Digital DRS Feasibility Study

Phase 2: End-to-end system design

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resourcefutures

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Limitations

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Founded in 2006, Resource Futures is an employee-owned, independent environmental consultancy with a 30-year heritage in the waste and resources industry. Resource Futures is a certified B Corp, which means that we're committed to using business as a force for good. Our vision is to create a sustainable world. For more information, please visit our website at https://www.resourcefutures.co.uk/

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INTRODUCTION

WHY A DIGITAL DRS?

The concept of a **'deposit return scheme'** (DRS) is not new, with several national schemes operating outside of the UK. In a DRS, the consumer pays a financial deposit when buying a drink, which is then refunded when they return the empty drink container. The financial deposit incentivises the consumer to return the empty container for recycling.

In the UK, **the Governments of all devolved nations have committed to the implementation of DRS** – and are in various stages of public consultation and legislation development to determine what shape the deposit return schemes will take. The Governments' aims for introducing a DRS include: increasing recycling rates of in-scope containers, increasing the quality of recycled material to encourage closed-loop recycling and circularity, and reducing litter[1],

Despite a delay, Scotland will likely be the first UK nation to launch DRS using the traditional format of **reverse vending machines (RVMs)**. For England, Wales and Northern Ireland (NI), the way in which DRS will be implemented has not yet been set in legislation. The devolved Governments published their response to the Extended Producer Responsibility consultation in late March, where they clarified high-level intentions regarding DRS, including:

- All containers between 50ml and 3L of liquid (i.e. 'all-in' approach) are in-scope for DRS in England, Wales and NI, sold individually or as part of a multipack
- England and Northern Ireland DRS will include PET, steel and aluminium cans
- The Welsh DRS will also see glass bottles included. England and Northern Ireland will not include glass in their DRS, but they will be in scope of EPR.

The England, Wales and NI government response to the separate DRS consultation will provide more detail, and provide a firm foundation for business and local authorities to prepare for upcoming producer obligations. One potential change could be including the flexibility to allow for a **digital DRS (DDRS).**

The Welsh Government especially is interested in exploring a hybrid solution that utilises digital technology to facilitate returns at the kerbside and understanding if it can help deliver a DRS solution in Wales.

This is largely due to the fact that **the recycling context in Wales is very different from England and NI**. The Welsh domestic recycling rate exceeds that of England and NI, at 56% in Wales compared to 45.5% and 50% in England and NI respectively (in 2019-20, as calculated by Defra[2]). The Welsh Government report local authority municipal recycling rate at 64.5% (in 2021-22)[3], and aim to reach a target of 70% by 2025. The Welsh collections 'blueprint' for local authorities also consistently produces high quality recyclate. Therefore the motivation and context for DRS is very different in Wales, as it is already performing well on two of the three aims for implementing a DRS in the UK (increasing recycling rates and increasing quality of recyclate). A digital DRS in Wales could, in theory, leverage existing kerbside recycling services and infrastructure, building on the existing high recycling behaviour of householders.

We live in a digital age and packaging is no exception. A DDRS offers the opportunity to align producer obligations, Government objectives, and current digital trend in the drinks, packaging and recycling industries. However, the main question that arises is – how might it be implemented, and at what cost?

In May 2021 Bryson Recycling and the Industry Working Group on DDRS commissioned Resource Futures to explore the DDRS concept and estimate the potential costs and benefits. The Resource Futures report identified more than £3.4bn in potential cost savings in the UK over an 11-year period, compared with the RVM model, if a DDRS could be developed that met the stated policy objectives.

Nonetheless, DDRS is a relatively new concept and whilst there have been some DDRS trials in the UK, there are no nationwide schemes yet in operation. Another key question that arises is – what would the system look like? This report attempts to answer this question.

[1] Defra consultation on DRS (March 2021); [2] UK Statistics on Waste, 2021
[3] New stats show Wales upholds world class recycling rates, despite pandemic (2021)

***What is* a DDRS?**

DDRS refers to a type of DRS design that gives consumers the ability to scan a serialised code on a drinks container to redeem a financial deposit using a smart phone app. The consumer would then place the container in their existing kerbside recycling bin instead of travelling to an RVM. **Serialisation** provides a unique code for each container and is required in a DDRS to prevent the user scanning the same drinks container multiple times to fraudulently claim extra deposits. By having uniquely serialised barcodes, each deposit is linked to a single specific drinks container and can only be redeemed once.

OVERALL RESEARCH AIMS AND OBJECTIVES

Resource Futures was commissioned by the Welsh government to research and evaluate if and how a DDRS might be implemented in Wales as well as in England and Northern Ireland, and whether the purported benefits can be realised. The research was split into two phases.

Phase 1 explored key stakeholder perceptions around the design and feasibility of implementing a DDRS. The report has been published and can be accessed here. The research provided a great level of detail regarding the different approaches for a DDRS, and attempted to provide views around key questions for DDRS implementation. However, conversations with stakeholders revealed that **more clarity is needed regarding an end-to-end system design**. Until such clarity is provided, discussions of feasibility will remain varied and open-ended, largely because the basic requirements of a DDRS have not been set, and thus several solutions and pathways to implementation exist. For example, a decision made early on in the DDRS process will undoubtedly have knock-on effects further down the value chain. Stakeholders are thus struggling to engage with the concept due to the many different ways the system can take shape.

Phase 2 of the research attempts to bridge this divide, by taking a more holistic view and developing a design framework for an end-to-end DDRS. Using this framework, three potential end-to-end deigns have been developed and evaluated, based on the current approaches and views from Phase 1 of the research.

While this research attempts to consider the main approaches being discussed by DDRS stakeholders to date, it is important to note that this research is not all encompassing. DDRS is a highly topical area of research with continual developments, both in technology and data, as well as in policy.

For example, the majority of the research for this report was undertaken prior to the devolved Governments' publication of their response to the EPR consultation, which stipulated that glass beverage containers will not be included in the DRS in England and Northern Ireland. While that does not fundamentally affect the findings of this report, it highlights that DDRS is a fast moving area of research. End-to-end system designs are likely to evolve in parallel with the requirements of Government and industry, and may well include future designs not identified in this report.

This report will:

- **Present a DDRS design framework** showing key design decisions, outlining their pros and cons and how this impacts the overall end-to-end design
- **Compare three different approaches to DDRS design** using the design framework and based on solutions currently being developed by the market
- **Spotlight key aspects of each approach**, including the technology needed, the challenges to overcome, and findings from DDRS trials
- **Discuss how a digital DRS might integrate with a traditional DRS**.

Figure 1. Source: The Grocer (2021)

RESEARCH STUDY: PHASE 1 AND PHASE 2

We concluded Phase 1 of this research study with a recommendation for Phase 2 to take a holistic view of the overarching research objective to "**research and evaluate if and how a DDRS might be implemented in Wales as well as in England and Northern Ireland, and whether the purported benefits can be realised**". By breaking this down into distinct questions, we aim to provide more clarity regarding the overarching design of a DDRS, in order to arrive at a common foundation from which to consider feasibility. Three key questions were identified:

1. **HOW** might a DDRS be implemented in Wales as well as in England and Northern Ireland?
2. **WHEN** could a DDRS be implemented in Wales as well as in England and Northern Ireland?
3. **CAN** the purported benefits be realised?

HOW

To answer this question, we have identified the basic design questions of a DDRS that are essential to the design of the scheme. There are several different approaches and technologies being developed that could form part of a DDRS solution. However, practical challenges remain in developing an end-to-end DDRS. Three of the most pressing challenges in how a DDRS will be implemented are outlined below, with links to further detail later in the report.

- **Printing of serialised codes on all packaging formats.** This is especially challenging for cans. However, it is also generally a challenge for smaller producers of drinks containers who do not own their production lines, as well as producers who export their drinks to the UK. See page 15 (Weaknesses), and page 29.
- **How to handle the sale of multipacks in a DDRS**. This is only an issue if 'activation' of the serialised codes happens at the point of sale. See page 19.
- **Who would bear the costs of serialisation**. While there are many benefits to serialisation (future proofing policy, supporting waste data tracking, etc.), serialisation will also require significant investments to production lines. This investment would be on top of the anticipated capital required for a network of RVMs. A discussion of this is provided on page 29.

While industry endeavours to solve these challenges, we have developed a framework with a sequence of design questions mapping a generic pathway towards DDRS implementation, with key design decisions and issues that must be addressed to develop an end-to-end solution. As part of this, we have provided an investigation into the different approaches being developed, and designed three potential DDRS 'process maps', in order to enable clear comparison. These are then evaluated and compared in order to understand the relative strengths of a DDRS solution as a whole, as well as any current gaps or uncertainty in the system, and the likely timescales for implementing a national scheme.

WHEN

For each process map, we have assigned 'market readiness levels' for each element of the end-to-end DDRS designs. This enables critical factors in timescales to stand out, as well as which value chain actor would require the most lead-in time. This will allow an assessment of what drivers might speed up implementation, and what actions might be supported by the Welsh Government and the DDRS IWG.

CAN

For each DDRS design developed, we explore the remaining questions around feasibility and benefits, as well as the challenges presented above. This has been done through a SWOT analysis of each DDRS design, 'spotlight' examples from industry, and a matrix to compare the results. Research for DDRS and DRS as a whole, around value for money compared to the RVM-model (e.g. value of consumers time, value of differing material quality, the cost of bringing kerbside up to RVM-output quality) is also provided in from page 24.

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DDRS DESIGN FRAMEWORK

DDRS DESIGN FRAMEWORK

There are **three key design decisions** in our design framework. These inform the **HOW** question in this research. They are:

1. The point at which to activate the deposit
2. The process for redeeming the deposit
3. How to verify that containers have been collected and recycled

There are several other decisions important to DDRS implementation (e.g. regarding the IT infrastructure – if it will be based on a central database or a blockchain, how collections of in-scope containers might happen at the kerbside – e.g. commingled or multi-stream, etc.). However, these decisions generally stand alone, and do not greatly influence the overall design of the system. The three decision investigated in detail in this report have been highlighted due to their pivotal impact on the overall design of the system.

Decision 1: Activation

Activation refers to the point along the product life cycle where the serialised codes on the containers are 'activated', thus making the deposit on the container 'live', i.e. redeemable. Options for activation of the serialised codes are either at**:** a) Production, or b) Retail.

A) If codes are activated at Production, this means:

- Producers will be responsible for activating the codes.
- It would likely involve placing a scanner or camera on production lines just before the items are packed or aggregated.
- The camera would be connected to the DDRS central IT system, where the code will be registered.

Tech providers and/or DRS system operators would have to include additional fraud prevention measures to avoid consumers scanning items stocked on retailers shelves and fraudulently redeeming the deposits. Some options to provide additional fraud prevention include:

- Opting in to Geolocation services as a pre-requisite for using the system (e.g. consumers must first scan a code on their bin – which is registered to their household – to start the returns process and using location services to confirm their location).
- Placing the serialised code in a location that can only be accessed after purchasing, and preferably consuming, the drink (e.g. inside the bottle cap of a PET drink container, or under the ring-tab of an aluminium can).

Both options for fraud prevention have benefits and drawbacks (e.g. accuracy of location services, placement of the code where it can not be easily separated from the container), and the DRS system operator should carefully consider the impacts of whatever option is chosen. A different point of activation is explored below.

