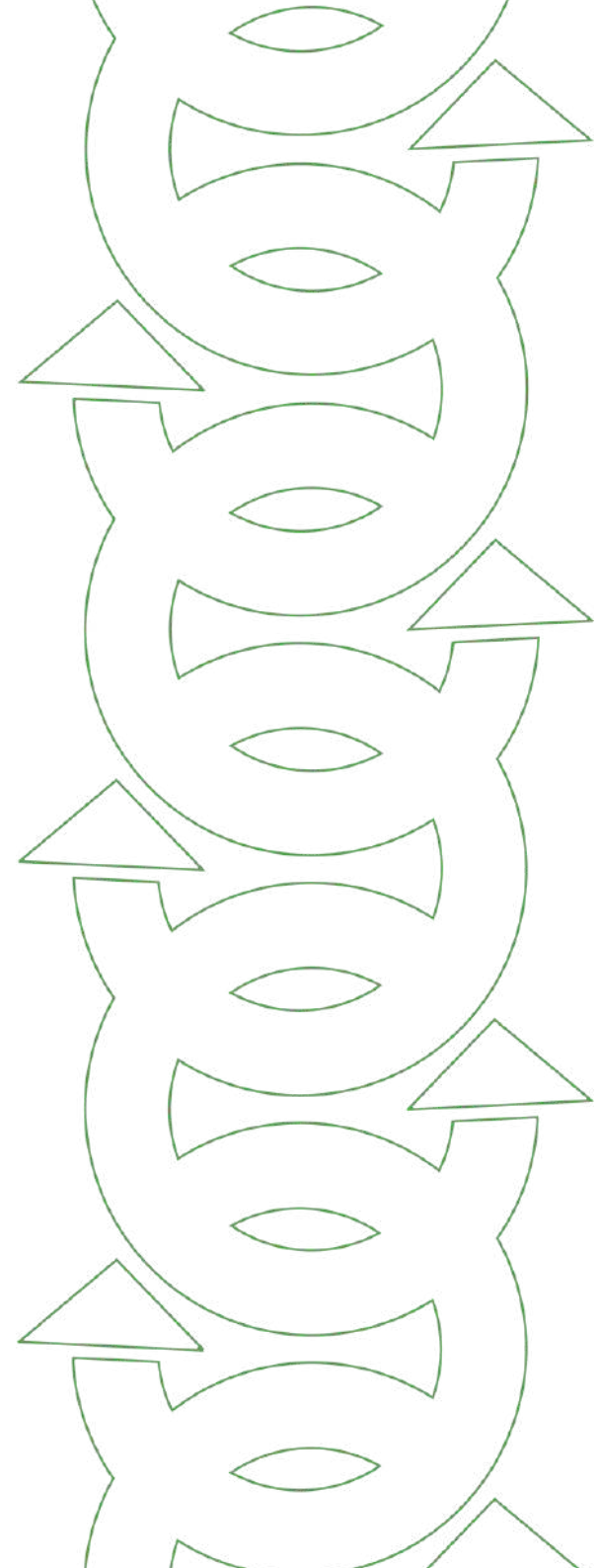


Case study: Reusable packaging systems incorporating RFID technology

2024

RECOUP

Leading a more circular
plastics value chain



About RECOUP

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.



The content and analysis contained in this report is based on the information received. While every effort has been made to ensure the accuracy of the contents of this publication, RECOUP cannot accept responsibility or liability for any errors or omissions. Opinions expressed by external contributors may not reflect RECOUP positions. Recommendations provided herein are offered for the purpose of guidance only and should not be considered legal advice.

All information contained in this report will remain the subject of copyright and any reference made to this document must ensure that RECOUP is credited.

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:



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



RFID technology and reusable packaging

Supply chains are becoming increasingly reliant on digital technologies to capture data to provide item level information to support supply chain efficiencies and optimisation. This data can also be utilised to determine environmental impacts through tools such as life cycle assessment (LCA).

Traceability of packaging throughout reuse cycles is of particular importance in order to monitor factors such as:

- Real-time visibility of packaging journey through the lifecycle.
- Accurate data e.g. reuse rates, asset management etc.
- Quality control e.g. packaging condition, allergen presence etc.
- Environmental performance.

The traceability technologies utilised by reusable packaging need to meet certain design and functionality requirements:

- Durability through several uses.
- Compatibility with packaging end-of-life scenarios, e.g. recycling.
- Ability to provide 'real-time' data.
- Data security.
- Integration across supply chain systems and platforms.

