) in the bottom and filter ash of incineration processes or landfill leachate.[59]

Practical testing

As part of the TRACE project, the University of Sheffield completed tests for the durability of tag adhesion and tag functionality throughout multiple wash cycles. Testing demostrated that tags applied via label can withstand multiple washes (both in terms of adhesion and functionality). The results of these tests are available in the Supplementary Technical Guidance to Reusability by Design (available on https://www.recoup.org/our-work/reuse/) alongside AMRC findings from a sorting demonstrator of RFID tagged packaging. The AMRC work explored the ways how reusable packaging can be automatically sorted using RFID tagging technology and provides further insights about tag location on the pack.

[58] César Aliaga, Beatriz Ferreira, Mercedes Hortal, María Ángeles Pancorbo, José Manuel López, Francisco Javier Navas (2011): Influence of RFID tags on recyclability of plastic packaging
[59] Technical and environmental assessment of end-of-life scenarios for plastic packaging with electronic tags. Ahamed et al, 2024
[59] https://www.researchgate.net/publication/295305926_Potential_impacts_of_RFID_labels_on_waste_treatment_processes

Traceability and tracking technologies design considerations summary

Application of the tag:

Depends on the **tag role in the user journey**. If the consumer needs to interact with the tag, to return or access the information then tag has to be clearly visible. If not, tag can be hidden.

Depends on the **lifecycle stages**: embedding is preferable for reuse stages to protect from damage during washing and from being removed by the user; labelling is better for the end of life.

Depends on the **limiting factors**: Space on the packaging, packaging format, manufacturing process, filling process(sterilization), washing conditions, consumer perception.

Cost

Cost of reusable packaging is a topic that comes up frequently when discussing adoption of reuse systems. Decisions made at the point of reusable packaging design can directly influence the cost of packaging to both the consumer and other stakeholders in the value chain and is a key factor in success or failure of reuse systems. The challenge of reusable packaging being costly to implement for business was cited as a challenge by 60% of survey respondents.

Each cycle that reusable packaging goes around in the reuse system reduces the initial cost of the packaging therefore achieving an optimum number of reuse cycles is key to reducing packaging costs. Unlike single-use packaging, reusable packaging must be treated as an asset of value rather than as a disposable item.

Considerations related to cost when designing packaging:

- Define **minimum number of uses** required to break even both environmentally and financially for packaging to be produced at a viable cost
- Do not overengineer the packaging and therefore increase **material** use when manufacturing the packaging which would lead to increased material costs
- Although not design specific, **consider return mechanisms** at the design stage i.e., can cost of packaging be subsidised by introducing deposits as part of the reuse system which would impact on how the packaging could be designed in relation to cost
- Design packaging to **utilise current infrastructure** where possible e.g., existing filling lines
- **Optimise design for transport** to reduce system costs e.g., more containers on a lorry means less journeys required which saves fuel and therefore environmental impact
- If adding cost to design through inclusion of functions such as tech-enabled packaging, **ensure that it is adding value** for all stakeholders including the consumer

In their consumer research both Hubbub[60] and IGD[61] recognised cost as a priority and the need for this to be as close as possible to single-use packaging in order to aid consumer adoption. Achieving this will be a fine balance between the cost of the packaging manufacture (determined by the design) and the number of reuses that the system can achieve.

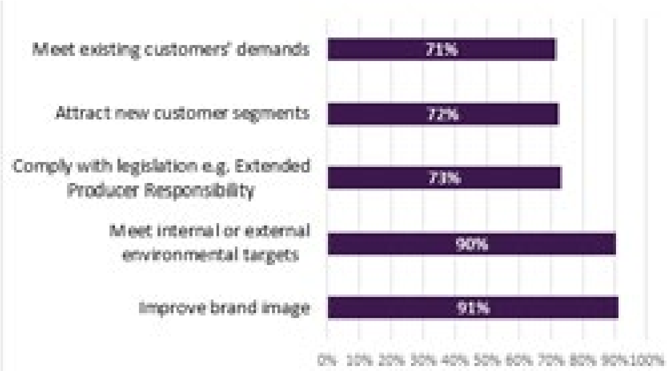
As highlighted in this section the design of the packaging can also directly influence costs throughout the rest of the supply chain and this needs to be a key consideration at the design stage. If the packaging design requires a change in infrastructure such as filling lines or retail space, then this is going to increase investment requirements and the overall cost of the system. There are however a number of opportunities to reduce system related costs through reusable packaging design, for example designing packaging to fit with current filling lines or designing for optimised logistics.

> *The best designs don't work if upfront investments are too high.*
> *Workshop attendee*

[60] https://www.hubbub.org.uk/reuse-systems-unpacked
[61] https://www.igd.com/articles/article-viewer/t/how-to-help-consumers-adopt-reusable-packaging/i/29147

Number of Reuses & Environmental Impact

According to the survey, reusable packaging is often considered by the industry as a tool to meet their internal and external environmental targets, and also as a potential tool to comply with future and current legalisation.



At the same time there is a concern of greenwashing, and 28% reported that environmental benefits of reusable packaging can be questionable.

> ***All unintended negative consequences must be explored and fully minimised so that a clear sustainability benefit can be confidently demonstrated.***
> ***Workshop attendee***

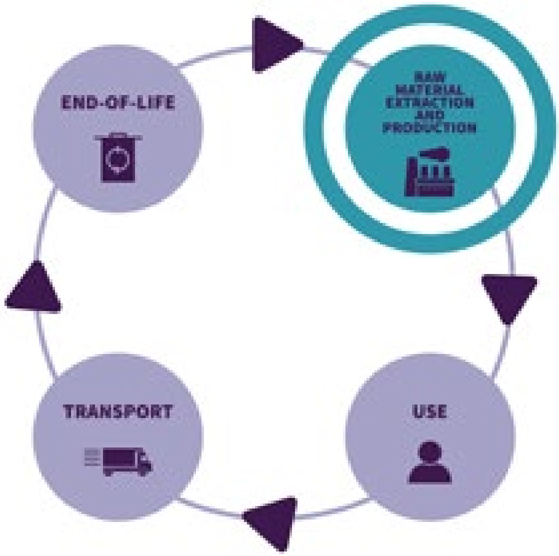
The **number of reuses**, **return rate** and **break-even point** is often used to assist in assessment of the environmental impact of the reuse system.

Number of reuse cycles (reuses, use cycles, loops) is the number of service trips completed by reusable packaging before being disposed of. The service trip includes the filling stage, use stage, washing and reuse preparation stage and transportation between them before the next reuse cycle begins. It is important to distinguish between potential number of reuses embedded in the packaging design, practical number of reuses identified from the reuse system perspective, and the actual number of reuses.