B) If codes are activated at Retail, this means:

- Retailers will be responsible for activating the codes.
- This would be done by scanning the codes on the products at the check-out.
- This would involve upgrading the software supporting point of sale (POS) retail scanners to enable the reading and processing of 2D barcodes.
- To avoid having to scan and activate each individual item from a multipack, producers would have to print a serialised code on the secondary packaging of the multipack. This would be purely an 'informational code' (i.e. itself does not bear a deposit) that links to the individual serialised codes on the containers within the multipack. This code would likely be printed on the multipack directly following product aggregation, and would require a scan of the individual items making up the multipack.

Decision 2: Deposit redemption

This refers to the point along the life cycle of the product that will 'trigger' the redemption of the deposit paid on the container. In a traditional DRS, this happens when the consumer 'hands back' the container (either at an RVM or at a manual collection point).

In a DDRS, the current options are either: a) immediate redemption following 1 scan, or b) delayed redemption following a 2-scan approach.

If deposits are redeemed immediately, this means:

- Simplicity and convenience for the consumer.
- The consumer scans the unique code on their bin, then scans their empty container(s), and immediately receives their deposits on their mobile wallet or app.
- 'Quick gratification', potentially increasing consumer uptake of the digital scheme.

If deposits are delayed, this means:

- Verification that the containers have been put out for recycling.
- The consumer would similarly scan the sticker on their bin, then scan their empty container(s). The total deposit they should receive would be visible on their app/account but not yet redeemable.
- When the collection crews collect the recycling at the kerbside, a second scan would occur. This would most likely be by the crew members themselves by lifting up the recycling bin with its unique 2d barcode to a code reader on the vehicle.
- The second scan will unlock the deposit redemption.
- This means consumers would receive their full deposit back either weekly or fortnightly, depending on how frequent recycling collections occur in their local authority. While this may disincentivise engagement with the system, it has been claimed as a possible fraud prevention measure.
- The second scan would also signal a change in the chain of custody of the waste material, from the consumer to the local authority (or waste management company), and enable increased visibility in the onward chain of waste management.

Decision 3: Recycling verification

This decision refers to the ways in which the DMO could produce evidence, if asked, that the drinks containers recorded on the digital system have indeed been collected and recycled.

In a traditional DRS system, RVMs and counting centres produce a 'count' of items that have been collected. In a DDRS, this is more challenging, as in-scope containers would likely not be collected separately at the kerbside. The current options for providing a similar 'count' to evidence collection (or recycling) are either to: a) have periodic audits, or b) have scanning individual containers at Material Recycling Facilities (MRFs).

If verification occurs through periodic audits, this means:

- Little disruption to current verification procedures.
- Waste composition audits would be undertaken periodically, most likely at MRFs, but potentially also at the kerbside ahead of the waste collection vehicles.
- The sampling requirements for MRFs in the current MRF code of practice would be expanded to include interim points in the waste supply chains that receive kerbside collections, such as waste transfer stations. However, implementation of the MRF code of practice would need to be more standardised, as previous studies have shown varying levels of robustness of the reported data.

If verification occurs through scanning individual containers at MRFs, this means:

- Additional accounting of containers and deposits.
- Producers must print an additional marker on the containers that can be scanned at MRFs, such as UV markings scannable from any angle.
- Scanning technology to recognise these markings must be retrofitted on MRFs.
- Containers must be scanned before any material compaction hides the marker from view or distorts it and prevents scanning.
- The scanning technology would scan recycling material received from the kerbside, and identify in-scope containers. This count information would be sent to the DDRS central IT system and compared to number of deposits redeemed.
- Waste bins may need to be scanned at the kerbside prior to or at the time of collection to generate data that could be verified through later scanning at MRFs.

The next page presents these key design decisions in a design framework in sequential order overlaid over the stages in the value chain (e.g. production, retail, consumption, etc).

DDRS 'ROADMAP'

Production | Retail | Consumption | Collection | Treatment

Codes are produced and applied on product

DECISION 1: Activation

1A

Option 1A: *Codes are activated at production*. Each code is registered onto the DDRS IT system and activated before being packed or aggregated.

Retail: Under 1A, additional fraud prevention measures are needed to prevent consumer from fraudulently scanning codes on retail shelves.

1B

Option 1B: *Codes are activated at retail*. POS scanners at retail must be upgraded to support reading and processing of 2D barcodes. Retailer scans either the codes on the multipacks OR the codes on individual items to 'activate' them.

Production: Under 1B, producers must print an additional code on secondary packaging of multipacks, linking it with individual codes within the pack.

DECISION 2: Deposit redemption

2A

Option 2A: *Immediate redemption.* Consumer scans code on recycling bin and code on drinks container. Deposit is redeemed immediately.

2B

Option 2B: *Delayed redemption*. Two-scan approach, first by consumer (as above) and then ____

2B

a second scan by collection crew or vehicle. The second scan will unlock the deposit redemption (weekly or fortnightly)

DECISION 3: Recycling verification

3A

Option 3A: *MRFs scan individual containers* (e.g. UV scanners, AI cameras). Information is sent to DDRS IT system and compared to number of deposits redeemed

3B

Option 3B: *Periodic waste composition audits*

Under 3A, at production, product tracking markers (e.g. UV) are printed onto containers

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DDRS PROCESS MAPS

DDRS PROCESS MAPS AND MARKET READINESS

In the following section, we use the key design decisions in the design framework to illustrate different approaches for end-to-end DDRS system designs. These designs, or 'process maps', have been designed based on existing approaches and technology.

The DDRS system design has been assigned a market readiness level from 0 to 9 at each step in the value chain (e.g. production, retail, consumption, etc.). These numbers inform the **WHEN** question in our research, and correspond to the scale shown to the right in Figure 2. The market readiness are provided at the bottom of each process map (see example below). In doing so, we can see which value chain actor would struggle most to achieve market readiness, and thus understand both which process map would be quickest to implement, and which value chain actors are furthest from full commercial application, thus requiring additional resources to speed up implementation.

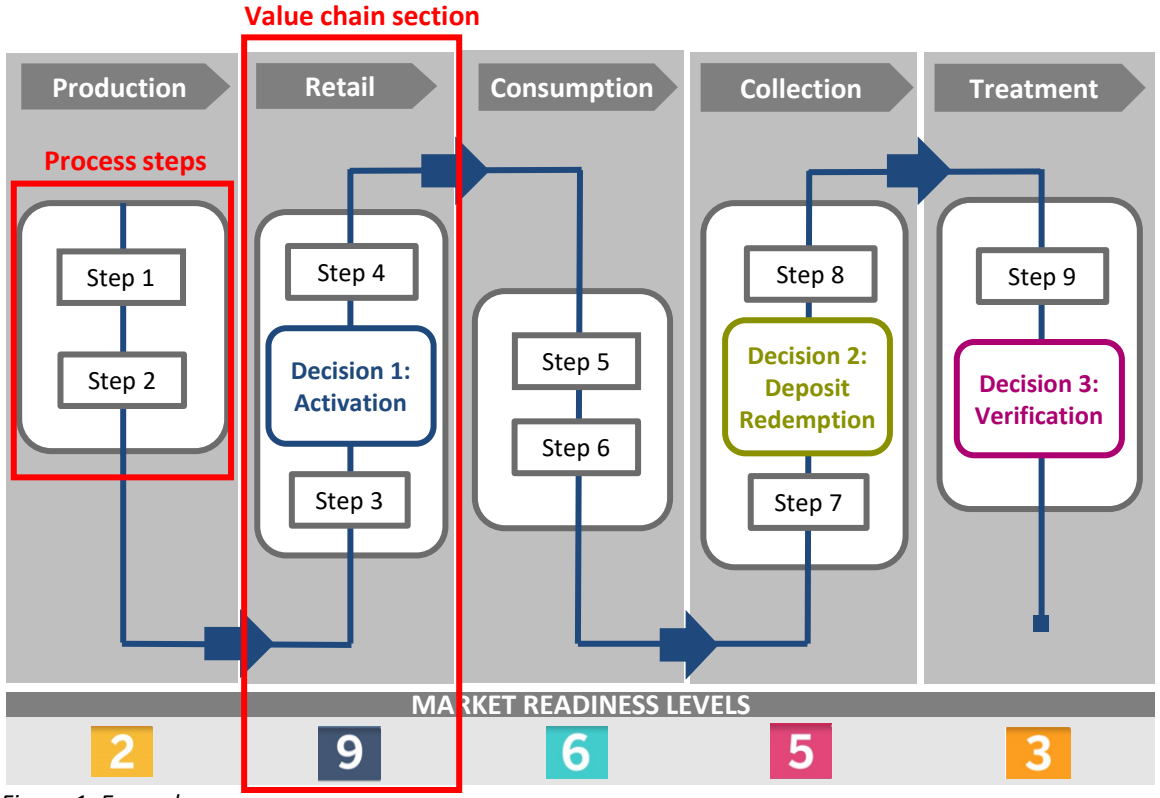
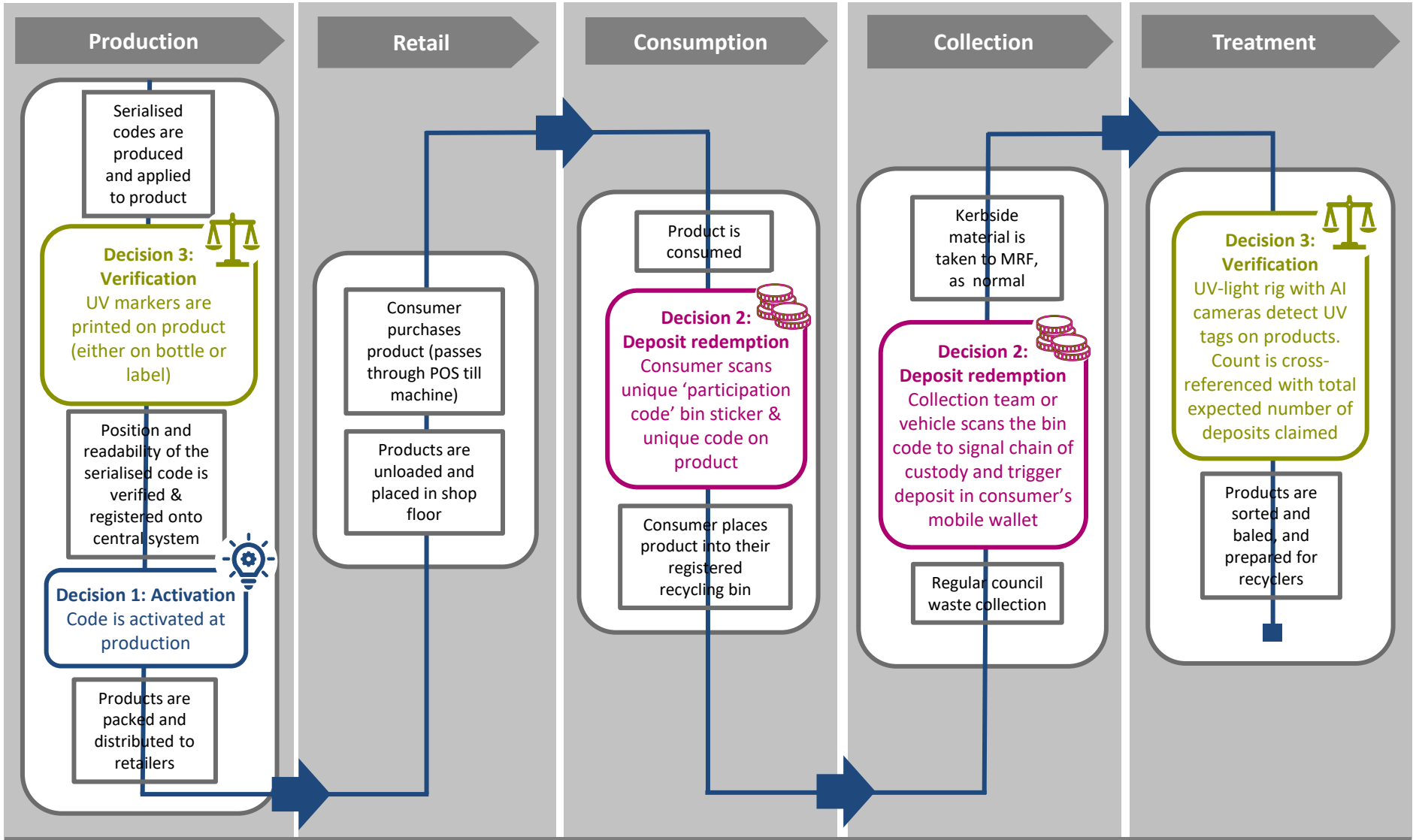


