REUSABILITY BY DESIGN

Summary

PROJECT TRACE

This 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 (SSPP) funded industrial research project lead by Pragmatic Semiconductor Limited. This document has been produced as a result of a work package focused on reusable packaging design.

Project TRACE aimed to address some of the challenges that currently prevent large-scale reuse. Work packages 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.

TRACE project partners included:

Pragmatic RECOUP University of Sheffield AMRC Cymru KME Ken Mills Engineering Ltd

A Smart Sustainable Plastic Packaging (SSPP) project funded and supported by:

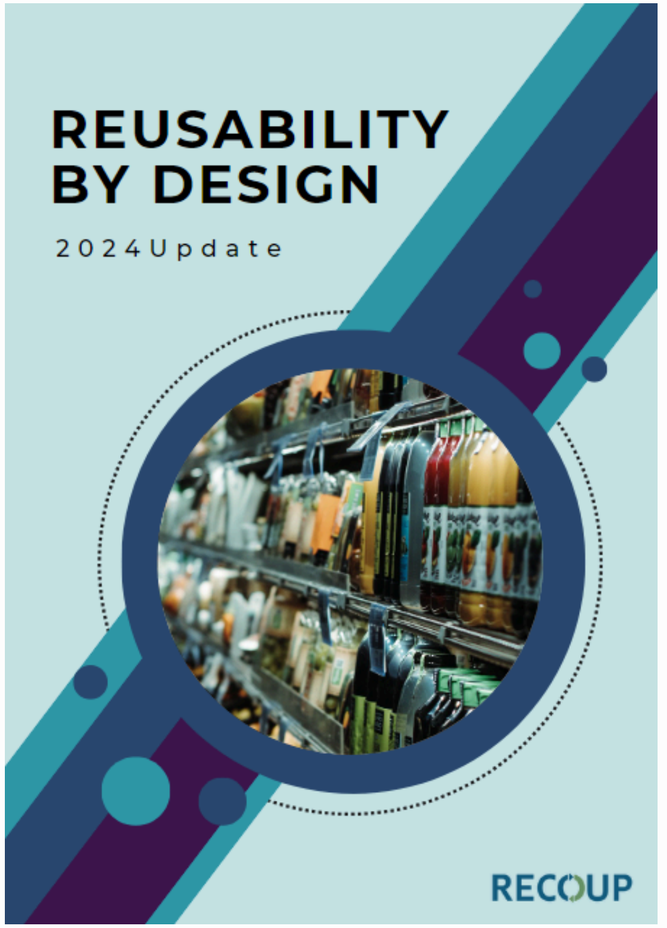
UKRI UK Research and Innovation

Introduction

The ‘Reusability by Design’ guidance, first published in 2023, 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. It incorporates input from various stakeholders including packaging manufacturers, packer/fillers, brands, retailers, consumers, waste management companies, plastic reprocessors, and service providers.

This document provides a summary of ‘Reusability by Design’ guidance, highlighting the main focus areas to assist with the design of reusable packaging such as:

- Designs to avoid
- Material choice
- Tracing technologies
- Decoration and Branding
- Standardisation
- Consumer
- Food safety
- Washing
- Transport
- Recyclability
- Sustainability
- Visual Summary



Designs to avoid

Some design features are not suitable for reusable packaging due to specific requirements associated with multiple use e.g. washing, transportation, consumer interaction. For example, while reusable packaging needs to look familiar to the consumer, it should be clear that it is not disposable and intended for reuse.

Appears disposable

Surfaces that are easily scratched/stained

Elements that can accumulate water and bacteria - “Bug traps”

Too robust for the application

Heat/moisture sensitive elements

Design that “transports air” (non-stackable/foldable)