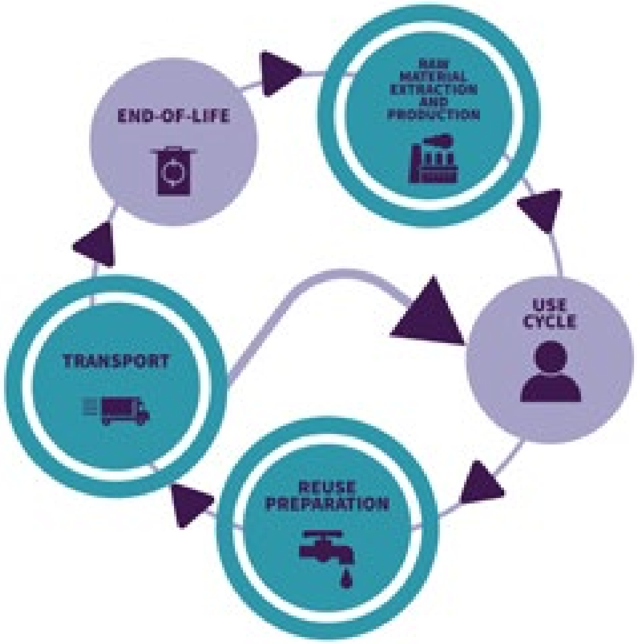
The point at which the impact per use for reusable packaging falls below that of a disposable counterpart, is the environmental ***'break-even point'***.

The break-even point for reusable packaging will depend on factors such as:

- Its weight and material composition
- The weight and material composition of the disposable alternative
- Manufacturing process
- End-of-life scenarios
- Transportation distances
- Washing protocols



Most impactful stages of single-use packaging life cycle



Most impactful stages of reusable packaging life cycle

Return rate is the percentage of reusable packaging units returned to the reuse system in comparison to the number of reusable packaging units introduced into the system. The return rate calculator below demonstrates the relationship between return rate and number of reuses.

NUMBER OF REUSES = 1/(100%-%RETURN RATE)

Return rate	Number of Reuses
50%	2
75%	4
80%	5
85%	6.67
90%	10
95%	20
99%	100

It is important to note that packaging can be lost from the reuse system due to the customer not returning it and as part of quality control rejection for damage/wear during retail display, backhaul, cleaning, and reuse preparation. These losses must be monitored and managed alongside the return rate.

Break-even point is used to determine after what number of reuses the reusable packaging becomes environmentally superior compared to single-use. The breakeven point is usually calculated using LCA and can be helpful to understand what lifecycle stages are the most impactful and where changes can be made to improve the performance of the reuse system. The LCA calculation of the breakeven point will be the most indicative if reliable real-life data is used for the calculation.

A review of reusable packaging studies showed that on average break-even point ranges around 10 to 15 reuse cycles. [64]

Reusable packaging	Break-even Point	Maxi-mum reuse cycles	Typical num-ber of reuse cycles
Club Zero, PP cup[65]	72	132	?
Cauli, PP tray	4	400	40
Luxemburg box, PBT tray[66]	4	50	?
GDB, PET bottle[67]	?	25	20
Recircle, PBT bowl[68]	15	200	?
Detergent, HDPE bottle[69]	10	50	?
Yo-yo, steel cup[70]	9	500	?

Reuse cycle	Returned	Number of reuses
0	100	0
1	80	20*1
2	64	16*2
3	51	13*3
4	41	10*4
5	33	8*5
6	26	7*6
7	21	5*7
8	17	4*8
9	13	4*9
10	11	2*10
11	9	2*11
12	7	2*12
13	5	2*13
14	4	1*14
15	3	1*15
16 -18	2	1*16
19- 23	1	1*23
24	0	1*24

Return rate calculation example:

100 reusable cups, 80% return rate.

Average number of reuses for each cup:

(1*24+1*23+1*16 +1*15+1*14+2*13+2*12+2*11+2*10+4*9+4*8+5*7+7*6+8*5+10*4+13*3+16*2+20*1)/100 = (24+23+16+15+14+26+24+22+20+36+32+35+42+40+40+39+32+20)/100 =500/100= 5

From this example, we can see that while some of the cups get to be used 20 -24 times, quite a lot of the cups are reused only several times.

64 https://www.wearecauli.com/faqs
65 https://drive.google.com/file/d/1C5Qzx31HQnVPg-EyglzR3PRDteQH5SfK/view?pli=1
66 https://doi.org/10.1016/j.spc.2021.03.022
67 https://petcore-europe.org/news-events/438-pet-%E2%80%93-from-recycling-champion-to-recycling-and-reuse-champion-state-of-play-2022.html
68 https://www.recircle.ch/en/recircleproducts/packaging/
69 https://pubmed.ncbi.nlm.nih.gov/25209251/
70 https://yoyocups.com/

Design for longevity and durability vs design for the reality of the system

When looking at the variety of currently available reuse schemes, it is often reported that packaging is designed to be reused a significant number of times ranging from 50 to 1000. This message is automatically received very positively as the environmental impact of reusable packaging distributed among its life cycles and the more packaging that is used, the lower impact and associated costs are. However, real life reuse systems, even very successful and well-established ones such as GBD in Germany, rarely go over the 95% return rate (over 20 reuses).[71] The number of reuses is a complex parameter that does not solely depend on the durability and longevity of the packaging (see diagram below).

Therefore, the main design goal for reusable packaging is not how to make packaging as durable as possible but how to make packaging durable enough to work for the product, the system it serves and to last the average number of uses per package.

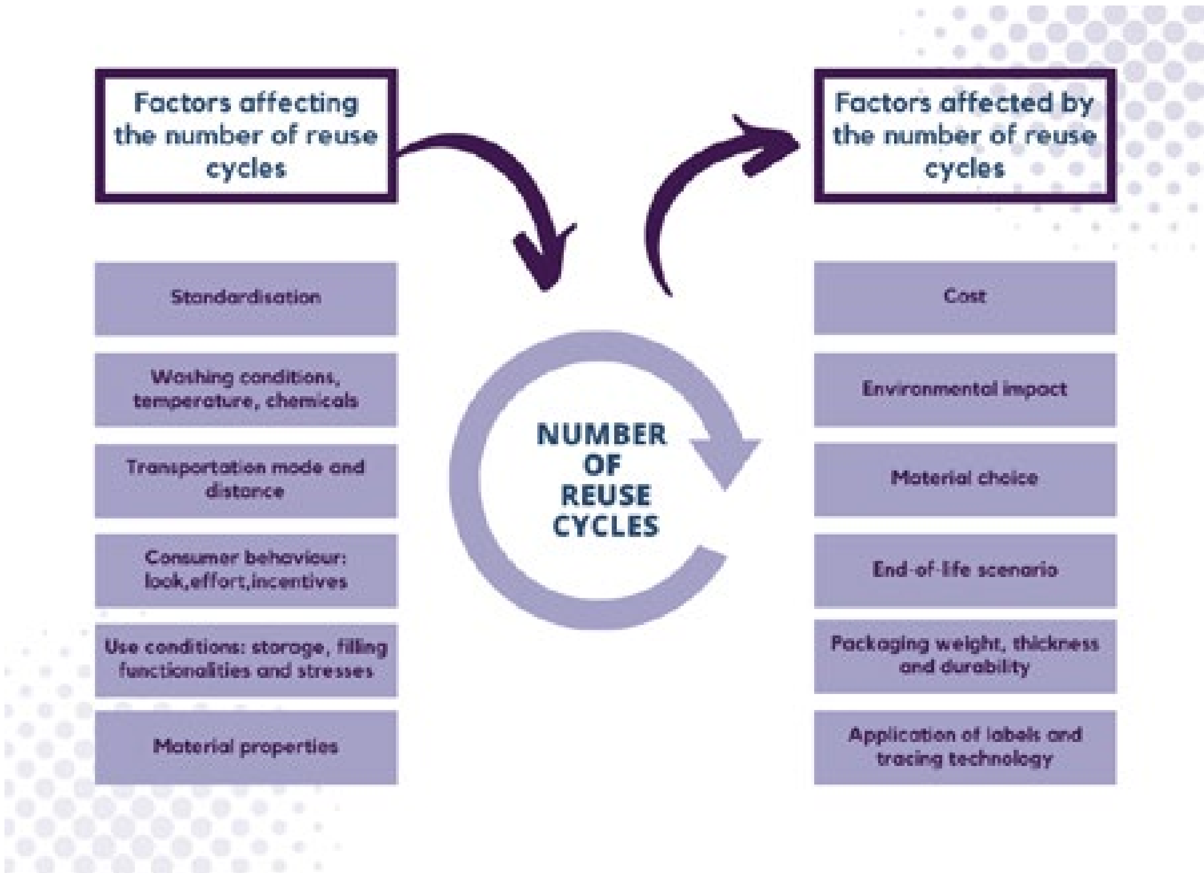
> ***Important to understand the actual reuse rate to not overdesign the packaging.***
> ***Workshop attendee***