Figure 1. Example process map

Figure 2. Market readiness levels. Source: CloudWATCH Europe 2017 - Enabling Innovation, Research and Growth in ICT for the Digital Single Market

APPROACH 1 – MRF SCANNING AND VERIFICATION



MARKET READINESS LEVELS

2 TECHNOLOGY FORMULATION
No trials have activated serialised codes on production lines, but concept and application has been formulated.

9 FULL COMMERCIAL APPLICATION
No change required to current process for retailers.

6 PROTOTYPE SYSTEM
Multiple trials have explored scanning a unique code on a bin to begin the returns process.

4 SMALL SCALE PROTOTYPE
There has only been one trial that scanned codes on bins by collection vehicles.

3 NEEDS VALIDATION
The technology for printing & scanning UV markers exists, but it has not been tested in a large-scale prototype.

SYSTEM OVERVIEW

This system is the **most demanding on producers**, as it involves printing of two different markers along the production line: a serialised code, linked to Decision 1 on activation, and a UV marker, linked to Decision 3 for verification. Generally, this system involves **investments by all actors of the value chain except for retailers**, who instead would focus on investments needed for physical return of containers in their shops.

This system also allows for the highest level of material tracking, due to the UV marker, making it the **most verifiable system**. However, as indicated by the technology readiness levels under 'Production' and 'Treatment', the technology to support printing and detecting UV markers has not been tested at scale, is not feasible for all packaging formats, and would involve significant investment on production lines and MRFs. Nonetheless, it would support increased traceability and transparency of supply chains, which is in line with policy objectives. See "Approach 1 Spotlight" for further discussion of the UV marking technology.

This approach would also require investments by local authorities to mount a scanner on their waste collection vehicles in order to be able to scan householders' recycling bins that have opted in to use the DDRS system.

APPROACH 1 – SWOT

Strengths

What separates this approach from the others? What makes it better?

- **Highest level of accuracy**, due to ability to trace the product through the value chain using the UV markers.
- **Clear chain of custody and traceability**. With key decision points spread over nearly all value chain actors, the product's life cycle will clearly show at what point the material has changed custody.
- **Retailers do not need to adjust internal systems**, and instead can focus on the return-to-retail mode of returns (i.e. RVMs).
- **There is no issue with multipacks** and marking the secondary packaging, as the codes will have been activated directly at production.
- **Potential for fraud prevention post consumption** due to delayed deposit redemption.
- **Rich consumer data** due to enabling location services.
- **Verification would be able to work even if label is detached from container post consumption**, due to UV marker.

Weaknesses

Any internal limitations that could keep this approach from succeeding.

- **Very demanding on producers**, and may be difficult for smaller producers to adopt necessary changes.
- **Risk of fraud at retail** where consumers could redeem codes on retail shelves; but technology providers could avoid this using geolocation services linked to authorised return points.
- **Potentially less engagement with the system,** due to deposits being redeemed at weekly (or fortnightly) intervals, depending on frequency of recycling collections.
- **An appropriate compaction point may need to be agreed and standardised across collection profiles**, to enable the UV code to be read at MRFs before compaction (see page 27).
- **Complications around product recall at production**, if codes have already been activated but need to be 'decommissioned' due to a product fault.
- **Complications around activating at production for imported products,** as international producers would need special production lines for products sold on the UK market.

Opportunities

Favourable external factors that support uptake of this approach.

- **Sorting lines at MRFs are continually evolving**, and adapting to external pressures for increased data, which means that verification of DDRS items through increased sorting at MRFs might tie in with other industry trends.
- **Industry interest in value chain traceability**, such as through UV tagging of products (i.e. Holy Grail 2.0 digital watermarking project)
- **Potential to support other policy objectives** around product traceability and supply chain visibility.
- **UV marking can clearly and robustly exclude DRS containers from EPR material**, resulting in the correct supply of evidence and accurate reflection in PRN prices and resulting investment in domestic reprocessing.

Threats

Unfavourable factors damaging to its strategy – a barrier, constraint or anything external that might cause problems

- **UV ink may fade over time**. This means that if a beverage container is kept at the household or on retailer shelves for long periods of time (unclear how long), it may not be picked up at the MRF scanning operations.
- **UV printing not yet possible on cans**. Generally, UV marking/printing needs to be further tested.
- **Disproportionate impacts on smaller producers**; many do not own the production process (printers, fillers, etc.) and so have little leverage to change current practices, particularly if they have low order quantities.
- **Risk of production downtime** if activation malfunctions on the production lines, which would be costly for producers.
- **Potential risk to brand reputation**, if items are released un-activated and consumers cannot redeem their deposit.

APPROACH 1 SPOTLIGHT – UV PRINTING TECHNOLOGY

One technology provider has developed a solution based on UV printing and reading to support supply chain visibility and product traceability. This technology is summarised below.

1. **Containers (and/or labels) are printed with UV markers.** These markers are not serialised, and instead contain just the information contained within the traditional 1D barcode (i.e. Global Trade Item Number, or GTIN). The printing would occur via a rig attached over the filling line, before the label is applied (see image on the top right). The UV marker can be printed onto the label as well. One UV print-operator has estimated that this technology could cost approximately £50 per million markers printed (4 markers per container is recommended to enable 360 reading, so £200 per million products). The printing speeds have been estimated at 250 metres per minute. More printing heads can be added to increase speeds, and the UV ink reportedly does not taint the quality of the material (i.e. does not interfere with food quality standards).
2. **Marked containers are identified at the MRF.** A UV scanner can be retrofitted onto MRF lines that can identify items using computer vision and AI. Machine learning can also allow the technology to identify products by shape and colour, as well as brand-assigned identifiers. UV-marked products underwent a series of abrasion and stress tests in a lab setting to ensure that UV codes are still readable by the machine. The scanner is able to identify material running through MRF belts operating at 1 metre per second. This scan could effectively replicate the function of a counting centre, identifying in-scope DRS containers, and, importantly, collect data to indicate which brand placed the packaging on the market.

The technology provider is also investigating selective material recovery using robotic picking of containers identified through the UV scan. They have received funding to trial their technology at a MRF to selectively pick recyclable waste received from the general waste stream, and importantly test the scanning accuracy.

Generally, greater sorting capabilities will likely be expected of MRFs in order to meet the requirements of future legislation changes such as Extended Producer Responsibility and DRS. This will include the need to go beyond identification of polymers and the potential use of AI and machine learning to sort products by material type and design. Many technology providers are offering solutions for increased sorting capabilities at MRFs (e.g. Holy Grail project with digital watermarks, Grey Parrot, One Bin project, Tomra recycling technology, etc.).

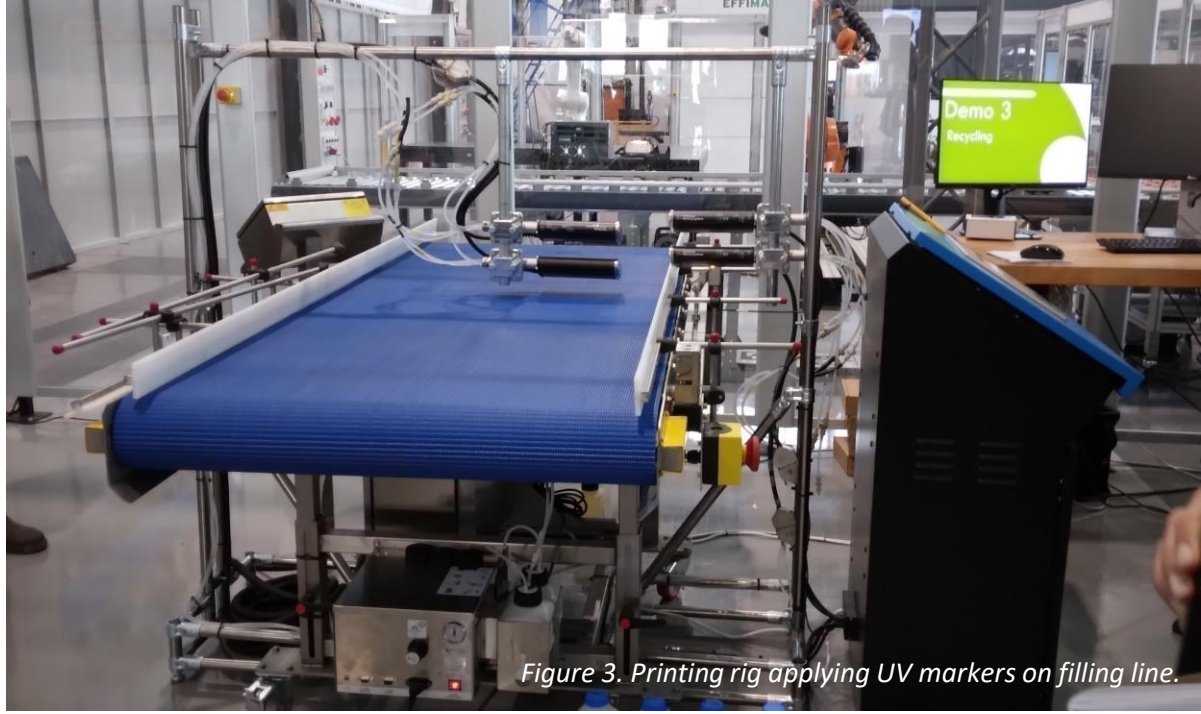


Figure 3. Printing rig applying UV markers on filling line.