Reusable packaging and RFID

Radio Frequency Identification (RFID) and barcodes are the two main types of technologies currently used for tracking and tracing items such as reusable packaging.

Barcodes represent data in a visual, machine-readable format. 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 they can be embedded in the tracked object.



All technology types have specific advantages depending on the intended application.

Modern RFID tags can be thin, flexible, shock and heat resistant, use various substrates, have customisable functionality, low costs, and be compatible with highspeed 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.

In conclusion, 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.

Key areas where RFID tag can assist wider adoption of reusable packaging



Tracking of the reusable packaging throughout the reuse cycle.



Confirmation of cleaning status and food safety requirements.



Data on the number of reuse cycles achieved.



Supply chain collaboration and communication.



Support consumer adoption of reusable packaging.



End-of life/end of reuse cycle capture, sorting and processing data and material traceability.

Applying RFID technology to reusable packaging

Incorporating RFID capabilities with reusable packaging improves functionality by providing valuable data to operate efficient reuse systems.

RFID tags can be applied to packaging incorporated into labels or embedded into the packaging. There are pros and cons to both of these methods.

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.



RFID applied via label

Pros	Cons
Easy and economical to apply.	RFID tag is more exposed and can be damaged during washing, transport, and user interactions.
Labels can be replaced if the tag is not functioning.	Application of the tag has to align with food contact safety regulation, only pre-approved adhesives for reusable food packaging applications can be used.
Adhesive can be used that ensure tags are easily removed during the recycling process.	



RFID embedded in packaging

Pros	Cons
RFID tag is protected during washing, refilling, transport, and sorting.	Failure of the tag can make the whole container unusable.
Packaging content is protected from interaction with the tag and adhesives.	The embedded tag may affect the recycling process.
The RFID tag cannot be removed by consumers or throughout the supply chain.	Compatible only with certain moulding processes and can add an additional manufacturing step.
	Tag might need additional protection during the embedding process, e.g. encapsulation in a different polymer.

Recyclability and sustainability of RFID tags

The benefits of applying tracking technologies 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.

Recyclability and recoverability of 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 packaging¹.

There are two pathways for tag removal from the packaging which can be considered: removal using 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 achieved², which is important to maintain traceability required for reuse applications. 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 packaging.

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 RAND¹, 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 and do not represent large volumes of material.

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.

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.

¹[Study on RFID tags and the recycling industry.](#)

²[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](#)

Case studies

RECOUP spoke to a range of companies to understand more about how they utilise RFID enabled reusable packaging, the data it provides them, and the benefits and challenges they see in using RFID technology.



kleen hub



circ ular & CO.



Fyllar



re-universe™



Located in the Netherlands, Fyllar have developed smart solutions for the refill market.

Packaging type & current target market

- Pouch & cap.
- Current focus on laundry detergent.

RFID enabled packaging

- RFID is located in the cap of the packaging, sitting inbetween two of the injection moulded parts.
- Packaging uses UHF RFID tags.
- Cap can be programmed to suit customer needs, for example linking it to specific products, lifetime requirements or number of uses.

How is the data collected by RFID used?

- Tag can provide information on product best before dates, when and what product was refilled, where it was refilled, amount of plastic saved and refill rates.
- Retailers get access to an online dashboard displaying how often and what products are being refilled, as well as amount of plastic saved.
- Consumers can access data on number of reuses/amount of packaging saved.
- Can connect RFID to loyalty point systems.

What do Fyllar see as the main benefits of using RFID?

- Traceability.
- Other options such as QR codes are subject to wear and tear and would need to directly align with readers, RFID can be hidden and easily identified by the refill machine.



www.fyllar.com

Do Fyllar see any challenges to the use of RFID?

- Added cost and complexity in production to add an RFID tag to the packaging compared to a barcode/QR code which can be printed on packaging.



Circular&Co are striving for global change, by making Circular Design the new standard. They design and manufacture a range of award-winning, Circular Reusables and Returnables, leading the transition away from single-use forever.

Packaging type & current target market

- Cups (PP) for hot and cold beverages.
- Replacing single-use cups at events, venues, attractions, offices, universities and engaging in open loop high street pilots.

RFID enabled packaging

- RFID is incorporated on the base of the cup via an ultra sonically welded cap with the RFID bonded inside.

How is the data collected by RFID used?

- No customer data is taken as part of the RFID use.
- Data used to track stock levels and cup movement within the supply chain and 'borrow cycle' e.g. pick up and drop off points.
- RFID reading points across lifecycle include production line (to check it is working), stock control, scanned at point of borrow, scanned at return point, scanned at wash to confirm return.
- Consumer does not interact with the RFID, only for supply chain use.

