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Preface

There are many requirements for good packaging - it needs to protect the product and enable a sufficient shelf life. However, over the recent years the demand for more environmentally friendly packaging has been increasing and many public and private stakeholders have reacted by starting to investigate and implement reusable packaging systems to mitigate the environmental effects and meet the public demands. Additionally, regulations have started to move towards supporting reuse with set targets.

Consumer engagement is critical to ensure success for businesses dealing with reusable packaging of fast-moving consumer goods (FMCGs). Some knowledge of consumers' views on reusable packaging and reusable containers exists, but the domain is still in its nascency. Overall, consumers hold somewhat positive perceptions and attitudes toward reusable packaging. However, concerns by consumers over several issues (e.g. convenience, quality, and pricing), confusion between recycling and reuse, negative attitudes toward certain solu-tions and low willingness to return and refill packages have been observed.

Well-performing business models are crucial to scale up reuse systems. Despite the growing interest of the private sector in the circular economy, the implementation of circular business models is still low in practice. Today, only very few products with reusable packaging are available in the FMCG industry, although a portfolio of new reusable packaging business models is emerging. Different barriers and success factors can be identified. For instance, reuse may be perceived as not allowed, unsafe, not sustainable, or not economically feasible. It is important to establish that there is no inhibiting regulation for reuse. However, a mix of policies and instruments is needed to support and incentivise establishing reuse systems on a large scale.

Safety is an integral aspect that need to be managed, it can also be facilitated by material and packaging design. In reuse cases, packaging faces requirements from both the product side and the system, which includes reverse logistics, reuse-related operations and maintenance, possibly intelligent elements such as sensors, and communication and marketing needs. The materials used today in single-use packaging are seen also in reuse applications, and the materials are not the main hindering factor in setting up reuse systems. However, the number of cycles the packaging can withstand is an important factor for the overall feasibility.

All circular solutions need their own reverse supply chains to enable circularity. The lacking infrastructure for collection logistics and washing solutions pose challenges for the uptake of reusable packaging, there are a lack of active operators in the field on a larger scale. To facilitate the reverse logistics and packaging monitoring, tagging technologies are available to allow connectivity to digital traceability platforms. Important digital platform features include access to data, data management, dynamic data, and data security. Tags and data can offer additional services for product safety and consumer engagement.

This publication outlines an overview of the operational environment for reusable packaging used in fast moving consumer goods (FMCG), which has been developed as a part of the Business Finland funded 4everPack research project together with the 4everPack consortium: VTT Technical Research Centre of Finland (coordinator), University of Vaasa, Berner, Borealis, Brightplus, City of Helsinki, HUS, Kamupak, Kesko, Kiilto, Kotipizza, Metsä Board, Nordic ID, SOK, Tomra and UpCode.

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1. Introduction

Packaging is key in the safe distribution of products in modern society; however, the packaging sector consumes a lot of materials that are utilised in single-use products. Most of today's packaging especially for fast moving consumer goods (FMCGs) is based on single-use packaging, which creates immense amounts of packaging waste. Reusable packaging is sought as a solution to mitigate the linked environmental impacts and high material usage.

Reuse as a concept is not new, the first known reusable packaging models date back to 1785, where the origins of the first milkman are documented. However, to implement reuse in today's global businesses and especially in FMCG concepts is complex. This publication outlines the current operational environment for reusable packaging used for FMCGs, which has been researched and developed as a part of the Business Finland financed 4everPack research project together with the 4everPack consortium: VTT Technical Research Centre of Finland (coordinator), University of Vaasa, Berner, Borealis, Brightplus, City of Helsinki, HUS, Kamupak, Kesko, Kiilto, Kotipizza, Metsä Board, Nordic ID, SOK, Tomra and UpCode

In addition to enabling efficient product distribution, packaging has a role also in improving sustainability, e.g. reducing food losses by preserving food longer. However, it also inflicts environmental impacts as well as costs for supply chains. Most of today's packaging, especially for fast moving consumer goods, is based on single-use packaging and emphasises linearity—make, use, dispose. Current activities intended to help linear packaging value chains transition to a circular economy are mostly focused on improving recyclability, but it is expected that more benefits can be gained by implementing reuse practices (Figure 1). Reuse should be a prioritised option wherever possible as it can retain the functionality of the material and product and result in potentially significant reductions in material use, generated waste, and furthermore, it can mitigate environmental impacts. Fundamentally, reuse can help to decouple economic growth or maintain the economic level from increased material use.