Following the principles of efficient material use will allow to lower the impact of logistics and transportation; it can also help to adjust the inbuilt durability of the packaging when realities of the system functionality and consumer behaviours are limiting the desired number of reuses.

Predicted number of reuses based on system modelling, data from similar schemes and reuse trials become a central decision point for the design of reusable packaging. Material choice, thickness, and durability of the packaging necessary to support a certain number of use cycles, end-of-life scenario, ways of applying the tracing technology, costs - will all be affected by the number of reuses.

For example, the cost of reusable packaging will consist of increased costs of the container itself, increased initial operational cost and initial investment in the reusable infrastructure. The increased cost of the reusable container itself can be easily balanced by just a few reuses, produced at scale the cost of the reusable container won't differ dramatically from that of a single-one. However, in order to compensate for the initial operational and infrastructure costs, a far higher number of reuses might be required. This kind of initial costs can only be mitigated by packaging design to a certain extent as these cost pressures represent higher level system changes.

[71] https://petcore-europe.org/news-events/438-pet-%E2%80%93-from-recycling-champion-to-recycling-and-reuse-champion-state-of-play-2022.html



Environmental impact - complexity, limitation of LCA and carbon tunnel vision

LCA is the tool used most often to estimate environmental impact of the reuse system and calculate the break-even points. However, it is known that this tool comes with a number of limitations. For example, in the case of the comparison of plastic bags and cotton bags, depending on the impact category used, the number of reuses to break-even can range from 31 to 7100 times which is a significant difference, differentiating feasible solutions from non-feasible. There are challenges associated with modelling transportation which usually has a significant impact, having a reliable and realistic data about the end-of-life scenario, accounting for local differences and also considering parameters such as litter, consumer behaviours and human health.[72]

It is also worth noting that the introduction of reuse systems can often address multiple issues and avoid 'carbon tunnel vision'. Carbon emissions is the environmental indicator that is most often reported in order to advocate for the benefits of a reuse system, however, it does not always provide a comprehensive picture, leaving other important factors e.g. resource use, water scarcity, ecotoxicity, health, inequality unnoticed.

While it is expected that reuse systems 'must be net positive for the environment'[73], this is something that will require time to be achieved and might not always be possible for all impact categories at the time of the reuse system introduction. In the cases when reuse systems solve some specific local issues e.g., waste management or affordability, it might be necessary to allow time for optimising economic, social and environmental performance.

> ***At the moment it [reusable packaging] is premium and more expensive than single use. Extra monetary cost, extra environmental cost, necessary breakeven point for both.***
> ***Workshop attendee***

It is important to remember that LCA is a decision aid, not a decision maker and estimation of the overall impact of reusable packaging should not solely rely on LCA and can employ additional tools such as material circularity etc.

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[72] https://drive.google.com/file/d/1jEJ31gfGE-0iErVpELbUl7FilwZ4Ng7h/view

[73] https://drive.google.com/file/d/1jEJ31gfGE-0iErVpELbUl7FilwZ4Ng7h/view

Number of reuses and environmental design considerations summary

Environmentally sound production process and components such as dyes/additives.

Sustainable tracking technologies.

Design based on solid environmental claims e.g. LCA.

Renewable or recycled feedstock.

Sustainability of the whole system: product-packaging, secondary/tertiary packaging.

Reusable Packaging Design Briefs

As part of research for this guidance, workshops were held and some time was dedicated to discussing the packaging design requirements of certain products in order to further understand some of the key design criteria for each market sector; in-store bakery, fresh fruit and vegetables and beverages.

Reusable packaging design briefs

In the hierarchy of desirable attributes for plastic packaging, reuse is considered a very important step towards creating a true circular economy. Packaging reuse systems can deliver reduced resource usage and lower emissions associated with its manufacture.
The workshops explored three product areas for the potential use of reusable packaging; bakery, fresh fruit and veg, and beverage. Project TRACE is primarily focussing on two types of system model for reusable packaging return and designs would need to fit these requirements:

In store model: Product is sold via a retail store **=>** customer purchases and consumes product **=>** packaging is returned to in-store return point **=>** contents collected by local logistics/waste management organisation **=>** Packaging is sorted and washed **=>** returned to supplier to be filled

Delivery Model: Consumer purchases product online **=>** order is delivered by service provider **=>** Consumer consumes product **=>** Product is collected by service provider **=>** Sorting and washing at service provider **=>** refilled

To aid the tracking and tracing of these pieces of packaging, a RFID tag will be included in the design. This will also enable capabilities such as supply chain tracking and consumer facing information to be stored with the packaging.

Design brief: Reusable bakery packaging

Create a design for reusable bakery item packaging bearing in mind the following conditions:

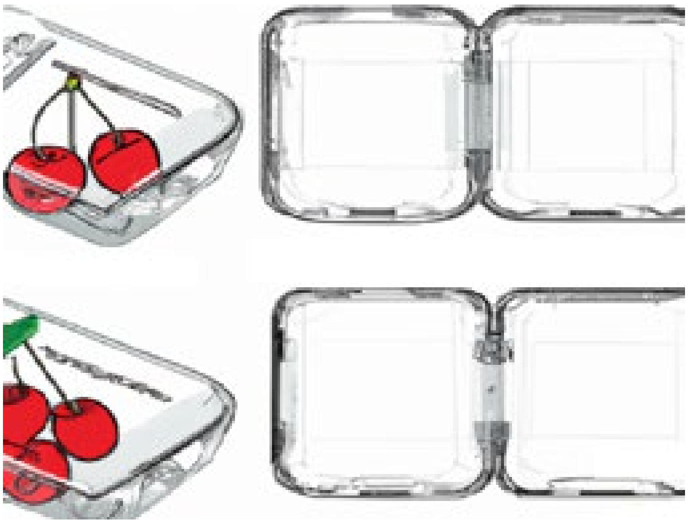
- **Product:** in-house bakery; a variety of items to be considered - individual treats such as croissants, cake slices, doughnuts, cupcakes, as well as larger items such as cakes and rolls or six mini-items.
- **Format:** Reusable clamshell, nestable, allowing customization for various products via inserts to secure the item in the position, collect moisture or via a variety of sizes from a single item to multipack.
- **Closure:** A one-piece, hinged lid is preferred.
- **Visibility:** Transparent, whole packaging or through the top only.
- **Material choice:** Mono-material, polymer suitable for hinges, these products have less tendency for staining the packaging.
- **Tamper evidence:** not required.
- **Label/branding:** not a priority requirement for this type of product; labels are easily removed in the washing process.
- **RFID Technology:** Applied via label to the bottom of the container 4cmx4cm.
- **Surface:** Flat and Smooth finish, on the sides and bottom/top.
- **Size:** Approx. 225 mm x 135 mm x45 mm – height.