What do Circular&Co see as the main benefits of using RFID?

- Traceability of the supply chain but also the customer 'borrow' journey.
- Ability to quantify a packaging's journey and lifecycle e.g. carbon impact.
- Ease of stock taking.
- Speed - ease for staff to scan return bins rather than counting individual cups.
- Customer perception - adds perceived value and increases return rates.



circularandco.com

Do Circular &Co see any challenges to the use of RFID?

- Some customers have the perception that they are being monitored by RFID.
- The RFID will enter the generic PP recycling stream but in such minor percentages it's not generally regarded as a problematic contaminate.
- Quality control - a small but valid % of RFID don't work and increases reject rates and packaging waste.

kleen hub

Located in Denmark, Kleenhub have developed an app and depositless system for ultimate consumer convenience when using reuse systems.

RFID enabled reusable packaging system

- Kleenhub do not own packaging but operate the reuse system/technology.
- Focus on coffee cups at the moment either with dishwasher safe stickers incorporating or embedded in cup base.
- UHF RFID - focus on high volumes at coffee chains, events, festivals etc.

Where are the RFID reading points across the reuse cycle and how do you use the data?

- RFID antenna at payment point which links the packaging to a credit card.
- Readers at drop off points/washing stations.
- System tracks the cups which can be used for logistics inventory management - assigning stock to different bars etc.
- Also collect data on number of lifecycles so can show environmental data.
- Website where customers can see return rate, average return time etc.

What do Kleenhub see as the main benefits of using RFID?

- Traceability - knowing where inventory is, losses, climate accounting etc.
- Convenience - easy to connect to payment method.
- Return ease - can scan 1000's of cups in a second, good for high volume quick return requirements e.g. stadiums.

Do Kleenhub see any challenges to the use of RFID?

- Challenges for recycling and end-of-life of RFID enabled reusable packaging.
- Cant guarantee that packaging is microwave safe.



www.kleenhub.com

Consumer interaction with the technology

- No interaction from consumers with the RFID tag. A QR code on RFID label can be used to see how much time is left to return the cup, sign up for reminders or to access a map of return points.
- No app required, packaging is linked to customer credit card. If the cup is not returned within 7 days then a charge is applied.



re-universe provides a digital returns platform, incentivising the customer through deposit returns or penalty holds. Providing comprehensive data and insights throughout the entire process.

RFID enabled reusable packaging system

- First company in the UK to deliver UHF RFID led reuse projects. These can be found at Blenheim Palace and the Eden project.
- re-universe do not own packaging but operate the reuse system/technology.
- Primary focus is food and drinks containers utilising UHF RFID.

Where are the RFID reading points across the reuse cycle and how do you use the data?

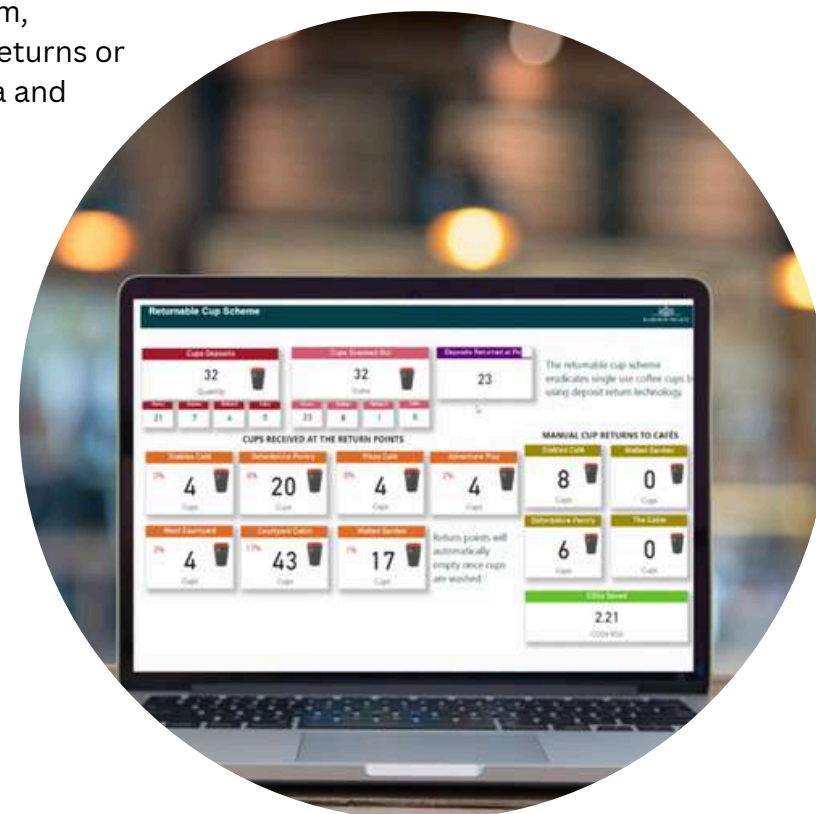
- RFID reading points at point of sale, point of return, washing stations and logistics/redistribution centres. This data is constantly being validated via an AI engine for fraud, behaviour patterns and quality.
- Data monitors and measures scheme effectiveness such as cup usage and accurate return rates, it also allows identification of key return hotspots and when return points need emptying.
- The data collected is provides real-time insights into the lifecycle of each item - helping to improve efficiency and sustainability.