Small, easy to break elements

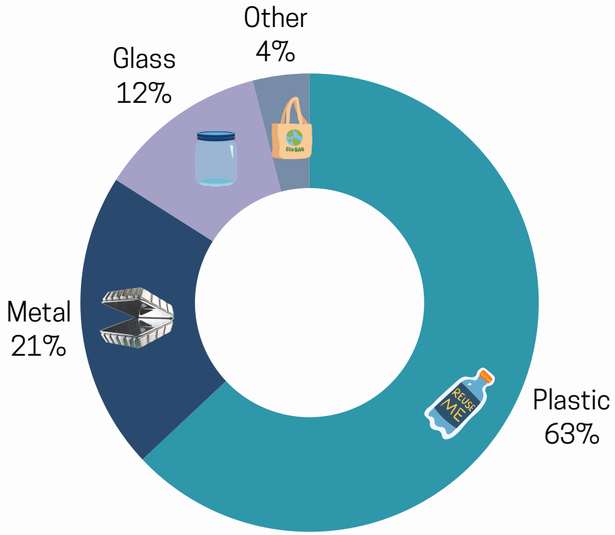
Non-recyclable

Luxury/too specific

*Images are AI generated

MATERIAL CHOICE

Materials used in reusable packaging



RECOUP Reuse Database

The main materials used in the production of reusable packaging are plastic, metal, and glass. All of these materials have an established recycling route and are collected kerbside. 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.

Polypropylene (PP) is the first choice polymer in reusable packaging, followed by PET and HDPE, with a small representation of other plastics, e.g., PBT and Tritan™. PP performs well in standard washing conditions, is durable, recyclable, and low cost.

5 PP 1 PET 2 HDPE 7 OTHER

FORMAT. SHAPE. SIZE.

- Replicate existing formats, sizes, and shapes but with increased durability.
- Supply chain requirements are a key consideration, e.g., filling, cleaning, and logistics.
- Product visibility within the packaging depending on the product
- Reusable closures with a reusable body are a preference, although this needs to be suitable for the whole supply chain.
- Tamper-evident packaging requirements need to be considered.

Design requirments

Resource efficiency

- Optimised weight
- Durable
- Renewable/recycled content

Functional performance

- Can retain product shelf-life
- Can withstand hot wash and commercial detergents
- Stain -resistant
- Shatterproof
- Displays minimal signs of wear
- Keeps shape

Outer surface

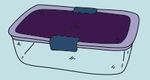
- Capability for printing/decorating/labelling
- Resistance to scratching or wear from phases of reuse

Visual performance

- Clear material for product display and cleaning reassurance
- Does not degrade though multiple use cycles
- Coloured if used for highly staining products

End-of-life

- Recyclable
- Mono-material



DECORATION AND BRANDING

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**

Temporary labels may be best way to decorate and brand reusable packaging. These still need to be kept to a minimum, be easily removed and be recyclable.

Reusable packaging might require innovative approaches to branding.
Embossing, washable inks, shape, format or colour and digital assets such as QR codes or RFID can be used to brand reusable packaging.

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.

Coca-cola bottle distinctive shape is recognised by consumers even without a label

The History of the Coca-Cola Contour Bottle

STANDARDISATION

"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."

Reusability by Design survey respondent

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

- Increase **cleaning** efficiencies at scale for the same packaging formats.
- **Reduce allergen** and cross-contamination risks if utilised by specific product sectors.
- **Return logistics** – quicker return cycles and smaller pooling volumes, space efficiency.
- Aid **consumer adoption** and build trust – same packaging/system across brands/retailers could increase the number of reuses as it's 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.
- **Improve recycling** at the end-of-life.
- Optimise **environmental impact.**

Consumer

Multiple studies indicate a strong consumer interest in minimising their environmental footprint through the use of reusable packaging. Design plays a crucial role in facilitating the shift from single-use containers by aligning with consumer needs. Key design aspects highlighted by consumers include:

- Convenience in storage, such as stackability
- Clear differentiation from single-use packaging, like distinct colours
- Durable and high quality
- Lightweight for effortless transport
- Practical functionality, like easy opening and closing.

BALANCE

Attractive, novel and pleasant to use

Not too beautiful so customer wants to keep

Looks clean and new

No extra cost

Ergonomic and inclusive

No extra effort

Easy and quick to use and return

Easy to store and transport

Designing for consumer needs means finding a balance between sometimes contradictive requirements

Food Safety

Food contact materials

Packaging materials must comply with food contact legislation if the reuse system is aimed at food or beverage products. Primary food contact regulations are listed below:

- EC 1935/2004 applies to all materials in contact with food.
- EC 10/2011and subsequent revisions, sometimes known as the PIM (Plastics Implementation Measure). This only applies to plastic.
- EC 2023/2006 Good Manufacturing Practice applies to all materials in contact with food.

There are specific regulations for inclusion of recycled content, intelligent materials/tech assets.