Reusable bakery packaging design imagery generated by Dall-e-2

Design brief: Reusable fruit and vegetable punnet

Create a design for a reusable fruit and vegetable punnet bearing in mind the following conditions:

- **Product:** loose produce packaged into individual punnets/trays in the UK, such as grapes, cherry tomatoes, cherries, and mini cucumbers.
- **Format:** Packaging to fit current logistic system (secondary crates) and industry standard for single-use formats. Tray with lid/closure.
- **Closure:** Lid or peel and reseal closure is required to protect the product during transportation, display, and control product quantity per pack. It is preferable for the lid or closure to be attached to the packaging.
- **Visibility:** Packaging to provide the product visibility via a transparent lid or the container itself as a customer might want to interact with the product, see, touch and smell it.
- **Label/branding:** not a priority requirement for this type of product; labels are easily removed in the washing process.
- **Tamper evidence:** Tamper evidence is not compulsory.
- **Material choice:** Polymer that can withstand staining by tomatoes and berries. Provide necessary protection to the soft product, recyclable.
- **RFID Technology:** Applied via label to the bottom of the packaging, size 4x4cm.
- **Sizes:** To adapt to the requirements of the logistic, washing and labeling, reusable packaging will be required to have flatter, more perpendicular sides without ribs and lips, while the increased thickness will still create are difference between external and internal sizing. Therefore, the sizes below reflecting the standard single use punnets are for indication purposes:
  - Size A - 155 mm to 185 mm x 90 mm to 120 mm x 90 mm – height.
  - Size B - 135 mm to 175 mm x 95 mm to 135 mm x 55 mm – height



Reusable fruit packaging design imagery generated by Dall-e-2

Design brief: Reusable beverage packaging

Create a design for reusable beverage bottle bearing in mind the following conditions:

- **Product:** soft drinks, water, dairy products.
- **Format:** similar to current single-use sizes: 330 ml, 500 ml, 750 ml, 1000 ml; consider shapes for more efficient logistic: more squared shapes to avoid transporting air, nestable containers for transportation. Neck sizes are compatible with current filling lines. Lightweight and portable. Suggest 500ml as initial target.
- **Tamper evidence:** needed and expected by the customer, tamper evidence that will stay with the closure, no small bits of plastic to be wasted, tamper evidence not interfering with filling lines.
- **Branding:** standardized packaging allowing branding/customization either via shape or removable labels.
- **Label/branding:** the same polymer as the bottle, if possible.
- **Visibility:** transparent.
- **Process requirements:** compatible with cleaning jets, hot wash conditions.
- **Closure:** closure allowing stackability, one-piece system, if possible, leakproof closure, screwable.
- **Material choice:** Recyclable, mono-material, HDPE, PP, PET, Tritan™.
- **RFID Technology:** applied via label (4x4 cm to the bottom or the side of the container) or embedded in the container during manufacturing.

Reusable bottle packaging design imagery generated by Dall-e-2

Reusable Packaging Design Considerations

Manufacturing

- Material choice is based on requirements of the product and supply chain
- Material use/durability is optimised for the defined number of use cycles
- Sustainable and efficient production process
- Sustainable formulation suitable for reuse application, renewable/recycled content

Transport/logistic

- Nestable, stackable, foldable
- Integrated system of primary, secondary and tertiary packaging
- Integrated design of the return point and packaging (e.g. return bin)
- Lightweight and durable
- Sustainable tracking technologies

Retail

- Formats, sizes and shapes suitable for current infrastructure e.g. filling lines, storage conditions
- Standardisation to reduce costs and increase uptake
- Agile, innovative, minimalistic branding
- Sustainability of product/packaging and primary/secondary/tertiary systems
- Tamper evidence and food safety information as per product requirement

Visual Summary

Use

- Familiar design but distinguishable from single-use
- Easy to store at home
- Lightweight
- Looks clean, hygienic and undamaged over multiple use cycles
- Design that encourages reuse

Reuse preparation

- Compatible with washing temperatures and chemicals
- Free from moisture/contaminant accumulating elements such as ridges, lips, holes
- Standardised for efficiency in collection and allocation in cleaning equipment
- Easy-to clean surface, shape and closure
- Robust to interact with cleaning process e.g. cleaning jets

End-of-life

- Mono-material, commonly recycled polymer, recycled content
- Compatible with current MRF and reprocessing facilities
- Sustainable recovery of tracking technologies at the end-of-life
- Clear information about disposal process
- Labels either removable at the end-of-life or made of the same polymer

Appendix

Review of how tracking technologies have been used within reuse systems for food and drink

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On behalf of the TRACE Project funded by the Smart Sustainable Plastic Packaging Challenge

September 2022

Executive Summary

An increasing number of systems for reusing packaging and containers are being developed in an effort to reduce waste and move towards a more circular economy. Being able to track containers potentially facilitates these systems; however, it is currently unclear what tracking technologies are available and what opportunities (and / or barriers) they present, both to those running the systems and those using them.

The current review identified 62 reuse systems for food and drink that incorporate tracking technologies (listed in Appendix A). For each, we identified: (1) the nature of the reuse model (e.g., refill vs. return), (2) what information is being tracked (e.g., when the containers are checked-out, when they are returned etc.), (3) the tracking/marking technology used, (4) how the technology facilitates or inhibits user engagement, and (5) how the reuse systems work.

The majority of the systems used a 'return on the go' model. All the systems tracked when the containers were returned, but fifteen different types of information were tracked across the systems identified. Return was most frequently tracked through the use of QR codes (67%). The systems differed in how the containers were checked-out and returned (e.g., some systems required users to use an app, while others didn't) – something that seemed to depend on a number of factors, including the type of technology used, where the technology was located (i.e., on the container or at the participating location), whether and how payment was taken for the reusable containers, whether and how users were incentivised for using the schemes, and whether users were required to use an app.

Overall, the current report highlights the potential of tracking technology in reuse models for food and drink.

Introduction

The UK Government has introduced measures to reduce the amount of waste sent to landfill or to be incinerated and has committed to moving toward a zero-waste, circular economy (Circular Economy Package Policy Statement, 2020). One way in which this can be achieved is to reuse containers. Reusable containers are designed to be reused for the original purpose (e.g., packaging of food) multiple times. Each time that the container is used, it is returned, washed and entered back into the economy (Ellen Macarthur Foundation, 2019). Reusing the containers multiple times keeps the material in circulation for longer before end of life (e.g., recycling or disposal).