What do re-universe see as the main benefits of using RFID?

- Enabling an easier user journey, validating returns and cutting out unnecessary steps that cause friction.
- Accurate item tracking.
- Data accuracy.
- Enhanced operational efficiency.
- Ability to provide real-time feedback on return and reuse rates.
- Technology helps identify patterns and optimise the reuse process.

Do re-universe see any challenges to the use of RFID?

- Initial cost of implementing RFID technology, including the tags and reading infrastructure.
- Potential user concerns regarding data privacy and security.



re-universe.com

Consumer interaction with the technology

- Process of consumer interaction with the system is seamless and user-friendly, requiring minimal interaction beyond returning the item.
- The non-mobile offering uses RFID to validate return of the container, instantly lifting hold or repaying deposit without the need for registration or use of an app.
- Accurate real time data is client and customer facing with access to raw data alongside an easy to view dashboard.

Costs vs. benefits of incorporating RFID

RECOUP also asked companies how they balance the increased cost of using of RFID and associated technology with the benefits, here is a summary of the responses.



Tag cost

The cost of the RFID tag itself is not inhibitive, the tags themselves are low-cost.



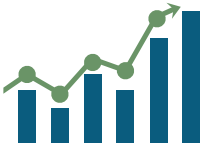
Functionality

RFID improves the functionality of reusable packaging.



Technology

The technology that sits behind the reuse system is the most expensive part of RFID use. However, the data and insights it provides are invaluable.



Data insights

Real time data on stock levels and stock flow helps to keep overall stock lean and saves on inventory costs.



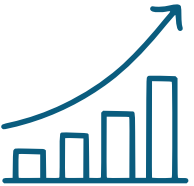
Looking to the future

RFID is seen as one of the main solutions to future proof businesses with long-term benefits and efficiencies gained through its use.



Supply chain costs

Improved return rates, rich data and optimised logistics lead to greater overall cost savings.



At scale comparability with single-use

At scale the cost of RFID enabled packaging and their systems will come down to be comparable with single-use.



Sustainability benefits

Enhanced functionality and tracking of the reuse system and improved efficiencies lead to sustainability benefits.

Additional examples

Company	About	Packaging type	RFID information on website
<p>CLUBZERØ www.clubzero.co</p>	<p>“CLUBZERØ was launched in 2018 to meet the demand of customer convenience by providing a truly sustainable, zero waste alternative to single-use.”</p>	<ul style="list-style-type: none"> • Cups (hot and cold) • Trays • Pots • Sushi box 	<ul style="list-style-type: none"> • Smart tracking providing real time environmental insights. • Track data through personalised CLUBZERØ dashboards.
<p>Algramo www.algramo.com</p>	<p>“Making circularity desirable and accessible to everyone. Our purpose to empower everyone to radically change consumption habits and secure a thriving future for current and next generations.”</p>	<ul style="list-style-type: none"> • Bottles • Pouches 	<ul style="list-style-type: none"> • RFID technology keeps track of refills and avoided plastic amount. • Smart packaging links the packaging with dispensers and the product to be dispensed ensuring product quality and traceability. • Smart packaging comes with a unique intelligent ID that is associated with product bought.
<p>MIWA www.miwa.eu</p>	<p>“Since 2017, MIWA has been developing smart solutions that help customers, retailers and manufacturers to buy, distribute and sell goods while minimising packaging waste.”</p>	<ul style="list-style-type: none"> • Reusable 12L capsules • Food container 	<ul style="list-style-type: none"> • Container equipped with integrated NFC chip that ensures full traceability. • NFC chips in capsules enable continuous monitoring of product shelf life and prevent cross-contamination. • Digital tracking of whole lifecycle.