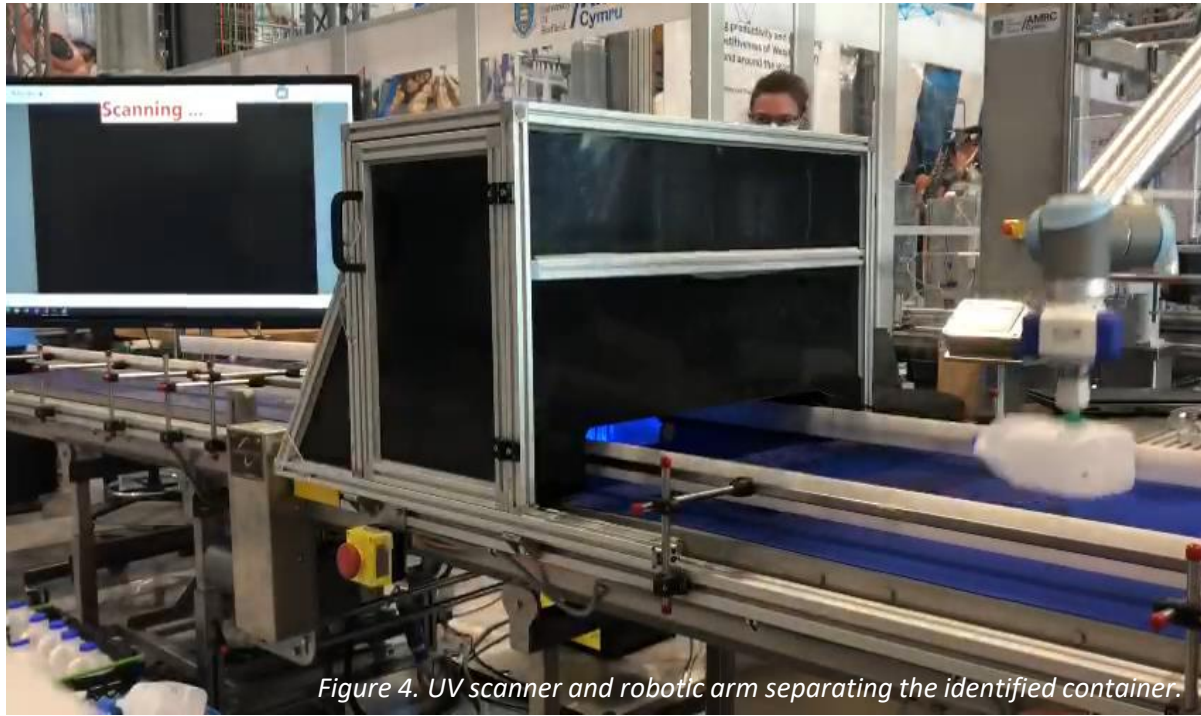
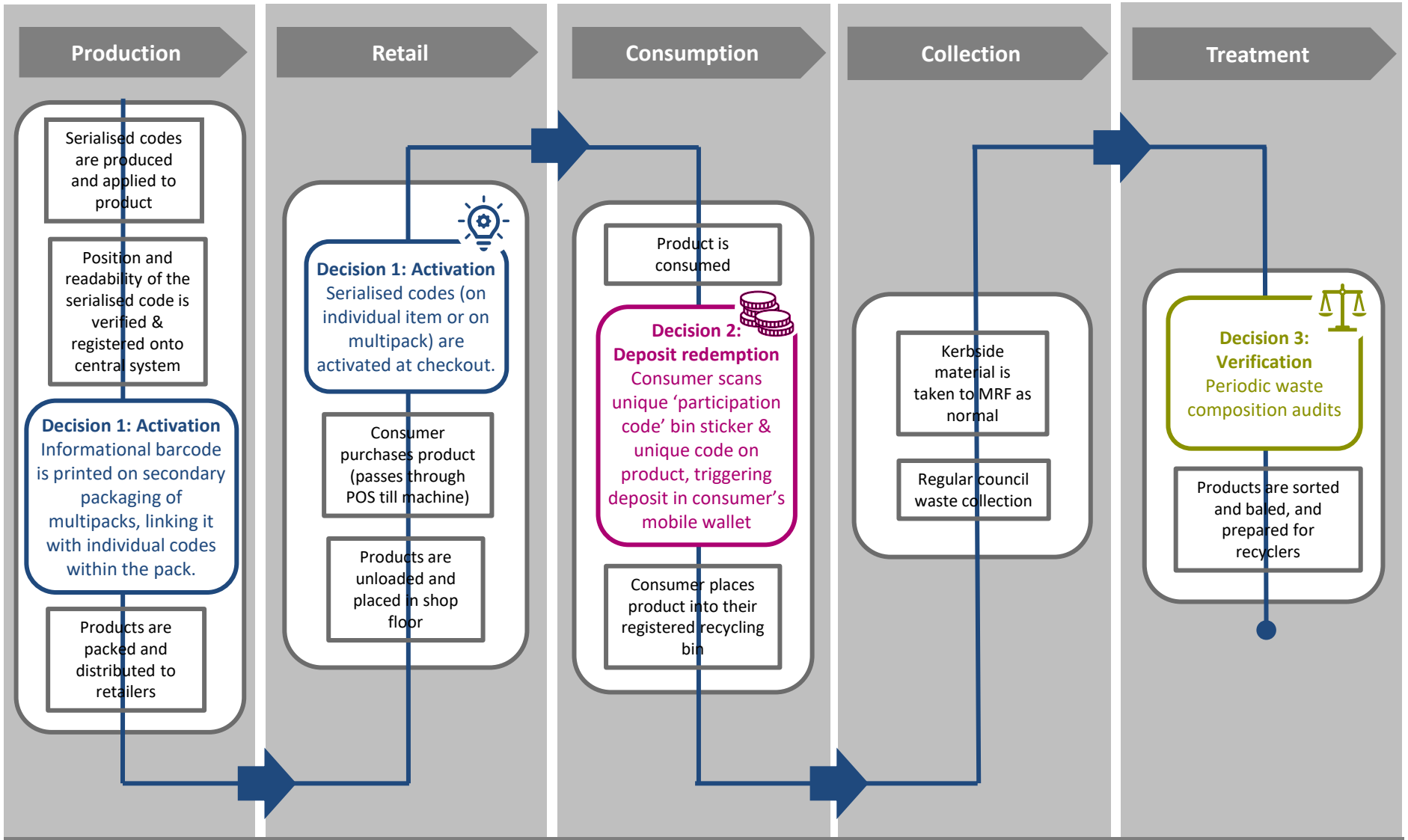


Figure 4. UV scanner and robotic arm separating the identified container.

APPROACH 2 – ACTIVATION AT RETAIL



MARKET READINESS LEVELS

3 NEEDS VALIDATION

Technology for multipack labelling exists (e.g. tobacco), but not tested for beverage containers.

3 NEEDS VALIDATION

All retail checkout points must be upgraded to support reading and processing of 2D codes. Technology exists but scale would be significant.

6 PROTOTYPE SYSTEM

Multiple trials have explored scanning a unique code on a bin to begin the returns process.

9 FULL COMMERCIAL APPLICATION

No change to current process for waste collection.

9 FULL COMMERCIAL APPLICATION

Minimal changes required to implement periodic waste composition audits; no specific technology required.

SYSTEM OVERVIEW

This example is the **least demanding on producers**, although it would still require the printing and labelling of serialised codes on containers.

Feedback from stakeholders has revealed that the systems required to update all POS till systems from all retail points to activate the serialised codes is not yet available, with some estimating this many not happen until 2030. It would involve updating the hardware on the till machines to be able to scan 2D barcodes, then also updating the software to recognise the code that has been scanned by connecting to a centralised (external) database, and notifying the system that the particular code has been 'activated'. Thus, this system could take the **longest to implement**.

However, by designing the point of activation to be closer to the point of consumption, this system is **inherently more secure**, and would not need to prioritise further fraud prevention measures.

This system also involves minimal involvement of value chain actors post-consumption, i.e**. provides the least tracing of products**, with no scans required by collection crews and only periodic audits by waste treatment.

APPROACH 2 – SWOT

Strengths

What separates this approach from the others? What makes it better?

- **Least disrupting to producers**, as it does not require them to activate codes. It still involves printing and labelling of serialised codes, which is still a significant challenge for some drink container formats and producers.
- **Lower risk for fraud**, with activation happening closer to the point of consumption (at retail)
- **Lower risk for deposit activation malfunctions**, with items passing through a scanner individually at check-out. Related lower risk to brand reputation from deposit redemption issues.
- **High consumer engagement**, with immediate pay-out upon scan of empty container, backed by successful trials.
- **Little changes required to stages post-consumption**, with no additional requirements from collection crews, and only additional sampling for auditing purposes at MRFs.

Weaknesses

Any internal limitations that could keep this approach from succeeding.

- **Greater demand on retailers,** as they would be required to activate products at point of sale.
- **Poor traceability,** with no additional marking or scanning of products post consumption.
- **No way to identify DRS containers if label is detached from container** post consumption, due to no other markings on the product.
- **Operational issues at aggregation stage of production** (linking the code on the multipack to the individual codes on products within the pack); it requires direct line of sight which is often not possible at product aggregation (see page 19 for more detail).

Opportunities

Favourable external factors that support uptake of this approach.

- **Work with and strengthen existing policy** (i.e. MRF code of practice), rather than designing new products or new policies.
- **Standardise auditing of waste across the industry**, and potentially the full range of post-consumer waste (not just DRS containers).
- **Support the trend 'evolve' from 1D to 2D barcodes** by requiring POS scanners to identify and process 2D codes. Some retailers are already looking into this, and would support the move to provide more product information to the consumer.

Threats

Unfavourable factors damaging to its strategy – a barrier, constraint or anything external that might cause problems

- **Doubt that all retail points could support reading and processing 2D barcodes by 2027**, particularly if required to communicate to an external database (see page 19 for more detail).
- **May disadvantage small producers that sell direct to consumers** (B2C), if they are required to activate codes as well.
- **Verification based on samples and audits will not be as robust** as a categorical count of items, potentially producing data that is not representative.

APPROACH 2 SPOTLIGHT – ACTIVATING CODES AT RETAIL

Activating serialised barcodes at retail would require: a) producers to print an informational code on the outside of a multipack, linking with individual serialised codes contained in the multipack, and b) retail point-of-sale till machines to be able to read and process 2D barcodes.

Printing informational codes on multipacks

This has been identified as an operational issue by both large and small producers. While printing a serialised barcode on the pack itself is relatively straightforward, linking it to the codes contained within the multipack is more challenging.

In order to do this, a reader or camera would need line of sight to read the codes within the multipack. The image on the right shows how bottles are received by one type of multipack aggregator. Most production lines aggregate in a similar way (i.e. in groups), meaning that there is no line of sight of the code. One solution could be to print a serialised barcode on the top part of the bottle, as is currently being considered for aluminium cans. However, as a bottle cap can be easily removed by the consumer, it is not an ideal placement of the code as they could be collected and redeemed without correctly disposing the bottle. Once line of sight is achieved, you may need two cameras/scanners: one to read the code on the bottle/can and another to read the pack code. Synchronising these two cameras will also be challenging.

Smaller producers also often do not own the production line where their products are aggregated, and so have limited influence over them and will find it hard to specify new requirements. The issue of how drinks containers produced (and/or aggregated) outside the UK would be labelled was also raised as a key consideration. Interestingly, smaller producers engaged in this research expressed a preference to activate at production (Option 1A), over printing an informational code on multipacks (Option 1B).