There are thought to be 4 different reuse models: return on the go, return from home, refill on the go, and refill at home (Ellen MacArthur, 2019). One of the key differences between the reuse models is who owns the packaging, with the packaging belonging to a business in the return models, whereas it belongs to the user in the refill models. For example, returnable containers might be owned by a retailer who prefills them with the product (e.g., pasta) which is then purchased by the consumer. The consumer would then return the empty container either from home or on the go following which it would be cleaned, refilled and made available for purchase again. The second key difference is where the reusable containers are either returned or refilled. For example, containers might be returned from home (e.g., collected by a delivery/collection service) or returned by the user 'on the go' (e.g., at a drop-off point).

Reusing containers is typically more sustainable than single-use alternatives (e.g., Coleho et al., 2020; Greenwood et al., 2021) and can reduce waste. However, reusable containers are often more expensive in terms of cost and the energy required to manufacture the more durable materials compared to single-use, disposable alternatives. Consequently, it is important that the reusable containers are reused multiple times to offset the higher greenhouse gas emissions involved in the manufacturing of the containers (Wood, 2019). However, reusing containers typically requires additional actions on behalf of the retailer (e.g., to refill containers), the consumer (e.g., to return the container), and additional stakeholders in the supply chain (e.g., a washing facility).

A number of strategies have been used to increase the likelihood that consumers will return containers and packaging once used. For example, there are penalty systems where the individual is charged if the container is not returned. Alternatively, deposit return schemes involve an individual paying a deposit for the reusable container, which they then receive back when the container is returned. Some deposit return schemes use cash/card payments for the deposit. However, deposit return schemes may be facilitated by digital technology to streamline the return of the deposits and also benefit other actors in the supply chain, who are able to track the movement of the containers (e.g., retailers could know whether the containers are with a customer, at a cleaning station, waiting to be refilled, as well as who has the containers, and when the containers have reached their end of life and are ready to be recycled). This additional information may help to keep the materials in circulation for as long as possible, helping to achieve a circular economy.

The current review

Given the potential of tracking technologies for facilitating reuse systems, the aims of the current review were (i) to identify examples of how tracking technologies have been used in reuse models for food and drink, (ii) use these examples to understand the different capabilities and information that tracking technologies could provide to consumers (e.g., on provenance, options for end of life, nature of the product), and (iii) start to identify and explore what actions are needed by those using and delivering the system (e.g., how consumers use the technology).[1]

Search Strategy and Inclusion Criteria

Several approaches were taken to identify examples of how tracking technologies have been used within reuse models for food and drink. First, existing databases of reuse systems such as the "Living Landscape of Reusable Solutions Database" (2022) and "Upstream Solutions Reuse Services and Business Directory" (Upstream Solutions, 2022) were searched for potential examples. Second, online searches were conducted by entering combinations of the following search terms into Google: reusable solutions / reusable containers / reusable packaging and digital tracking technology. These searches identified websites describing specific systems, as well as reports (e.g., Ellen Macarthur, Hubbub Report) that were used to identify additional systems. Third, examples were identified through consultation with experts and stakeholders within the TRACE Project network. These searches were conducted between August and October 2022.

To be included in the review, the systems had to:

- Be designed to enable reuse of containers / packaging
- Be designed for food/drink (i.e., not home or personal care products)
- Include technology that enables tracking of the container.

With respect to (c), relevant technologies were defined as the marking technologies outlined in a report by Pragmatic (Young, 2022) on the benefits and opportunities that marking technologies have in reducing plastic waste (see p. 10 of the current report for a brief description of each of the technologies identified in the review). Tracking was defined as being able to garner information about where the containers are within the supply chain. For example, tracking can allow information to be known on whether a container has been 'checked-out' by a consumer or whether it has been returned. Additionally, information can be provided regarding what has happened to that container, such as what food/drink has been in the container, whether and how the container has been washed, the materials the container is made of and when it was made, when it was refilled and - depending on the type of tracking - who has the container. No restrictions were placed on the location of the reuse system; thus a number of international examples were identified.

Data Extraction

Appendix A shows the key features of each of the reuse systems incorporating tracking technology; namely, (i) the location of the reuse system, (ii) the tracking/marking technology used (e.g., QR codes, RFID, NFC, barcodes - as outlined in the Pragmatic report), (iii) the reuse model used (i.e., return on the go, return from home, refill on the go, refill at home), (iv) what information was tracked (e.g., when the containers were being checked-out, when they were returned etc.), (v) how the technology sought to facilitate user engagement, (vi) how the reuse system worked, and (vii) whether the technology was embedded within the container or not. If information could not be found in the identified source (e.g., a website describing the system), then the company/ies running the system were contacted via email. Only examples where sufficient information relating to the factors of interest – such as the type of technology used, what was being tracked and how the system works – was available were included in this review. Consequently, while comprehensive, this is not intended to be an exhaustive list of how tracking technologies have been used within reuse systems for food and drink.

1 It is important to note that there are a number of actors in the supply chain who the technology would benefit at different stages. For example, tracking technology could help retailers to determine their stock levels, waste processers to know what material is in the containers, and logistics companies to identify where in the supply chain the containers are. However, due to the information in the current review being based on publicly available materials, the focus is largely on the how the tracking technologies work for the consumer.

Findings

62 reuse systems for food and drink incorporating tracking technology were identified (see Appendix A). The systems comprised both: (1) business-to-consumer systems in which consumers purchase food and drink in digitally enhanced containers from a company/ retailer (e.g., CanCan), and (2) business-to-business systems in which one company provides the tracking technology (e.g., software and tracking tags) to a second company to include on packaging of their choice (e.g., Reath).

Reuse models

The majority of systems adopted a 'return on the go' model, whereby users were asked to return the packaging, either where they originally acquired the container, at another participating business, or at an alternative drop-off point (e.g., a return point on the street). For example, &Repeat (originally barePack) is a reuse system in France, which allows consumers to get takeaway food in stackable reusable containers that have a QR code printed on them. Consumers order food from a restaurant (or via a food delivery platform such as Deliveroo), receive their food in a reusable container, and then return their container(s) to any of the participating restaurants. Similarly, Junee is a London based reuse service who partners with workplaces to allow them to have their own stock of reusable containers that employees can then use to get their lunch on the go. They also provide return points at the workplaces to make it easier for employees to return their containers. QR codes are used to track the movement of the containers.

Six of the systems provided a 'return from home' service. For example, ClubZero offers RFID enabled reusable cups and food containers to consumers which can be requested when ordering food and/or drink in-store or for delivery via Just Eat. Once finished with the container, users can return them to any of the yellow boxes or bags – locations can be found via the app – or they can arrange a collection using the return bag for a small fee. In line with the majority of the examples adopting a 'return on the go' or a 'return from home', 53 of the systems identified allowed people to reuse coffee cups or bowls for takeaway food. Knowledge of how tracking technology is used within these types of reusable containers could – and perhaps should – be applied to other food and drink containers such as groceries.