Company	About	Packaging type	RFID information on website
<p>SwapBox www.swap-box.com</p>	<p>“At SwapBox, we provide a comprehensive suite of eco-friendly solutions designed to meet the needs of businesses looking to adopt reusable packaging.”</p>	<ul style="list-style-type: none"> • Food packaging • Coffee cups • Festival cups • Crates for transport 	<ul style="list-style-type: none"> • RFID enabled packaging enables seamless integration with washing and packaging rental services. • System utilises smart bins.
<p>Cuploop cuploop.com</p>	<p>“Vision - A future where there is no plastic waste. We see Cuploop Smart Kiosks as a critical part of a smart city infrastructure plan, located just like regular trash bins to use on the go. A convenient & integrated network to collect reusable containers.”</p>	<ul style="list-style-type: none"> • Cups 	<ul style="list-style-type: none"> • RFID adhesive tags and cups of all shapes and sizes. • Using RFID technology alongside smart kiosks offers efficiency and security.
<p>Quppa www.quppa.be</p>	<p>“Disposable cups are so... passé. We think it can be done better and developed Quppa, an easy system for reusable coffee cups. We want to realise the transition to reusable packaging on a large scale.”</p>	<ul style="list-style-type: none"> • Coffee cup 	<ul style="list-style-type: none"> • All cups are uniquely identified with RFID. • RFID technology allows each cup to be linked to users accounts and measure the number of reuses.

Company	About	Packaging type	RFID information on website
<p>Validfill www.validfill.com</p>	<p>“ValidFill uses the magic of RFID technology placed on drink ware to deliver a new level of intelligence and business opportunity to beverage dispensing. “</p>	<ul style="list-style-type: none"> • Drinkware 	<ul style="list-style-type: none"> • RFID embedded into the drinkware to store information that allows the drink dispenser to read the value of each mug/cup prior to dispensing the beverage.
<p>1Less www.1less.org</p>	<p>“We have invented a technical solution to offer a sustainable circle economy system for B2B companies....developing a re-usable set of cups, plates and cutlery for use in all aspects of food delivery.”</p>	<ul style="list-style-type: none"> • Cups • Plates • Cutlery 	<ul style="list-style-type: none"> • RFID tags are part of the cups and can be separated and recycled fully. • RFID tags and “intelligent” garbage cans with RFID sensors, separating normal waste and reusable pieces of cups & plates.
<p>Reusables.com</p>	<p>“We decided to break down the barriers of reuse and design a new solution that is reshaping the way we consume and how businesses package food. Today, we are working with enterprise food service operations across North America and over 100 food businesses in Canada.”</p>	<ul style="list-style-type: none"> • Food packaging 	<ul style="list-style-type: none"> • UHF-RFID tags • Technology platform tracks unique container level data ensuring high return rates. • Smart bins for seamless returns, traceability and zero contamination.

Company	About	Packaging type	RFID information on website
<p>r.world reusables www.rworldreuse.com</p>	<p>“All of us at r.World share the same vision—to build the national infrastructure, platform, and movement for the reuse economy, to end single-use addiction, and to create a more sustainable future.”</p>	<ul style="list-style-type: none"> • Cups • Food boxes 	<ul style="list-style-type: none"> • RFID enables inventory tracking and environmental impact reports.
<p>Kamupak.com www.kamupak.com</p>	<p>“We want to act as a catalyst for new circular economy solutions, both in Finland and abroad.”</p>	<ul style="list-style-type: none"> • Dishes 	<ul style="list-style-type: none"> • Strategy to leverage AI and advanced RFID to provide a future proof and friction free experience for consumers and takeaway operators.
<p>Dizzie getdizzie.com</p>	<p>“Dizzie addresses the problem of packaging waste in groceries. We are here to help any retailer or brand transition from single-use packaging to reusable packaging.”</p>	<ul style="list-style-type: none"> • Pots/tubs 	<ul style="list-style-type: none"> • RFID tags attached to the bottom of pots via label with a QR code printed on top. • Customers can interact with QR code to find out more about the product and re-order. • RFID readers throughout the supply chain provide traceability, accurate stock forecasting etc.