Activating 2D barcodes at retail

GS1 is a non-profit organisation that develop and maintain international standards, including barcodes. GS1 Global has initiated the 'migration to 2D' programme – where the hope is that all retail scanners will be capable of reading both 1D and 2D barcodes by 2027, initiated in the USA roughly 3 years ago. This 'migration' to 2D barcodes has already started in countries such as Australia, Denmark, Spain, and Brazil, among others. Generally, it is focussed on fresh food, with the key aim of preventing out-of-date food from being sold to consumers as well as making stock management easier.

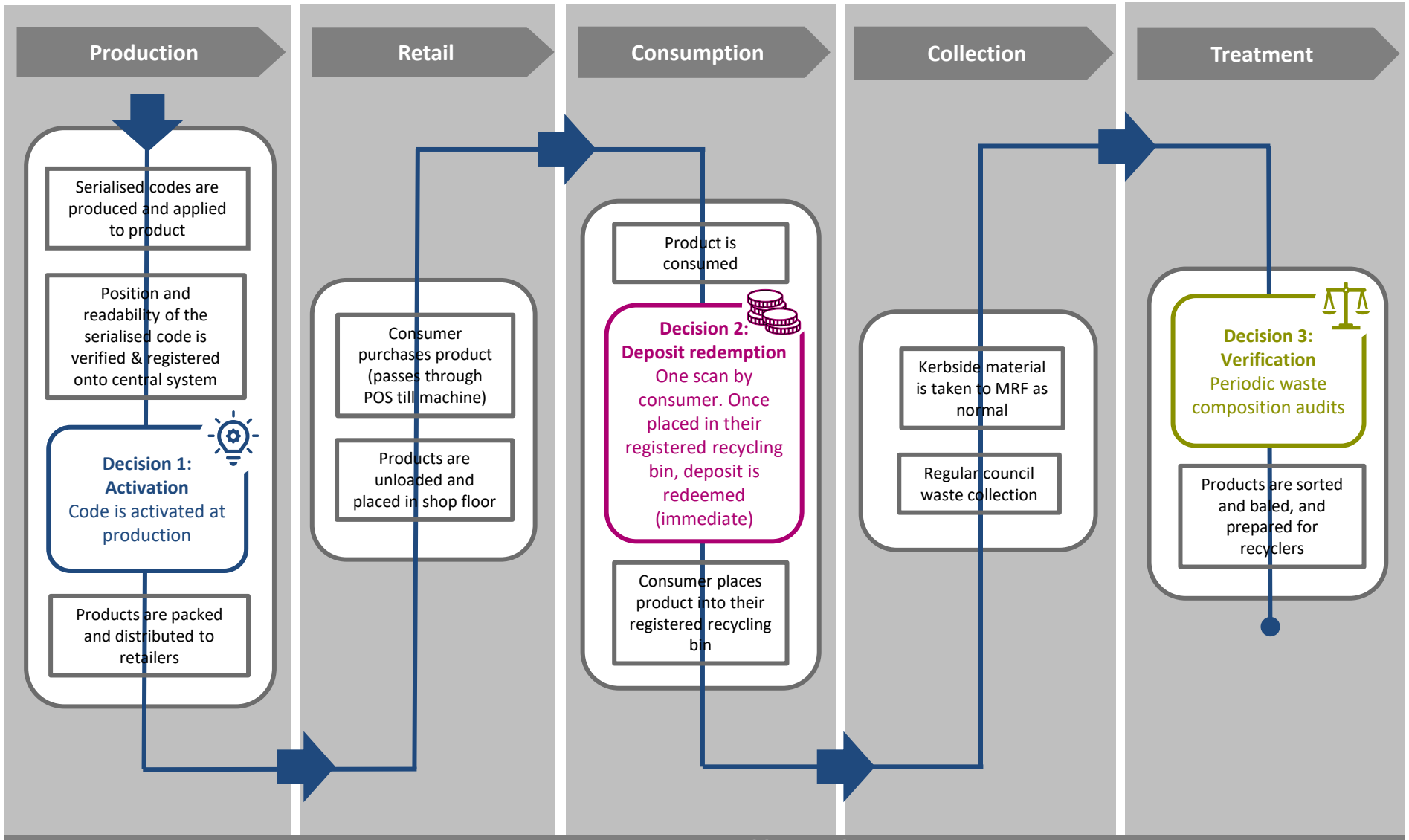
GS1 UK has been speaking to a number of UK retailers about any plans they might have to upgrade their scanners and internal systems to be capable of reading and processing 2D barcodes. Reponses showed that only one UK retailer can scan 2D barcodes at point of sale. However, significant development is still required in their back-end systems to be able to process additional data e.g. batch/lot, expiry dates, serial numbers etc.

In order for UK retailers to be able to scan 2D barcodes at point of sale, all UK tills would need to be replaced with image scanners as opposed to laser scanners from a hardware perspective. Form a software perspective, all systems would need to be updated in order to recognise and process the codes and the data which sits within the codes. This will take substantial time and investment.

In some countries, the grocery sector is dominated by a couple of main players which makes significant changes such as migration to 2D at point of sale easier to manage. The UK market is highly segmented and consists of many grocers, a handful of discounters and a rapidly expanding convenience (e.g. corner shops) and on demand sector.

Figure 5. Glass bottles arriving at bottle aggregation stage.

APPROACH 3 – ACTIVATION AT PRODUCTION



MARKET READINESS LEVELS

2 TECHNOLOGY FORMULATION
No trials have activated serialised codes on production lines, but the concept and application has been formulated.

9 FULL COMMERCIAL APPLICATION
No change to current process for retailers.

6 PROTOTYPE SYSTEM
Multiple trials have explored scanning a unique code on a bin to begin the returns process.

9 FULL COMMERCIAL APPLICATION
No change to current process for waste collection.

9 FULL COMMERCIAL APPLICATION
Minimal changes required to implement periodic waste composition audits; no specific technology required.

SYSTEM OVERVIEW

This approach is the 'go-to' version used by most when explaining and conceptualising DDRS, and thus is the **most familiar**.

This system would be **the quickest to implement**, given the least amount of disruption to the value chain sections compared to other process maps (e.g. no change to retail or waste collection processes). This approach could be considered the most 'stripped back' version.

Due to its light touch, this approach would thus also have **the highest potential for fraud**, relying heavily on technology providers' algorithm detections on consumer behaviour as opposed to explicit product tracking and/or verification points.

Given it's high degree of technology and market readiness, this approach is generally the one that scheme and technology providers trial on the ground to establish proof of concept. **A large-scale trial mirroring this approach is planned in Welshpool for mid-2022**. Learnings and market readiness levels should be revised following this (and other) trials.

APPROACH 3 – SWOT

Strengths

What separates this approach from the others? What makes it better?

- Relatively **simplest/quickest** approach to implement due to its minimal disruption to the current product value chain.
- **High consumer engagement**, with immediate pay-out upon scan of empty container, backed by successful trials (same as Approach 2)
- **Most familiar system**, allowing for more speedy uptake.

Weaknesses

Any internal limitations that could keep this approach from succeeding.

- **Highest potential for fraud and abuse,** given early activation of codes, one-scan and immediate pay-out of deposit, no product tracing post consumption and minimal verification.
- **Poor traceability,** with no additional marking or scanning of products post-consumption (same as Approach 2)
- **Disproportionate impacts**, with producers shouldering most responsibility to serialise products and activate codes.

Opportunities

Favourable external factors that support uptake of this approach.

- **Build on successes from trials** that have implemented this approach, integrating lessons learned to design an evidence-based system.
- **Work with technology and processes that have already been tested**, rather than new/emerging technology.
- **Work with and strengthen existing policy** (i.e. MRF code of practice), rather than designing new products or new policies (same as Approach 2).
- **Standardise auditing of waste across the industry**, and potentially the full range of post-consumer waste (not just DRS containers) (same as Approach 2).

Threats

Unfavourable factors damaging to its strategy – a barrier, constraint or anything external that might cause problems

- **Would depend on a robust and powerful IT system** to intercept fraud and cope with the lack of visibility in value chain.
- **Disproportionate impacts on smaller producers**; many do not own the production process (printers, fillers, etc.) and so have little leverage to change current practices, particularly if they have low order quantities (same as Approach 1)
- **Risk of production downtime** if activation malfunctions on the production lines, which would be costly for producers (same as Approach 1)
- **Potential risk to brand reputation**, if items are released un-activated and consumers cannot redeem their deposit (same as Approach 1)

APPROACH 3 SPOTLIGHT – VERIFICATION THROUGH AUDITS

A recent DDRS trial conducted in Dublin, Ireland aimed to assess the return rate of kerbside-returned DDRS items using existing collection infrastructure.

Customer bins and eligible containers (in this case, only home-delivered milk cartons) were labelled with RFID chips and uniquely coded stickers, respectively. An important element of the trial was to verify the number of containers returned. This was achieved through two means: 1) **Separate collection of recycling bins,** scanned prior to collection. This helped in differentiating between completed and missed collections; and 2) **Hand sorting of recovered materials at the MRFs,** where crew members scanned the unique stickers on the containers were scanned. This link to the individual customers enabled fraud prevention if the return was attempted by someone else, by identifying customers who might scan the code and discard items anywhere other than their bins.

A **return rate of 94%** (excluding missed collections or those that were recovered later) was estimated at the end of the trial. However, inclusion of only a **small range of eligible containers** is a limitation to demonstrating scalability of the system. Nonetheless, for the purposes of the trial, a small range of items was required. This was because despite requests for returns to be presented 'clean, loose and dry', they were often found inside cereal boxes, other bags or damaged either at source or due to compaction in the collection vehicles, making hand sorting of the mixed materials at the MRF difficult. However, the high container return rate proved customer engagement and the potential for DDRS items to be integrated into kerbside collections.

In a DDRS, where possible, verification of quantities collected and recycled should draw on existing practice. For example, Welsh local authorities already have **statutory targets for recycling**. They must submit their recycling data to the national regulator (National Resources Wales), which undergoes high level checks, before it becomes a national statistic. **The current regulatory system also already mandates periodic MRF sampling audits** to verify quality of input and output materials and record contamination levels. In a future DDRS system, this could happen earlier in the flow (e.g., at bulking and transfer stations as proposed under the EPR reform proposals) to facilitate greater verification.

This could involve **a combination of checks** such as counts of customer scans of DDRS items, percentage of eligible materials in mixed materials received at interim (e.g., transfer stations) and destination (e.g. MRFs) points and sales data submissions by producers/retailers among others. Transportation logistics (if compaction is avoided until material are scanned) and technology options for identifying compacted materials will be key considerations while designing a suitable DDRS.

Figure 6. Photo from the DDRS trial in Dublin, showing manual sorting for eligible containers among 1,200kg of mixed recyclables. Source: Digital DRS Trail Report, Rewards for Waste and IWMA.