A further 6 systems adopted a 'refill on the go' model, with one also allowing 'refill from home'. For example, MIWA containers have an RFID tag which is detected by a dispenser in the store which pours the contents into the cup. Payment is then made via the app. This removes the need to weigh the empty containers before filling them and to scan labels. Validfill works in a similar way, allowing users to refill drink cups across different locations such as theme parks and University campuses. Infinitag and Fill it Forward are different in that these companies allow users to buy a tag with a QR code to stick onto their own reusable containers. The idea is that the individual scans the QR code every time that they use their reusable container (e.g., to track the social and environmental impact of reuse). Additionally, each scan of the Fill it Forward tags contributes to a charitable project as charities receive funding from product sales and corporate partnerships.

What is being tracked?

The majority of systems tracked when the containers were checked-out and/or returned (e.g., Cupkita). Other systems extended this to track who has the container (e.g., Costa's "Borrow, Use, Reuse, Take-Back" (BURT) Scheme, Pyxo in France, and Quppa in Belgium). These systems typically require users to create an account, for example, users made a one-off payment of £5 to join the Costa BURT scheme and then scanned the QR code on the cup which was be linked to the users account via blockchain technology. When the cup was returned, the cup was scanned and unlinked from the user's account. Other examples - such as Ringo Eco in Estonia - also tracked the number of times that the containers were used through users scanning the QR code, which allowed them to determine when the container was ready to be recycled.

Two examples also provided information on the washing of the containers including Recube and Conscious Container. Conscious container – who provide reusable beer and wine bottles with a QR code etched onto the bottle – also have the capability to provide information regarding who filled the container and when, where it has been and who originally made the bottle.

Finally, some companies provide users with information regarding the impact of using reusable containers. For example, Choose: Reuse Cup Program in Hong Kong provides individuals with information regarding their individual and collective impact when they return their cups to the smart return station. To return the cups, users place the cup on the NFC reader on the smart return point. Users can then see information such as how many times the cup has been borrowed and how much waste has consequently been saved from landfill both on the app and the screen on the smart return point. Similarly, r.Ware provides users with information regarding their personal impact and the environmental impact of the program overall when the containers are returned.

Based on the systems identified in the review, the following summarises the information that can be tracked within reuse systems:

- Which containers are in use.
- When the container is checked-out.
- When the container is (due to be) returned.
- Who has the container(s).
- How many times the container has been used.
- When the container needs to be removed from service (e.g., has been used X times, is X months old).
- How many times the container has been washed.
- How the container has been washed.
- When the container was last filled.
- Who last filled the container.
- Where the container has been.
- Who originally made the container.
- What material(s) the container is made of.
- What product(s) have previously been in the container.
- The environmental impact of using (and reusing) the container.

It was not always clear who could see the information being tracked and the type of information tracked may influence who could see it (i.e., the retailer/company or the user). For example, for some systems it is likely that only the retailers/companies had access to the information that was being tracked, whereas other systems – such as those who shared impact data –made the data accessible to the users too. Information was typically made available to users via an app. Out of the 55 business-to-consumer examples identified, 36 of the reuse systems required the users to download an app to their smartphones (e.g., Muuse, Green Caffeen, and Okapi) and a further 8 of the systems directed users to web-based apps (e.g., Friendlier, Quppa, and Suppli). Thus, the majority of the reuse systems available have the means to share information with users via the use of apps.

Technology used

A number of different technologies have been used to track the use and movement of reusable packaging through the supply chain, including:

(1) QR Codes which are a type of barcode that consists of black squares arranged in a square grid pattern that can be scanned by a camera (e.g., on a smartphone) to open a webpage or application; QR codes were used in 42 of the 62 systems (68%).

(2) Radio Frequency Identification (RFID) which uses radio waves to identify the object that has the tag on. Unlike QR codes, the tag does not need to be visible to work. RFID was used in 11 of the 62 systems (18%).

(3) Near Field Communication (NFC) enables wireless communication between two devices over a short-range. NFC was used across 7 of the systems identified (11%).

(4) Barcodes of which there are two types: (i) one-dimensional barcodes which represent data in the spacing between parallel lines, and (ii) two-dimensional barcodes that represent data using other patterns such as rectangles, dots and hexagons. Barcodes and digital IDs were used across 5 of the examples identified (8%).

One thing that became apparent when reviewing the reuse systems is that the location of the technology varies.

Specifically, there were examples where the QR code is printed (e.g., CanCan, Cano), attached using a sticker (e.g., Friendlier), and etched (e.g., Conscious Container) onto the containers. This was the case across 26 of the examples identified. Across 14 of the examples identified, the QR code/2D barcode was not on the container, but located at the participating location (e.g., the restaurant) and/or at the return point. For example, Green Caffeen asks users to order their drinks in a reusable cup, and while the drink is being made, they scan the code on a poster on the counter via the Green Caffeen app. This then checks the cup out and the user can see how many Green Caffeen cups they have checked out. When they want to return the cups, the user can go to any of the participating cafes and again scan the code to return their cup via the app. Scanning a QR code at the return point is typically the system used when food has been ordered online. Indeed, placing orders online is another way of keeping track of the containers that are in use. For example, Full Cycle Takeout in Hawaii asks users to check out the containers via a webpage by entering the number of containers that their meal came in. Then, to return the containers, they scan the QR code at the return point and enter the number of containers that they are returning. In short, reuse systems that do not have the technology printed on/embedded within the containers typically track the movement of the containers in terms of numbers as opposed to being able to track specific containers, which is only possible when the technology is printed on/embedded within the containers.

There are also examples where the participating location, rather than user, scans the QR code or tag. For example, CanCan is a system for reusing cups for hot drinks from cafes. Users sign up via an app which gives them their own personal QR code. When they order a drink, the barista scans the user's personal QR code and then the QR code on the cup. Aroundr also use personal QR codes which are scanned in the participating locations when the containers are checked out and when they are being returned. In other instances, apps are solely used to track the check-out and return of containers. For example, DeliverZero asks users to order their food online in the reusable containers and then when they return the container they manually log it on the app. reCircle use a similar app-based method with manual logging for the majority of their reusable containers. Thus, it seems that technology can facilitate reuse even when the technology is not printed on/embedded in the containers themselves.

Tracking technologies such as RFID and NFC are typically embedded within the containers. For example, the Goodless Smart Cups and the Choose:Reuse scheme embed the technology within the reusable cups, which are scanned automatically by the readers in the smart return point. This technology means that the users of the systems do not have to manually scan the containers or the QR codes located at the participating location using their phone. Additionally, with smart return points, the return is automatically processed which may reduce any consumer concerns regarding whether their return has been processed.

Does the nature of the technology shape what information is tracked?

Appendix B highlights what types of information the different technologies track. All the types of technology track when the containers are returned, thus suggesting that this is an essential piece of information to track. QR codes are currently the most frequently used technology in reuse schemes and are used to track numerous pieces of information, however, none of the examples tracked everything outlined above.

How do the systems work?

The key stages for a user wanting to reuse a container are typically: (1) checking out the container, (2) using the container, and (3) returning the container. However, there are also differences across the different schemes. For example, as highlighted above, there are differences in how the cups are checked-out and returned based on the tracking technology used, but other similarities and/or differences including whether and how users pay for the reusable containers, whether and what incentives are provided for using the reusable containers, whether there is an app, and the information that is shared with the users about the reusable containers. These are considered further below.