- Regulation 450/2009 applies to active/intelligent materials
- Regulation 282/2008 for recycled plastic processes.

Labelling and printing

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.

Allergens

Risk mitigation::
Washing: correctly set up cleaning protocols can efficiently remove allergens.
Labelling: according to The food information regulation (2014), PPDS amendment
Traceability: tech assets can help to monitor packaging journey and provide analogue to "batch traceability".
Design: Standardisation - specific format for specific products, and easy to clean shapes.

Design properties suitable for reuse

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.
Staining and taint -Staining and taint are complex issues that might severely affect the acceptance of reusable packaging by the consumer and retail.
Migration - Polymer and packaging specialists will be able to help and assess suitability of formulations for specific reuse applications to make sure only components with required stability are used.

Washing

Design considerations for the washing process:

- No lips, ridges, holes or ‘bug traps’: elements that can accumulate water and bacteria.
- 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 other formats, coloured surface can help to mask stains while visual evaluation for cleanliness/product quality can be done via top.
- Safe for multiple uses.
- Standardised packaging formats for efficient washing processes.
- Looks clean for the customer, with inbuilt cleaning indicators if possible.

Wash cycle up to 60 ˚C
Rinse cycle up to 90 ˚C

Commercial strength alkaline detergent is usually used. The main ingredient is sodium hydroxide (caustic soda).

Wash - detergent
Rinse - rinse aid
Disinfect -sanitiser
Dry - additional drying step is vital for plastic packaging due to low heat retention and surface properties.
3-10 mins per cycle

TRANSPORT

Beneficial for environmental impact and costs	Beneficial for product protection and safety
Protect product from damage and loses	Cushioning, protective structures
Lightweight, material efficient	Durable to withstand movement and handling: impact, puncture, surface fraction
Stackable, foldable, nestable	Stackable
No closures	Durable secure closures
Optimised for maximum cube utilisation , avoid shipping air, “square bottle”	Optimised for product properties
Automation and technology for increased efficiency	Automation and technology for traceability and contamination prevention
Labelling minimised, digitalised, automated	Marked with all necessary information: content, packaging journey, handling instructions.
Standardised, integrated with secondary and tertiary packaging and servicing equipment e.g. washing trays	Optimised for the product

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

Tracking Technologies

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.

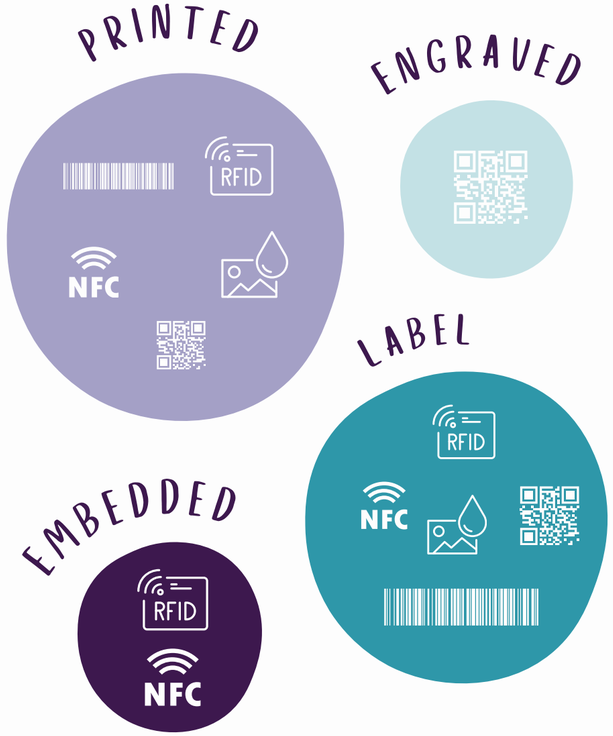
RFID is a technology that uses radio waves to passively identify a tagged object. RFID tags are comprised of an integrated circuit, an antenna and a substrate. The RFID tag holds identifying information in unique machine-readable codes. UHF (Ultra-High Frequency) RFID operates in the frequency band (860MHz - 960MHz and is the most common type of RFID tag. UHF RFID particularly suitable for reusable packaging sytems with high volumes, enabling fast and efficient inventory management. 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 such as mobile wallets or reusable packaging.

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.