Figure 7. MRF. Source: Circular Online. "New Sampling And Testing For Materials Recovery Facilities"

PROCESS MAP OVERVIEW MATRIX

Lowest (worst) to highest (best) performing benefits

	Approach 1 MRF Scanning and Verification	Approach 2 Activation at Retail	Approach 3 Activation at Production
Traceability of products and accuracy of system accounting	High	Medium	Low
	Highest potential for traceability due to tracking markers and second scan by collection crew	Medium potential, due to minimal involvement of value chain actors post-consumption.	Lowest potential, due to minimal involvement of value chain actors post-production.
Fraud prevention	High	Medium	Low
	Combination of delayed deposit redemption and high product traceability afford greatest protection against fraud and abuse	Delayed activation in retail, but immediate deposit redemption.	Early activation at production, and immediate deposit redemption.
Market readiness	Low	Medium	High
	Significant changes required across entire value chain.	Also potentially significant changes required, however mainly focused on producers and retailers.	Least amount of changes required to system.
Distribution of impacts	Medium	High	Low
	Producers have extra responsibility to print UV marker, but balanced by need to retrofit MRFs to read them. Retailers operating as normal, however must oversee physical returns in RVMs.	Relatively even distribution of impacts across value chain, with only waste collection operating as normal.	Producers bear most/all responsibility for functioning of system, compared to others (i.e. not even distribution).
Cost	High	Medium	Low
	Most costly. Printing of UV markers on production lines, additional scanning tech on collection vehicles, and retrofitting MRFs to individually scan items	Operational changes to production lines for adapting aggregation, changes to POS scanners to read & process 2D barcodes.	Least costly, minimal investments needed beyond serialisation.

The matrix to the left attempts to rank the three Approaches from High to Low based on key criteria. Based on these rankings:

- **Approach 1 scores highest** on all criteria except 'market readiness' and 'distribution of impacts', signalling that this may be the most robust system, albeit requiring most changes and investment.
- **Approach 2 scores a medium** across most criteria, signalling an approach that could be a 'halfway house' between Approach 1 and 3.
- **Approach 3 scores lowest** across all criteria except 'market readiness', signalling that while this approach may be the quickest to implement, other factors cause problems that impact a lower score.

It is important to note that the design framework could be used to develop other process maps not presented in this research, e.g. combining elements from the current approaches (e.g. to drive down cost in Approach 1).

It is also important to consider that the three approaches here are analysed in isolation, and not compared to the current proposal of a RVM-based DRS. For example, on its own it may well be that Approach 3 ranks lowest in its ability to generically control the risk of fraud, however it may still be better than a traditional RVM based approach due to containers being serialised.

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INTEGRATING WITH A TRADITIONAL DRS

RESEARCH QUESTIONS

While the previous section looked at different ways that a DDRS could be implemented, it is important to remember that **DDRS would not be implemented in isolation**. Technology could facilitate the return of containers at the kerbside, but this would be in addition to the traditional method of returning containers via RVMs and manual take-back points. Thus, the ways in which DDRS would integrate with DRS are important to consider as well.

Here we investigate some of the key characteristics that are implicit in a traditional RVM model in order to help inform how these may be replicated in a digital model. These characteristics are centred on:

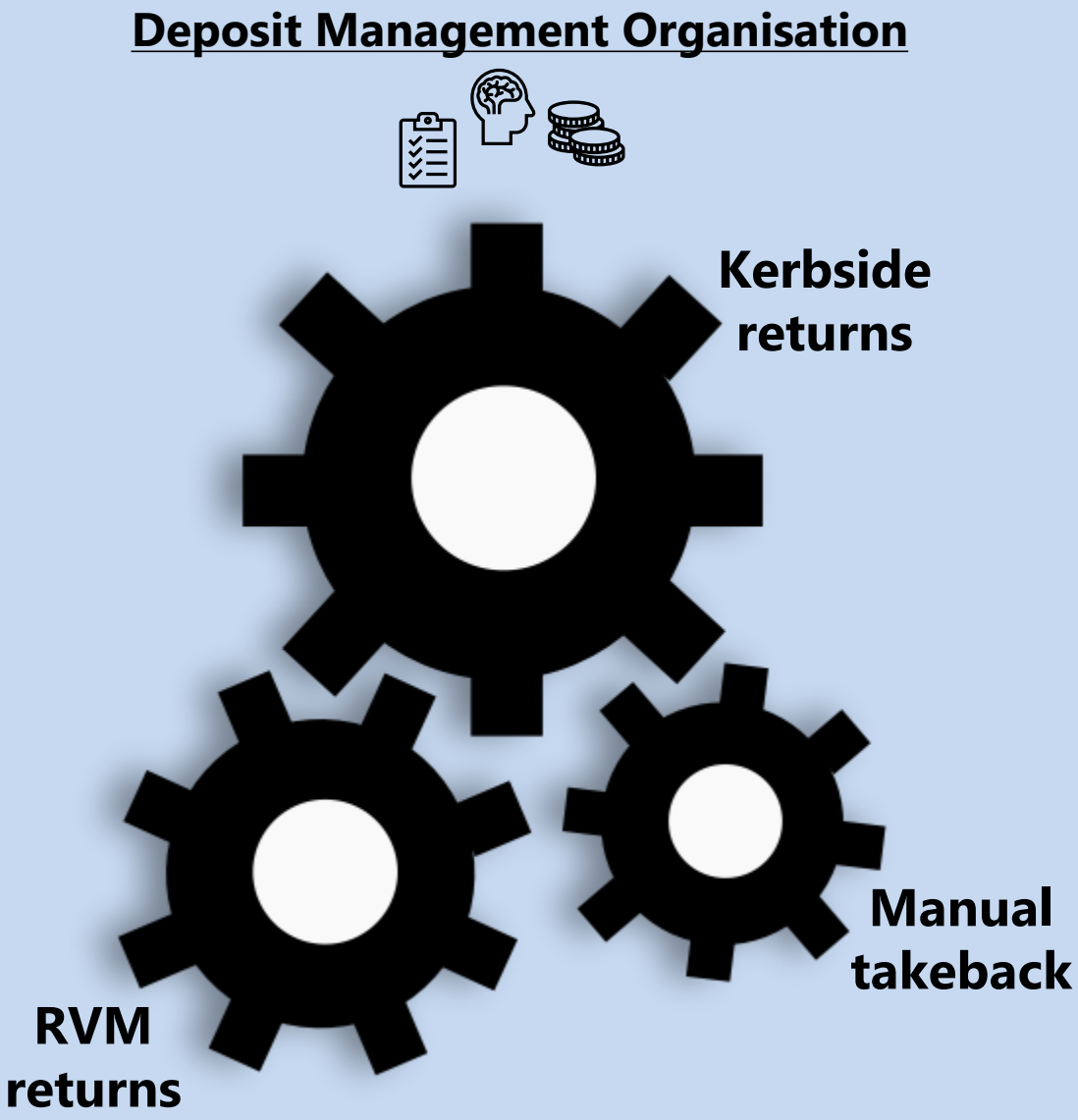
1. **Material quality**;
2. **How to verify quantity of material collected and recycled**;
3. **Consumer engagement with the system (in particular, convenience and the value of people's time), and**
4. **Labelling and serialisation**

A national DRS (and by extension DDRS) design must set out the desired policy outcomes of an end-to-end solution so that each organisation knows what is expected of them. Without such clarity, there is a risk that implementation partners will remain flexible, but no end-to-end solution will emerge suitable for Wales and other UK nations. However, Governments may not wish to be too prescriptive in setting standards and dictating how a DDRS should be designed. The basic requirements can instead focus on the outcomes of DDRS to give a clear message to the market of what would be expected from any national system.

One way to do this, while also encouraging a level playing field, is to mandate a **closed-loop recycling standard for DRS**. By requiring recyclate to be used for closed-loop recycling, this could go a long way towards material quality and scheme performance. It would be left up to the market to decide if investments should be made in increasing segregation at source (kerbside recycling) and/or in increasing segregation and sorting post-collection (at the MRF) in order to achieve closed-loop recycling.

Defra, in coordination with Welsh Government, is expected to release it's response to the public consultation on the introduction of a DRS in England, Wales and Northern Ireland, which should provide clarity as to the Governments' desired policy outcomes for a DRS.

Integrated Deposit Return Scheme



1. KERBSIDE VS. RVM MATERIAL QUALITY

There has been a **recurring assumption that RVM collection systems improve material quality, when compared against kerbside collections** (particularly co-mingled). Whilst this may be true, it has been difficult to verify this with empirical evidence or quantify the likely improvement in quality in the UK.

Price can be an indicator of material quality, but a direct comparison could not be made in this research as RVMs are not yet in operation in the UK and the spot prices paid for kerbside collected materials are typically commercially confidential.

According to TOMRA, in the USA post-consumer PET bales collected and processed in DRS jurisdictions via RVMs can have a value approximately 40% greater than PET collected through a kerbside program. However, it should be noted that recycling collections and treatment in the USA is quite different from the UK and any comparisons are difficult as material prices are highly volatile.

Data provided by Reloop Platform – which was supplied by a European PET recycler –shows that across Europe **higher quality material bales are achieved in countries with an integrated deposit return scheme utilising RVMs**.

Another indication of material quality is the level of additional processing required before the material can be used in new products. Co-mingled recycling collections typically require the greatest level of additional sorting and treatment when compare to multi-stream collections. Even RVM collected material can require some additional sorting to maximise recycling value (e.g. separating clear bottles from coloured bottles).

Much of Wales already has multi-stream collections, and additional national drivers are being introduced to do the same in England. This would support DDRS with higher quality material capture at the kerbside.

Historically, Regulation 13 of the Waste (England and Wales) Regulations 2011 requires that waste collection authorities collect recyclable materials separately. However, the regulation also states that these collections must be "technically, environmentally, and economically practicable" (TEEP). In practice, this means that many councils can offer co-mingled collections of recycled materials, where the cost of separate (e.g. multi-stream) collections is prohibitively high. These regulations were superseded by the Waste (Circular Economy) Regulations 2020; while the specific TEEP phrasing has been removed, exemptions are still offered where separate collections is "not technically feasible".

In May 2021, Defra opened a public consultation for Consistency in Household and Business Recycling in England. While the intention is to increase consistency in recycling collected, the consultation document also seeks to standardise the TEEP assessment. For this reason, while some authorities may shift to multi-stream collections, there is a risk that some will continue to use the TEEP assessment to carry on with comingled or to justify a twin-stream collection.

Wales has more ambitious recycling collection goals, as part of Welsh Government's 'Collections Blueprint'. There are 22 local authorities in Wales, all with a national focus on moving from co-mingled collections to segregated (multi-stream) kerbside collection in the next 6-8 years. Key research that informed the Blueprint policy framework was a report from 2011 – conducted by Eunomia, Resource Futures and HCW Consultants – which found that multi-stream collections outperform co-mingled and two-stream collection systems on environment and financial cost[1].

1. WRAP Cymru, 2011. Kerbside Collections Options: Wales.

The Blueprint motivates a push towards universal multi-stream collections, with 12 local authorities already providing segregated multi-stream, and an additional 4 changing to multi-stream in 2022 as shown in Figure 8.

In Northern Ireland (NI), 5 of the 11 local authorities offer multi-stream collections in at least part of their council area. While there is expectation that upcoming guidance is likely to discourage glass mixed in with comingled collections, it is unclear whether there are any strong drivers to move toward more multi-stream collections. However, with the UK's upcoming adoption of Circular Economy Package (CEP), DAERA has been working with WRAP on increasing recycling potential in NI, and working towards a municipal recycling rate of 65% by 2035.