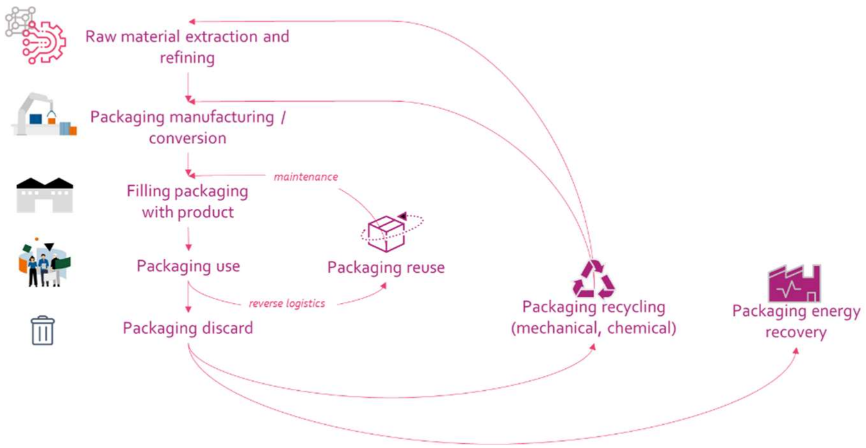

Figure 1. *Favouring reusable packaging before recycling or energy recovery could bring further benefits and help decouple companies from the excess use of virgin and primary resources.*

In this report, with reusable packaging we refer to either refillable or returnable primary or secondary packaging in consumer applications. In other words, in line with the definition of (Sustainable Packaging Coalition, 2022), reusable packaging is packaging that allows putting the same type of purchased product back into the original packaging, is designed to be returnable and/or refillable, is used several times and is part of a business system that enables reuse.

Reuse business models can offer several advantages. They reduce the amount of packaging waste produced (especially plastic waste), reduce the amount of materials used, help to prevent littering, cut packaging costs in transportation, create savings and optimisation of distribution and logistics, create opportunities in data mining and knowledge, improve user experience, identify potential for customer-centric products and manufacturing, and improve brand loyalty especially with different deposit and reward schemes. Consumer oriented businesses can have different reuse models where product refilling can happen at home or on the go, and different return schemes can be established on the go or at home as well. For example, the reuse model has been applied to personal and home care bottles, beverage bottles, pallets, larger rigid packaging. Moving from single-use to reuse models is at the core of a circular economy of packaging and is predicted to have a big impact (Ellen MacArthur Foundation, 2019).

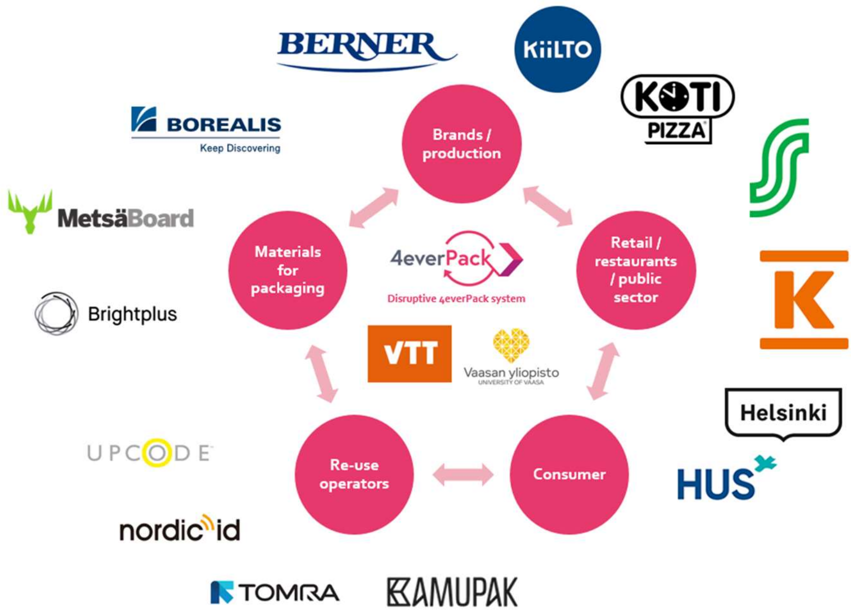

Figure 2. *4everPack project consortium*

Looking into plastic packaging alone, globally around 146 million tonnes of plastic are used every year and the consumption is increasing rapidly. Close to 133 Mt of plastic packaging waste is landfilled, incinerated or in worst case, littered in nature. These materials are lost from circulation. It is estimated that 95% of the value of plastic packaging material, between 70–105 billion EUR, is lost annually to the economy after a very short first-use cycle. Demand for recycled plastics today account for only 6% of the plastic demand in Europe (European Parliament, 2021), so the recycled plastics market is rather underdeveloped. Globally, it is estimated that 8 million tonnes of plastic waste finds its way into waterways, which equals one garbage truck, or 15 tonnes of plastic waste, entering the world's water systems every single minute, which is only expected to increase in the future. If no action is taken, this is expected to increase to four trucks per minute by 2050 (World Economic Forum, 2016).