How tracking technologies facilitate payment. Reuse systems typically require that users pay a deposit for the container. For example, Choose:Reuse asks users to pay a refundable deposit of HK$30 via contactless payment before ordering their drink, ShareWares charge a refundable deposit of $1.50 on top of the cost of the drink for the reusable cup, which is then refunded via the users bank account when the cup is returned, and CupLoop returns the deposit to customers when they return their cups to the smart return point and tap their cards on the NFC reader. Other reuse schemes - including GoBox, Paradigm to Go, Quppa and Usefull - operate via a subscription system. Typically, there are different levels of subscriptions that a user can sign up for, each with their own benefits, such as determining the number of reusable containers that an individual can check out at once. Other reuse schemes do not charge a deposit or ask users to sign up to a subscription, so borrowing the cup is essentially free of charge. For example, reuse schemes such as Again Again, Bumerang, Revelo, and Vytal, do not charge users to check out of the containers, but when users sign up for the reuse scheme via the respective apps, they are asked for their card details and then charged if the containers aren't returned within the return window (typically 14 days).

How tracking technology can be used to incentivise reuse. Reuse systems differ in whether incentives are provided to the users for using the system, returning the containers, and other activities that promote engagement (e.g., referring others). For example, Cano – which uses QR codes – gives users 100 points when they register which they can exchange for a free drink. Users can then receive additional points by returning containers within 48 hours and referring others to the reuse scheme. These points can be redeemed in participating locations in return for free drinks and food depending on the number of points. Similarly, Inwit Zero Waste Takeout provides users with 'impact points' that can be redeemed for a discount on food – the faster that the NFC enabled containers are returned, the more points the user receives. Similarly, CauliBox provides users with 'CauliCoins' which they can collect each time that they use CauliBox – which is calculated when the QR codes on the containers are scanned – and in turn redeem them to receive rewards and discounts. CauliCoins also act as a way of quantifying and demonstrating the user's impact. The trial at Blenheim Palace also incentivised users by entering them into a prize draw when the QR codes were scanned and the reusable cups returned. Finally, Infintiy Box provide a discount on orders that are requested in reusable containers.

Alongside financial incentives, some systems provide users with information regarding their environmental impact, which may also act as an incentive to encourage users to keep reusing the schemes. For example, alongside their 'shelf', users of the Again Again can also see information regarding their reuse (e.g., the number of containers they have borrowed overall, the number of participating locations visited) and the impact that reusing the containers has on the environment; specifically, the number of containers that the users have borrowed is equated to how much waste they have saved from landfill. This information is also provided as a visual representation (e.g., 450g waste saved from landfill is the weight of 3 baby turtles). Users can also receive virtual trophies when they reach certain milestones (e.g., a specific number of containers borrowed, a specific number of locations visited) which they can also share on social media. Choose:Reuse also provides users with information about the collective impact of reuse both via the app and at the smart return point.

The use of apps alongside tracking technologies. The majority of the reuse schemes use an app which users either download to a smartphone or access via the web. These apps often play a central role in the functioning of the reuse system, in the sense that the app is used at key points in the reuse process. For example, an app is often used to check-out and return the containers – particularly in systems where QR codes and barcodes are used (e.g., Green Cafeen) as the app is how the users will scan codes. Apps can also be used to link containers to a specific user and, in turn, to their card details which can allow any deposits to easily be returned to the user and/or any late fees or non-returned penalties to be charged. For example, Revelo asks for users' card details when they register on the app. While borrowing the containers is free of charge, if the containers are not returned within the 14 day borrowing period by scanning the QR codes on the return poster, users are charged €10 per bowl and €5 per cup that is not returned. Users are notified of the upcoming charges from day 11 and can choose to extend their loan period by a further 5 days.

Apps can also provide users with information, such as the number of containers that they currently have and when the containers need to be returned. For example, users of the Again Again scheme can see a virtual 'shelf' which has images of the different containers that they have checked-out and a visual representation of a countdown until they have to return the containers. Many apps, including Again Again, Encora, Inwit, Muuse and Okapi include an interactive map that enables users to identify locations where they can borrow and return containers. It is also important to note that, while the digital technology aspect of the reusable containers is central to the current report (and, indeed, the systems focused on in this review were selected as they incorporated some form of digital tracking technology), some systems (e.g., ShareWares) still encourage individuals who don't have a smartphone to participate in the reuse system by returning the containers to the depot.

A number of reuse systems function without an app. For example, Forever Ware provides NFC enabled reusable cups to cafes. However, users are not required to engage with a downloadable/web-based application. Instead, Forever Ware supply the participating cafes with a phone, which they use to take the users phone number to link the reusable cup with the user. The cup is checked-out by the member of staff by scanning it on an NFC reader located on the counter and then the user scans the cup at an NFC reader located by the return point when the cup is returned.

Therefore, apps are not necessary for the reuse schemes to function successfully. That said, this may depend on the technology used within the schemes (e.g., NFC, RFID vs. QR codes) and whether the information that can be tracked is to be shared with users or companies.

Conclusion

This report has identified and reviewed 62 examples of how tracking technologies have been used in reuse systems for food and drink. The review highlights a number of similarities and differences across the different reuse systems. For example, variations in the tracking technologies used mean that the way in which the containers are borrowed and returned varies. For example, some schemes require users to manually check out/return containers via an app, whereas others are scanned by the user/staff member and the checking out of containers seems more automated (e.g., RFID/NFC enabled containers). Additionally, differences in where the tracking technologies are located (e.g., on the container vs. at the participating location) also means that the process of borrowing and returning the containers differs, even when the same technologies are used. Systems also differed in whether they charge for the use of the returnable containers and / or incentivise users for engaging with the reuse systems. However, while the current review provides an overview of how tracking technologies are currently used in reuse models for food and drink, no conclusions can be drawn regarding the effectiveness of the different reuse schemes, as the various properties and features of the systems have not been linked to uptake, return rates, or other outcomes. Therefore, the current report highlights the potential of tracking technology, but there are still questions regarding how the technology is being used and with what effect.