What can be tracked:

- When a container is borrowed and returned, who has the container, container location.
- Container's material and when it needs to be recycled.
- How the container is washed and how many times.
- 5 Number of reuse cycles.
- Environmental impact.
- Who filled the container , when the container was last filled?
- What products have been in the container previously.

TECH ASSETS APPLICATION



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.

LABELLING:

- ▪ Easy and economical to apply to various packaging formats.
- ▪ Labels can be replaced if damaged.
- ▪ 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 label securely stay on the pack during use cycles.

- ▪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.

EMBEDDING:

- ▪ 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.

- ▪ 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.

Alternative application technologies for RFID tags are over moulding and incorporating RFID chip into removable parts such as lids.

Recyclability

Design for recyclability

Design principles maximising reusable packaging recyclability at the end-of-life will be similar to those of single-use packaging:

- Use of mono-material or mixed material of the same type is preferable.
- If mixed materials are used, it is important to make sure they can be easily separated.
- Use of currently widely recyclable polymers with proven end markets.
- Use of unpigmented polymers as these have the highest recycling value and the widest variety of end uses.

Increased durability might create a challenge during the sorting process. If reusable packaging is made of non-mainstream polymer, it will need to be captured through a closed loop system.

Decoration and branding elements need be recyclable.
It is important that reuse is not confused with recycling and packaging goes through a number of cycles before being recycled. Information about material recyclability needs to be easily available to the users of the system.

Circularity

Material traceability offered by reusable packaging presents a unique opportunity for recycling.
Information about products that were in contact with packaging, cleaning process confirmation, number of reuses and packging journey details, provided by tech assets, can support food-grade recycling.
Reusable packaging captured for recycling during inventory stage can be reconditioned or recycled via closed loops for the same application.
Tech assets such as RFID can also improve sorting efficiencies.

Tech assets recyclability

Tech assets can add a level of complexity to the recycling process.
The reusable packaging design needs to consider the system where the packaging will be circulating. For tech-enabled packaging entering household waste stream tech elements need to be easily removable in the recycling process.
Closed-loop systems can allow more flexibility, e.g. separation process can be incorporated in the inventory and tech assets can be recycled e.g. via chemical recycling.

Sustainability

Reusable packaging should be designed not for maximum durability but for sufficient durability based on the system's actual reuse rates. The cost and environmental impact of reusable packaging depends on balancing durability, material choice, and the realities of consumer behaviour and system functionality.

Lightweight but durable.
Renewable or recyclable feedstock.
Environmentally sound production process and components such as dyes/additives.

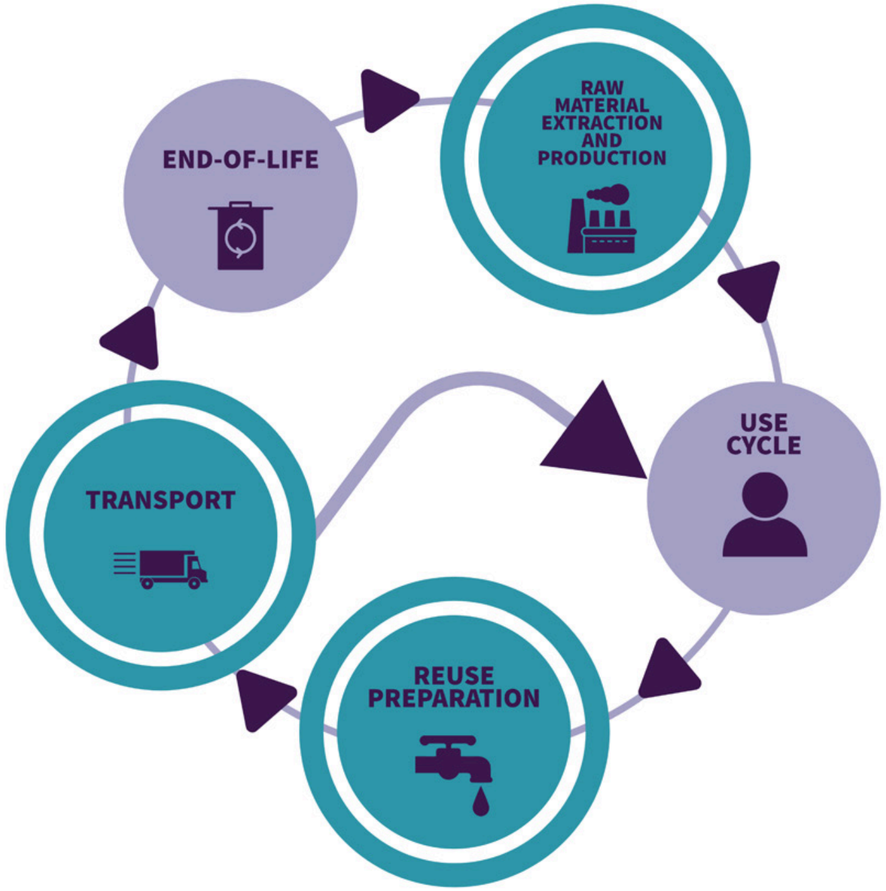
Stackable, durable, lightweight.
Sustainability of the whole system: product-packaging, secondary/tertiary packaging.