Other available resources

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

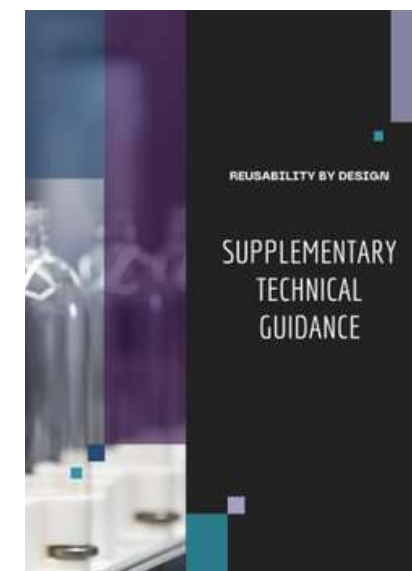
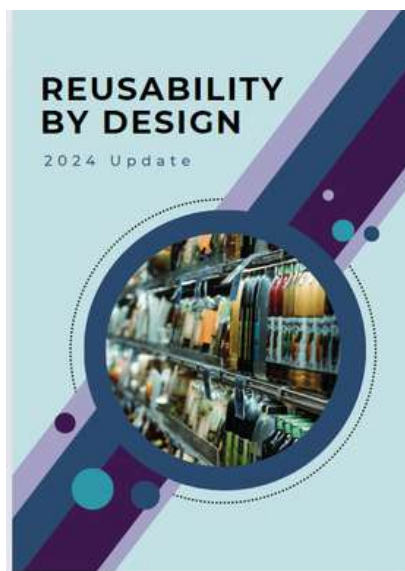
Reusability by Design guidance (including a summary document) - www.recoup.org/reuse

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>



Abbreviations and Acronyms

HDPE - High Density Polyethylene

ISO - International Organisation for Standardisation

LCA - Life Cycle Assessment

MHz - Mega hertz

NFC - Near-field Communication

PET - Polyethylene Terephthalate

PP - Polypropylene

QR - Quick-response

RECOUP - RECycling Of Used Plastics Ltd

SSPP - Smart Sustainable Plastic Packaging

TRACE - Technology-enabled Reusable Assets for a Circular Economy

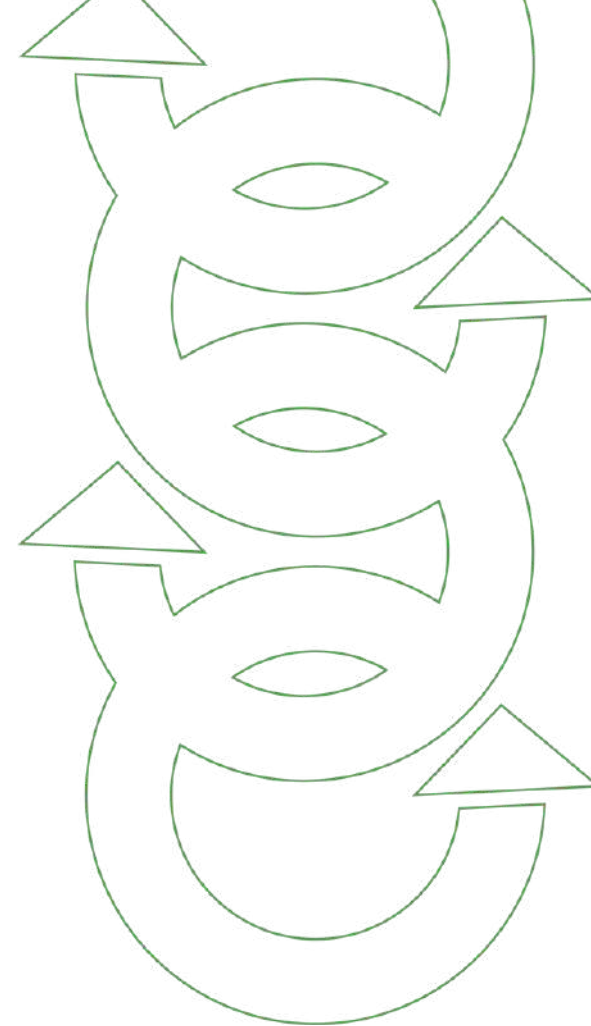
UHF - Ultra-high Frequency

UKRI - UK Research & Innovation

**1 Metro Centre
Welbeck Way
Woodston
Peterborough
PE2 7UH**

T | 01733 390021
E | enquiry@recoup.org
W | www.recoup.org

RECOUP



Registered in England & Wales Number: 02435729
VAT Registration Number: 546 5837 10
Registered Charity Number: 1072029
RECYcling Of Used Plastics (RECOUP) Limited