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Appendix B

Details of reuse schemes that incorporate tracking technology

Reuse Scheme	Tracking technology	Reuse model	What is tracked?
Again, Again	NFC	Return on the go	2. When a container is borrowed 3. When a container is returned
Around	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
barePack (acquired by &Repeat)	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
Bold Reuse (was originally GoBox)	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
Bumerang	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned 4. Who has the containers
CanCan	QR Code	Return on the go	2. When the container is borrowed 3. When the container is returned 15. Environmental impact of using the reusable container
Cano	QR Code	Return on the go	1. The container(s) being used
Canteen by Dig	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
CauliBox	QR Code	Return on the go	1. The container(s) being used
Choose: Reuse Cup Program (ch00ze.club)	Digital ID	Return on the go	15. The impact of using the container
Circolution	2D unique identifier	Return on the go	
ClubZero/CupClub	RFID	Return to the go/from home	3. When a container is returned
Conscious Container	QR Code	Return on the go	7. How many times the container has been washed 9. When the container was last filled 10. Who last filled the container 11. Where the container has been 12. Who originally made the container
Costa: BURT	QR Code	Return on the go	3. When the container is returned 4. Who has the containers
Cupable (Recube)	QR Code	Return on the go/from home	5. How many times the container has been used 7. How many times the container has been washed 8. How the container was washed
Cupkita	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
CupLoop	RFID	Return on the go	3. When a container is returned

CupZero	QR Code	Return on the go	4. When a container is returned
DeliverZero	App	Return on the go/from home	3. When the containers are returned
Fill it Forward	QR Code	Refill at home/on the go	15. Environmental impact of using the reusable container
Forever Ware	NFC / RFID	Return on the go	2. When a container is borrowed 3. When a container is returned
Friendlier	QR Code	Return on the go	2. When a container is borrowed
Full Cycle Takeout	QR Code	Return on the go	3. When a container is returned
Goodless Smartcup	RFID	Return on the go	1. Which container has been borrowed 2. When the container has been borrowed 3. When the container is returned 4. Who has the container
Green Caffeen	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
Green Cups	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
Green GrubBox / Encora	QR Code/RFID	Return on the go	1. The container(s) being used
GreenToGo	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
GRIN / Revore	RFID / QR Code	Return on the go	3. When a container is returned
Infinitag	QR Code	Refill on the go	15. The environmental impact of using the reusable container
InfinityBox	QR Code	Return on the go/from home	3. When a container is returned
Inwit (Zero Waste Takeout)	NFC	Return on the go	3. When a container is returned 4. Who has the container
junee	QR Code	Return on the go	3. When a container is returned
Loop	QR Code	Return on the go	3. When a container is returned
Loop-it	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
MIWA	RFID/NFC	Refill on the go	1. The container(s) being used
Muuse	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
My Fresh Bowl	Barcode	Return on the go	3. When a container is returned
NoWW	QR Code	Return on the go	3. When the container is returned
Okapi	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
OZZI	Barcode	Return on the go	3. When a container is returned
Paradigm to Go	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
Pyxo	QR Code / NFC (?)	Return on the go	2. When a container is borrowed 4. Who has the containers

Quppa	RFID	Return on the go	2. When the container is borrowed 3. When a container is returned 4. Who has the container 5. How many times the container has been used
r.Ware	QR and RFID	Return on the go	2. When a container is borrowed 3. When a container is returned 6. When the container needs to be recycled
Rastal Smartglass Smart-Tec	NFC	Refill on the go	
re-universe / Reward4Waste	QR Code	Return on the go	3. When a container is returned
Reath	Digital passports (Reuse.ID)	Return on the go / from home, refill on the go	5. How many times the container has been used 12. When the container was made 13. What material(s) the container is made of 14. What product(s) have previously been in the container
Recirclable	QR Code	Return on the go	1. Which container is borrowed 2. When a container is borrowed
reCIRCLE/reTURN Station	NFC	Return on the go	3. When a container is returned
Relevo	QR Code	Return on the go	2. When a container is borrowed
Repeater	App	Return on the go/from home	2. When the containers are borrowed 3. When the containers are returned
Reusables	QR Code	Return on the go	3. When a container is returned
Reusabol	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned
Ringo	QR Code	Return on the go	3. When the container is returned 4. How many times the container has been used 5. When the container needs to be recycled
ShareWares	QR Code	Return on the go/from home	3. When the container is returned
Suppli	QR Code	Return on the go	3. When the container is returned
Trashless Takebacks	QR Code	Return on the go	15. The environmental impact of using the reusable container
Usefull	QR Code	Return on the go	2. When a container is borrowed 3. When a container is returned 15. The environmental impact of using the reusable container
ValidFill	RFID	Refill on the go	1. The container(s) being used 4. Who has the container 5. How many times the container has been used
Vessel Works	QR Code	Return on the go	2. When the container is borrowed 3. When the container is returned 15. The environmental impact of using the reusable container
Vytal	QR Code	Return on the go	2. When the container is borrowed 3. When the container is returned 4. Who has the container

Appendix B

Types of information tracked using the different types of technology.

	Information Tracked	QR Code	RFID	NFC	Barcode	App
1	**The container(s) being used**	☒	☒	☐	☐	☐
2	**When the container is borrowed**	☒	☒	☒	☐	☒
3	**When the container is (due to be) returned**	☒	☒	☒	☒	☒
4	**Who has the container(s)**	☒	☒	☒	☐	☐
5	**How many times the container has been used**	☒	☒	☐	☐	☐
6	**When the container needs to be recycled (e.g., has been used X times, is X months old)**	☒	☒	☐	☐	☐
7	**How many times the container has been washed**	☒	☐	☐	☐	☐
8	**How the container has been washed**	☒	☐	☐	☐	☐
9	**When the container was last filled**	☒	☐	☐	☐	☐
10	**Who last filled the container**	☒	☐	☐	☐	☐
11	**Where the container has been**	☒	☐	☐	☐	☐
12	**Who originally made the container**	☒	☐	☐	☐	☐
13	**What material(s) the container is made of**	☐	☐	☐	☒	☐
14	**What product(s) have previously been in the container**	☐	☐	☐	☒	☐
15	**The environmental impact of using the reusable container**	☒	☐	☐	☒	☐

Acronyms & Abbreviations

AI - Articficial Intelligence

AMRC - Advanced Manufacturing Research Centre

ATP – Adenosine Triphosphate

BEIS – Department for Business, Energy & Industrial Strategy

BRC – British Retail Consortium

DRS – Deposit Return Scheme

EC – European Commission

EFSA – European Food Safety Authority

EMF – Ellen MacArthur Foundation

EPR – Extended Producer Responsibility

EPS – Expanded Polystyrene

EU – European Union

EUPIA – European Printing Ink Association

FCM - Food Contact Material

FlexICs - Flexible Integrated Circuits

FMCG – Fast Moving Consumer Goods

HACCP - Hazard Analysis and Critical Control Point

HDPE – High Density Polyethylene

HMRC – His Majesty's Revenue and Customs

HVM - High Value Manufacturing

ISO – International Organization for Standardisation

IGD – The Institute of Grocery Distribution

LCA – Life Cycle Assessment

MRF – Material Recycling Facility

NFC – Near Field Communication

NIR -Near-Infra RED

OPRL - On-pack recycling label

PBT – Polybutylene Terephthalate

PET – Polyethylene Terephthalate

PIM - Plastic Implementation Measure

PP – Polypropylene

PPWD – Packaging & Packaging Waste Directive

PRF – Plastics Recycling Facility

PS – Polystyrene

PVC – Poly Vinyl Chloride

QR code – Quick Response code

RECOUP – RECycling Of Used Plastics Ltd

RFID – Radio Frequency Identification

SSPP – Smart Sustainable Plastic Packaging

SUP – Single-Use Plastics

TRACE - Technology-enabled Reusable Assets for a Circular Economy

TVC – Total Viable Count

UKPP – UK Plastics Pact

UKRI - UK Research & Innovation

UV – Ultraviolet

WEEE – Waste Electrical and Electronic Equipment

WFD – Waste Framework Directive

WRAP – Waste and Resources Action Programme

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