Easy to clean and maintain as new appearance.

Optimised for maximising the number of reuses.

Sustainable tracking technologies.

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



Environmental hot spots of reusable packaging

Mitigating "hot spots" impact can lead to higher environmental gains.

DESIGN

MANUFACTURING

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

REUSE PREPARATION

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

RETAIL

- Formats, sizes and shapes suitable for current infrastructure e.g. filling lines, storage.
- 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.

END-OF-LIFE

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

USE

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

TRANSPORT

- 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.

SUMMARY

OTHER RESOURCES AVAILABLE

A number of other publicly available documents have been produced as part of the TRACE project, these include:

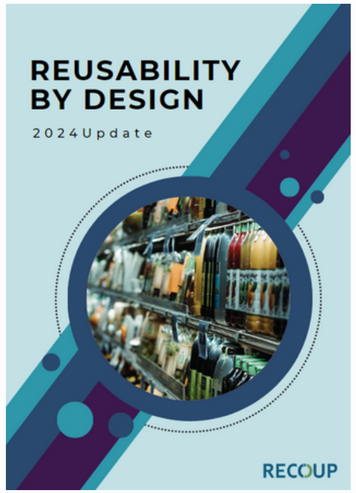
Reusability by Design guidance (including a summary document) - www.recoup.org/reuse

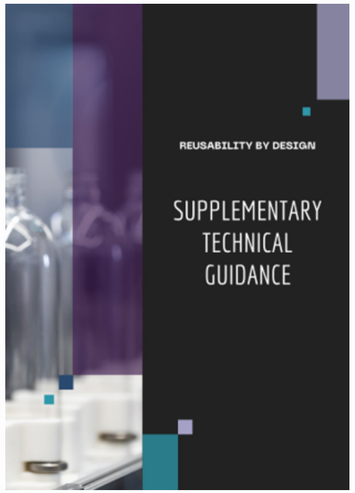
Reusability by Design - Supplementary Technical Guidance - www.recoup.org/reuse

Technical and environmental assessment of end-of-life scenarios for plastic packaging with electronic tags. Ahamed et al, 2024 - www.sciencedirect.com

Understanding Consumer's Willingness to Engage with Digital Reuse Systems. Matthews & Webb, 2023 - https://www.mdpi.com

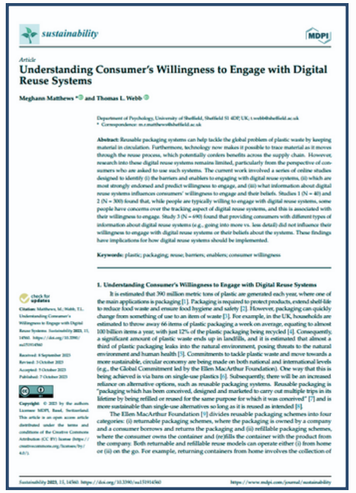
Does Providing Information about the Environmental Benefits of Reusable Packaging Systems for Consumer Products Increase Consumers' Willingness to Use Them? Tonikidou&Webb, 2024 - https://www.mdpi.com






Resources, Conservation & Recycling

Technical and environmental assessment of end-of-life scenarios for plastic packaging with electronic tags


sustainability

Understanding Consumer's Willingness to Engage with Digital Reuse Systems


sustainability

Does Providing Information about the Environmental Benefits of Reusable Packaging Systems for Consumer Products Increase Consumers' Willingness to Use Them?

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