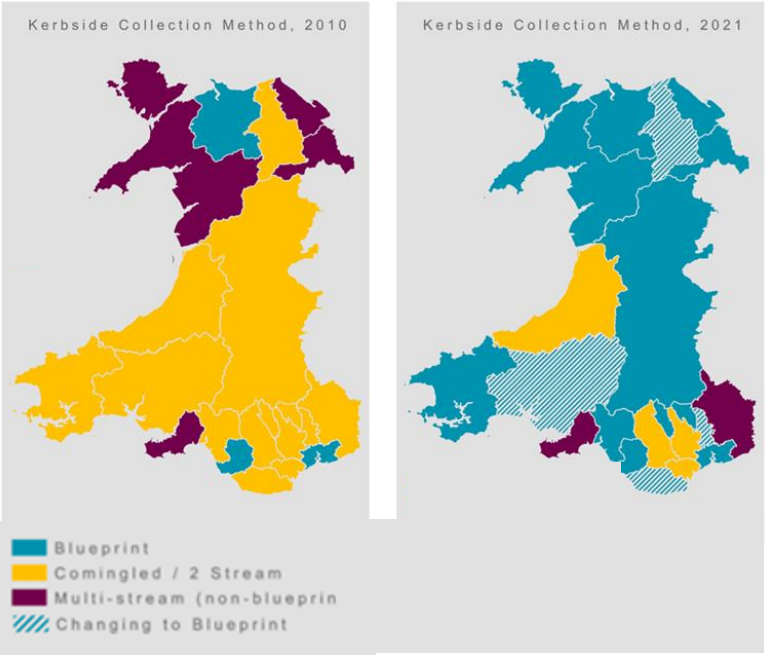


Figure 8. Change in kerbside collection methods in Wales by authority (shared by WRAP Cymru)

2. HOW TO VERIFY QUANTITIES COLLECTED AND RECYCLED

A detailed analysis of typical material and data flows in traditional DRS in different countries and the monitoring approaches used as part of the current kerbside waste collection system in the UK was undertaken to identify key considerations for designing a suitable verification mechanism for a DDRS. This analysis is presented in the accompanying Technical Appendix and summarised below.

Verification processes in traditional DRS are based on registration data submitted to the DMO by the producers. These include standard product barcodes; expected volumes of sale and numbers actually placed on market (POM); physical samples for size and dimensions; a range of weights of individual containers with and without residues.

In automated returns (i.e. RVM-based returns), verification begins directly at the RVM, where information about the container is collected, e.g. barcode, physical dimensions and weight. This data (redemption data, see Figure 9) is directly shared with the DMO before compaction of the container. RVMs without compaction and manual returns use RFID tagged bags to bundle containers, allowing tracking of these returns.

The manually returned items are transported to a counting centre, where they are processed through an industrial-sized RVM that collects the same data and shares it with the DMO.

Key fraud prevention measures include limits on the number of containers per bag to preserve the integrity of the containers and obligatory compaction of scanned containers to prevent fraudulent repeat-returns. Scanners are also designed to recognise the shape and weight of the containers to allow rejection of ineligible containers (e.g. if they are not empty).

Verification under a DDRS will depend on the type of kerbside collection system (comingled vs twin- and multi-stream). In the UK, comingled and twin-stream collections are currently transported to MRFs to be sorted into separate materials.

Since compaction typically happens early on (e.g. in the collection vehicles, unless glass is included), in-scope drinks containers co-collected with kerbside recyclables would likely be crushed or distorted, making barcodes/serialised code scanning later in the process difficult.

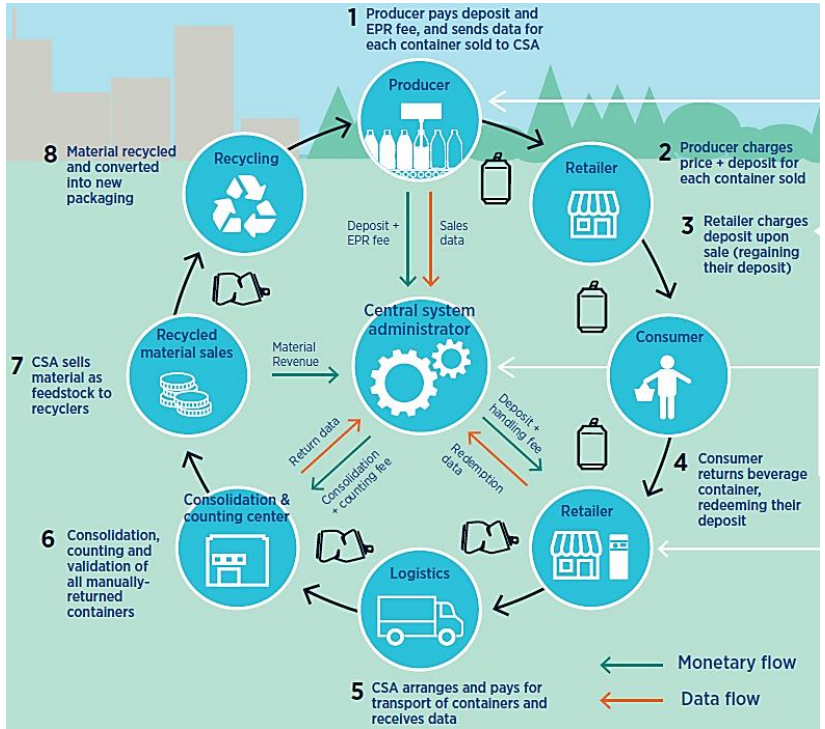


Figure 9. Typical high performing DRS flows. Source: TOMRA [CSA is the Central System Administrator, i.e. DMO]

However, use of scanning technology based on advanced AI and machine learning abilities to enable identification of in-scope DRS items may be used. If the container has UV tags printed all over the label and on the container itself, one stakeholder has found that the error correction built into 2D data matrix (i.e. ability to identify a data matrix code only partially visible) makes it possible to identify even under significant crush.

Retrofitting the existing technology at MRFs to record a count of products being sorted may be a cheaper alternative to UV tags. However, there are concerns around distinguishing between in-scope and other containers. 'Material drag' or loss of target materials stuck to other materials due to compaction or contaminants (e.g., liquids or food) with rejects is another concern.

There is also a concern that the risk of 'missing' containers may be high. With an error rate of just 1% applied to 25 billion containers (i.e. including glass containers) per year, this would amount to 250 million errors in verification per year. The DMO would have to consider these error bars in verification of deposits.

Frequent input and output material composition analysis through sampling at MRFs can support data generation (and machine learning) for verification purposes. However, limited accuracy due to lack of regular 'count' data and 'material drag' will remain concerns.

Option 2B (delayed redemption using a 2-scan approach) could also support verification. E.g. by linking each property where items are collected from with the first delivery destination after collection, and linking each property to a council and it's service provider, it should be possible to calculate the number and weight of each item that should be received by specific MRFs, and thus in theory the amount of material due to the DMO.

3. CONVENIENCE AND VALUE OF PEOPLE'S TIME

The value of consumers' time to engage with a DRS system has not yet been quantified (e.g. in Defra's latest impact assessment for DRS), and yet it is claimed as one of the main motivators for implementing a DDRS, because it is perceived to be more convenient for consumers. **Resource Futures has undertaken preliminary research to quantify that convenience**, in terms of the value of consumers' time to interact with a DDRS compared to interacting with a traditional DRS system.

Assessing the value of consumers' time is not always considered when modelling the impact of new public systems, however, it is an important step in understanding the impact of service intervention. By considering the value of time it is possible to have a complete picture of the 'true cost' of implementation and ongoing engagement with this new system, as well as assess which of the DRS options are most convenient for the user.

Table 1 outlines the results of this research. A low, central, and high scenario have been shown to account for the variability in how individuals could interact with this system, but also to account for the ways in which the value of this time could be calculated. The methodology for these results has been outlined in an accompanying Technical Appendix.

Using the low, medium and high scenario's outlined, the value of additional consumers' time was estimated on a national scale for a largely RVM-based model and a largely DDRS model (the calculations are based on a blend of engagement with both systems). Table 2 outlines the results of this research.

Returns via DDRS at the kerbside represent the lowest cost in terms of consumer time to engage with the system. Returns via RVMs and manual takeback carry a much higher time cost to the consumer, driven primarily by the travel and queue time required.

The central scenario suggests that DDRS returns at the kerbside could be up to twice as fast for the consumer as using an RVM. The estimated value of people's time in Table 2 carries a lot of uncertainty, but is comparable to other non-traded impacts in the previous Defra DRS impact assessment, the largest of which is reduction of disamenity of litter £1,452 million per annum by 2025. **Convenience is therefore not only vital for successful update of the scheme, but also represents a significant impact for consumers and should be carefully considered in any DRS implementation**.

However, it is important to highlight that the national cost impact represents every household taking a little time every day to engage with this service. The maximum time calculated was the RVM-based returns (15 h 23 min per year). This is the equivalent of an extra 2 min 30 sec per day to engage with this service, which is achievable for most UK households.

Time was considered under three key stages: travel time (additional car journeys, which varied from 0 to 1 per fortnight in the low and high scenarios), service engagement at home, and service engagement at return point. More detail can be found in the accompanying Technical Appendix.

An overall value was derived by combining £/hour for travel and £/hour for waste sorting and service engagement. The monetary value of this 'work' time could be derived in many different ways, the three different scenario models outlined in this report attempt to cover this range of possibilities (e.g. the government's value of unpaid work, as defined through carers allowance (£1.93/hr)[2]., the standard value of work as defined by the living wage, (£9.50/hr)[3] and the actual value of unpaid work as derived by the Office of National Statistics (£8.58/hr)[4]).

Table 1: Summary of £/hhld/year (and hrs/hhld//year, underneath) to consumer for different DRS options

Scenario	RVM	Manual takeback	Kerbside DDRS
Low	£10.45 *(5h25m)*	£12.66 *(6h34m)*	£8.59 *(4h27m)*
Central	£98.80 *(10h24m)*	£82.91 *(8h44m)*	£47.75 *(5h18m)*
High	£149.28 *(15h23m)*	£105.00 *(10h54)*	£48.09 *(5h36m)*

Table 2. Summary of national value of people's time, £/year, for different DRS options.

Scenario	Largely RVM based returns*	Largely kerbside DDRS returns**
Low	£274 million	£231 million
Central	£2,540 million	£1,440 million
High	£3,800 million	£1,650 million

* 95% of participating households use RVM, 5% use manual takeback
** 84% of participating households use kerbside (DDRS), 15% use RVM, and 1% use manual takeback
RVM based model proportions are based on Defra DRS impact assessment.

1. Survey, N. T. (2015). Why people travel shopping. Department for Transport
2. Government, U. (2021, April). Carers Allowance. Retrieved from GOV.UK: https://www.gov.uk/carers-allowance
3. Government, U. (2022, April). National minimum wage rates. Retrieved from GOV.UK:
4. Statistics, O. f. (2016, November). Women shoulder the responsibility of unpaid work. Retrieved from Office for National Statistics:

4. SERIALISATION

Throughout this report and the existing DDRS research to date, the fundamental and defining characteristic of a DDRS has been the serialisation of beverage containers. However, **printing serialised codes on beverage containers is not a trivial task**, and indeed is one of the main challenges outlined on page 7.

