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 such as mobile wallets or reusable packaging.

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.

All technology types have specific advantages depending on the intended application. The scheme below illustrates the benefits of different technologies for automation and consumer engagement.

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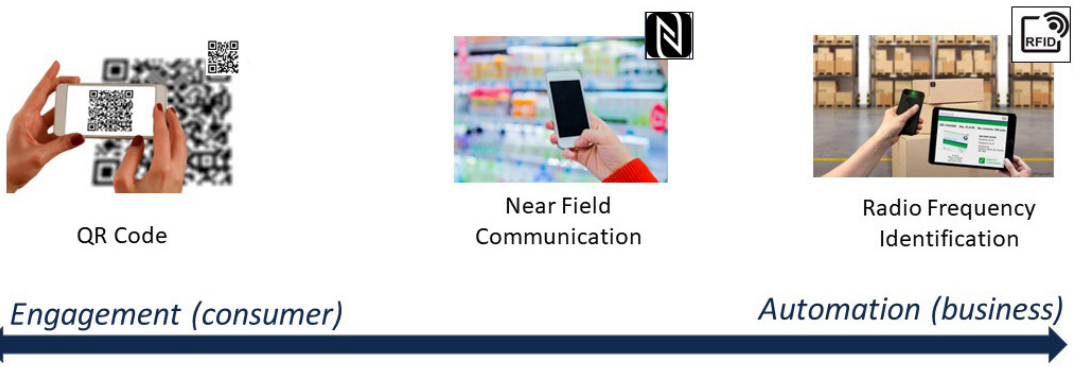


How items can be tracked by technology

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:

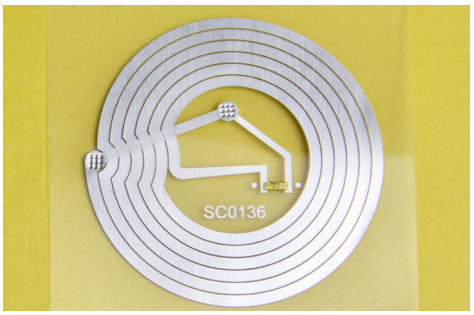
Role of RFID tags in life cycle

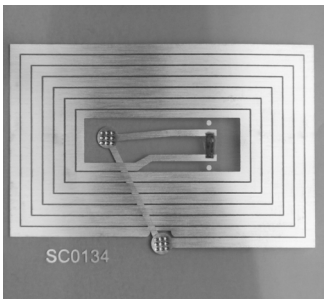
- Communication of the packaging journey
- Confirmation of cleaning status and food safety
- Information about number of reuses – 'badge of honour'
- Supply chain collaboration
- End-of-life capturing, sorting and processing

RFID application design considerations

Tag application method

RFID tags are applied to the packaging mainly via labels or embedded in the plastic. The pros and cons of both of these methods are outlined in the table below.

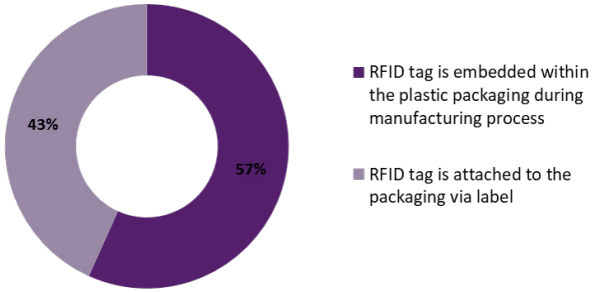




Pragmatic RFID tags

	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.



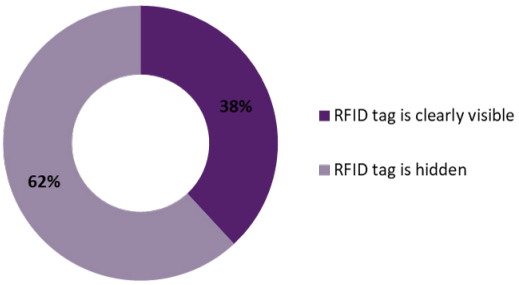
Location on the pack (visibility)

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.

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> ***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 ClubZero) analysed the environmental impact of PP injection moulded reusable cups with PE lids and RFID tag through 132 life cycles using LCA methodology. Environmental contribution of RFID is nearly negligible in most of the 18 analysed impact categories including Global Warming, reaching approximately 1-3 % in only four impact categories (freshwater ecotoxicity, marine ecotoxicity, human non-carcinogenic ecotoxicity, mineral resource scarcity). [54] [55]

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 volumes.

According to the report by RAND, use of technology instead of manual sorting to separate the tags and create RFID tags pre-concentrate 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 (Schnideritsch 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

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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.

Experiments on chemical depolymerisation of PET and RFID tags demonstrated that the process of depolymerisation was similar to the process for material without the tags. 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 aluminium as well. Chemical recycling offers 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.

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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 project TRACE University of Sheffield is currently conducting tests for the durability of tag adhesion and tag functionality throughout multiple wash cycles. Initial testing suggests tags can withstand multiple washes (both in terms of adhesion and functionality). The results of these tests will be available in the next edition of the Reusability by Design report alongside with AMRC findings from sorting demonstrator of RFID tagged packaging. AMRC work will be looking into the ways how reusable packaging can be automatically sorted using RFID tagging technology and will provide further insights about tag application methods.

[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] 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 user journey**. If 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 stage 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.

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