There are essentially two ways to serialise containers using visual markings:

1. Pre-print codes onto labels, which are later applied to the containers;
2. Print container serialisation markings directly on the container in the production line

Regarding the first option, marking pre-printed labels with serialised codes (e.g. for plastic and glass containers) is generally straightforward; in Phase 1 of this study it was agreed that it does not present significant issues. There is a cost consideration to support digital printing of unique codes on labels, however it is technically feasible. Besides the cost consideration, the main issues related to printing on glass and plastic bottles is related to aggregation for multipacks, which is only problematic if the codes are activated at point of sale (see page 19).

However, the technical and economic feasibility of the second option, i.e. printing on containers as they move through the production line, is more challenging. This is currently the only feasible option for marking cans, as they generally do not have labels attached to them as the other in-scope materials do (with the exception of plastic shrink-sleave wrapped cans).

Aluminium cans are more difficult to print on due to can production line speeds and the inability to isolate and orient each can to print the code in a consistent place. One solution to this issue currently being investigated by industry is to print the serialised codes on the can ends, i.e. the flat tops of the cans. The production speed of can ends is slower than the can bodies, and so can accommodate the digital printing of codes.

However, some trials have revealed that the codes can be difficult to read by scanning technology. Due to the aluminium surface of the can end, a printed code on aluminium will be very reflective, making it problematic for a camera to read due to the low contrast between the serialisation markings and the metallised surface colour of the can end. A solution to this is to add contrast by dying the can end a solid colour, e.g. red or blue, as seen in Figure 11, so that the serialised code can be more easily read by smart phone cameras. However this solution would involve an additional cost consideration

Figure 10. (left) 2D Data Matrix code pre-printed onto the label, which is later applied onto the bottle. Source: Polytag Conwy Pilot results.

Figure 11. (below) example of different placements for printing 2D Data Matrix codes directly on the container in production. Source: FOBA laser marking and engraving solutions.

4. SERIALISATION

Due to the fundamental challenge around printing serialised codes, there have been some conversations that consider **whether a DDRS could be feasible through other means not requiring serialisation.** By not requiring serialisation, other related challenges (e.g. the 'multipack issue' and the printing and linking pack codes with individual unit codes – see page 19) become non-issues.

There are a range of ideas, one of which is related to demonstrating a **proof of purchase** in order to redeem a deposit**.** This approach is a halfway point between full serialisation and existing 1D barcodes. It relies on a unique code that is printed onto a purchase receipt. At the end of a consumer's purchase, the till machine can print a 2D barcode that references all the items that have been purchased. The consumer could then scan that code, which is unique, and 'bank' any in-scope item contained within that purchase onto their app. When the consumer wants to redeem the deposit, they would then need to scan the existing 1D barcode on the empty container, which is then cross-referenced with the list of 'banked' items in your app/account. In this way, you would only be able to receive a deposit for items which you can prove you have purchased – even if they are not unique themselves. Several examples have been found where till machines print unique 2D barcodes on receipts containing purchase information. However, this would require consumers to retain receipts (either physical or electronic).

It should be noted that it is **currently at the ideation stage**, but is shared here to stimulate discussion and explore faster routes to implementation. Doing away with serialisation altogether has its drawbacks and potential for fraud, however it also presents operational benefits that serialisation currently does not provide. Nonetheless, it must be noted that one of the main benefits of serialisation is to enable higher traceability of products through its lifecycle, which could be the basis for future waste tracking and other policy and industry objectives.

DDRS may be a catalyst to advance research and development in the area of serialisation. The DMO could incentivise producers to opt-in to the digital scheme, to compensate for the current operational difficulties to serialise (e.g. paying lower producer fees, particularly if a digital DRS is less expensive to run).

Figure 10 (above). Product with different labels (1D barcode, batch code, and QR code (serialised to a specific batch)

Figure 11 (right). Itemised receipt with ability to pay through QR code.

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CONCLUSION AND RECOMMENDATIONS

CONCLUSION

If done correctly, DDRS has the potential to place the UK at the forefront of digitisation and innovation, integrating smart waste tracking with DRS. However, many still believe that the practicalities are too challenging, largely due to the fact that it requires a considerable and coordinated effort by all actors along a product's value chain, from producers through to waste management. Considering our original research questions:

1. **HOW** might a DDRS be implemented in Wales as well as in England and Northern Ireland?

We see that there are at least three different ways that a DDRS could be implemented. However, the design framework presented in this report could be used as a basis for creating other end-to-end designs, based on more current approaches as they develop.

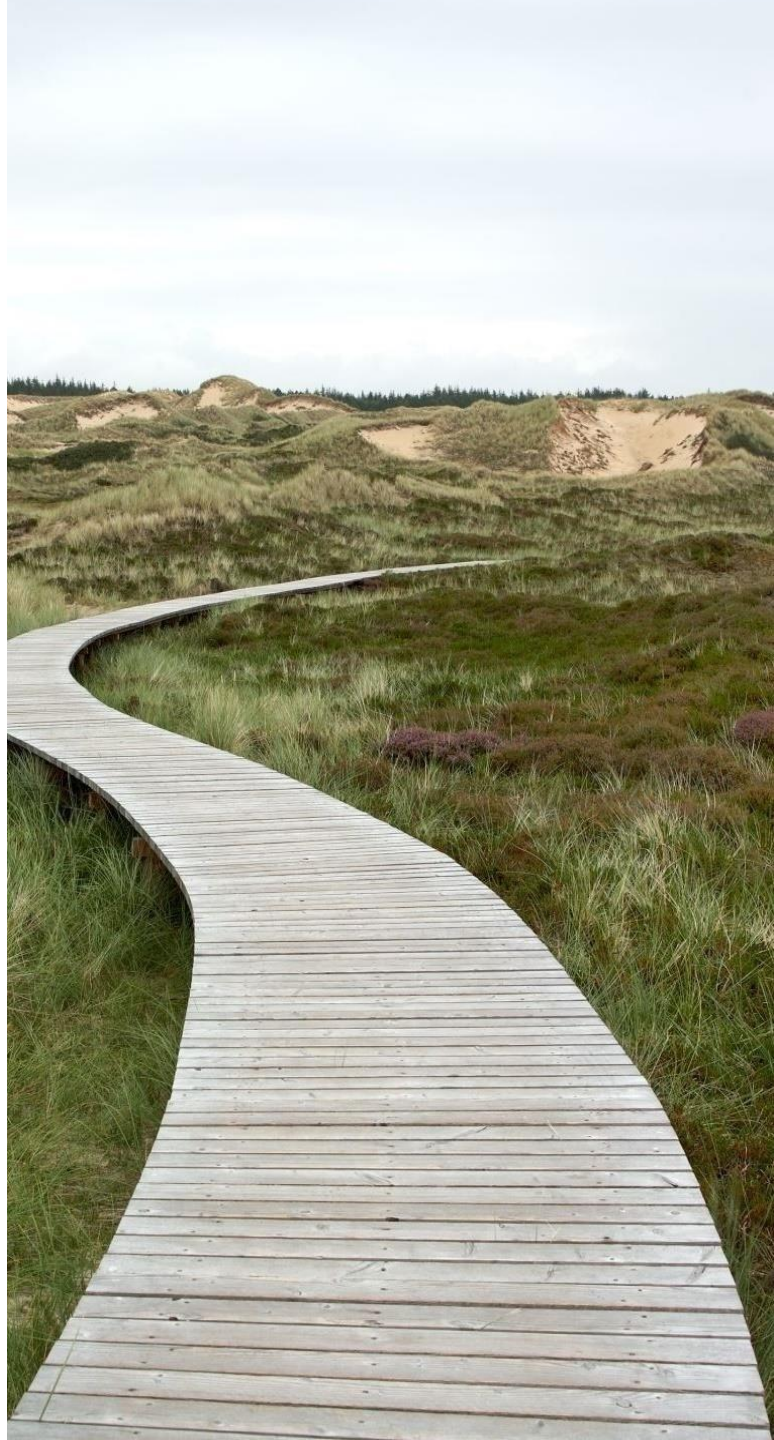
2. **WHEN** could a DDRS be implemented in Wales as well as in England and Northern Ireland?

Using the market readiness levels provided in each of the process maps, we see that the approach with the highest level of market readiness is Approach 3, which requires the fewest structural changes compared to current practices. Depending on the fuller picture of benefits and challenges, investments and resources can be deployed to accelerate particular value chain sections experiencing the longest delays within Approach 1, such as the serialisation and activation of 2d barcodes at production.

3. **CAN** the purported benefits be realised?

We have assessed the strengths and weaknesses of different DDRS designs and drawn out examples from real world case studies. Assuming that there is a solution for the HOW and WHEN in satisfactory timescales, we have seen in this research some merit in a DDRS over and above the traditional RVM approach to DRS. We have also concluded that DDRS generally has a strong advantage related to convenience and the value of people's time. However, we have also seen that RVM-based models inherently support higher quality recyclate material; this remains an important question that feeds back into **HOW** a DDRS can be implemented to ensure similar material quality.

In understanding whether purported benefits can be realised, it is important also to consider SMEs and other more vulnerable value chain actors to ensure that they are not being disproportionately burdened, and that they are sharing in the benefits. **There are many nuances within even one part of the value chain to unravel**. A balanced assessment of impact approach is needed, for each of part of the value chain, to ensure that all perspectives are considered. For example, the views of large retailers may differ greatly to those of small convenience stores, or those of purely online retailers. Urban local authorities will also have different challenges to face compared to rural local authorities. Communicating the three approaches presented in this report, with a view to understand the specific concerns of different groups, will be a key way to explore and advance DDRS in an inclusive and open manner



FURTHER RESEARCH NEEDS

There has been a great uptake in interest in DDRS over recent months.

Leading industry events and expos, such as the Chartered Institution of Wastes Management's annual resource conference in Wales, LARAC Wales conference and RWM, have all had dedicated speaking slots on the topic of DDRS.

Technology providers have also confirmed that there are several trials planned in the coming months to continue testing various aspects of feasibility, with the participation of large-scale private partners.

The trials will undoubtedly shed light on key remaining questions. However, both **industry and government would benefit from additional insight,** addressing whole-systems thinking, rather than specific feasibility questions.

Industry and government would benefit from additional insights specifically in the area of carbon impacts, system costs and implementation.

The **carbon impacts** of a DDRS vs DRS is an important area that to date has not been investigated in great detail. Understanding the carbon impacts of any new policy is critical in today's climate emergency *(see: Welsh Government makes climate emergency declaration).*

To support government in deciding the selection criteria and appointment of a future deposit management organisation (DMO), an understanding of the net carbon emissions of both an RVM based DRS and a Digital DRS will be a vital consideration. This motivation is driven by Welsh Ministerial commitment for Wales to achieve net zero carbon emissions by 2050 and the Well-being of Future Generation Goals where Wales is a low carbon, low waste economy.

System costs, and particularly how they fall across the value chain and across different sized stakeholders, is a continued area of interest by stakeholders that have so far been engaged in this research. The consideration of overall value for money is also a critical one for government. Providing both government and industry with a better understanding of these costs and who would be most impacted is key for future uptake in the system.

Finally, understanding **how DDRS might be implemented alongside a traditional DRS** is necessary in order to have a more complete picture of DRS as a whole. This should be based on the greater understanding of the design parameters and options established though the DDRS feasibility work to date. This systems-thinking can provide clarity to those who still view DDRS as a separate system to DRS, by showing information and financial flows and feasibility of implementation.