The purpose of this report is to present the operational frame concerning today's packaging reuse, particularly regarding fast moving consumer goods, and to discuss the key aspects that can foster reuse. By doing so, the report aims to provide a detailed picture of key technological, cultural, business, and regulatory aspects that are relevant to the development and growth of efficient reuse systems. First, we focus the key factors that drive the change.

2. Key drivers of packaging reuse

2.1 Environmental concerns over plastics use

Anthropogenic pollution, particularly arising from the increasing use of single-use plastic packaging, has gained global attention. The role of civil society has been significant, and several non-governmental organisations such as the WWF, Friends of the Earth, and the Ellen MacArthur Foundation, as well as the media have actively campaigned to raise awareness of this global challenge.

Over the past years, a significant number of initiatives have been launched such as the Global Commitment 2022, led by the EMF in collaboration with the UN Environment Programme to transition to circular packaging by targeting that all packaging will be reusable, compostable, or recyclable by 2025. The Commitment represents 20% of the global packaging value chains.

Furthermore, an increasing number of countries have implemented various policies and regulations to mitigate the damage to the environment and society. Regulatory initiatives, such as bans, have mainly addressed relatively easily manageable items such as plastic carrier bags or plastic straws, while more complex plastic products like food packaging have only recently been addressed (Sundqvist-Andberg & Åkerman, Sustainability governance and contested plastic food packaging – An integrative review, 2021). An example of this kind of regulation is the European directive on certain plastic products (also known as the Single Use Plastics Directive, SUPD). Even though reuse is still marginal compared to the single-use plastics packaging, there is a growing global trend towards tightening regulations on single-use plastics. In this context, packaging reuse is seen as a solution to plastic waste and littering problems.

Besides global plastics pollution, the use of fossil-based raw materials for packaging production has raised concerns particularly from the climate perspective. Thus, various policy interventions are being implemented to improve resource efficiency and to find alternative ways to replace single-use fossil-based plastics in packaging applications, reusable packaging being an example of such an approach. Frankly, it is also becoming more evident that without doing anything and without decoupling economic growth from material use, in this case for packaging, natural resources simply will not be able support the ever-increasing population and its needs.

2.2 The circular economy and digitalisation leading to safe circularity

All activities in the reusable packaging supply chain play their part in the safe circulation of packaging. In the reuse cycle itself there is no reproduction of materials, meaning that there are fewer risks from that perspective in the packaging material itself. However, the process for the cycle should be safe to avoid any contamination that could be harmful for the packaging and to ensure that the packaging can stay in circulation for its full lifetime. One concern for safe cycles in reuse is the possibility that the consumer may use the packaging for something else before returning the packaging. In the loop, there is a need for quality checks to ensure that the packaging is suitable for reuse. In washing, there is the aspect that the washing needs to remove impurities but also the aspect that the packaging material needs to endure the washing process including heat and chemicals, for example. After the packaging comes to its end in reuse, recycling and safe circulation in the recycling loop is relevant. Ultimately, it should be the goal that the recycled packaging returns back to the original use to form a truly closed cycle. When compared to standard recycling practices, with reusable packaging the traceability and knowhow from the product lifecycle should enable this.

Digitalisation of any value chain is a global trend. Digital technologies, such as item-level identification systems or digital product passport are applications which are unique for each product and contain respective value chain and lifecycle data. They can help to overcome the challenge of data losses in value chains, serving as a valuable data source for stakeholders. Blockchain technologies can help to capture dynamic data, thus providing value chain transparency, because it allows interoperability with existing systems, storage in private and public systems, decentralisation, and high data integrity. Combined with advanced identification and monitoring technologies (described in Section 4.3) blockchain enabled technologies can help to overcome existing challenges related to traceability and identification of reusable packages. Similarly, digital solutions can help in gathering data to define sustainability and circularity (e.g. end-of-life and recycling of reusable packages) aspects and requirements.

Package traceability should be maintained throughout the lifecycle of reusable packages. Technologies, such as identification technologies, monitoring technologies, blockchain and digital twins could be used to ensure item-level traceability and identity. The traceability technologies should meet several, often contradictory, requirements, such as durability throughout several uses, compatibility with package end-of-life management schemes, the capability to provide up-to-date information, data security, access for relevant users, and integration with the other systems and platforms.

3. Reuse business models

FMCG companies are increasingly confronted with the challenge of finding solutions to solve environmental problems. Incremental changes in products and processes are not always sufficient to transition towards a sustainable circular economy. A focus on absolute reductions by designing out waste and keeping products in longer use is needed. In the Circular Economy strategies hierarchy (e.g. *Rethink, Redesign, Reuse, Repair, Remanufacturing, Recycling, Recover...*) a change from material recycling to product reuse is considered more positive as more value is retained (Kirchherr;Reike;& Hekkert, 2017). Hence, the reuse of packaging represents a major opportunity to retain the functionality of the material and product and achieve potentially large reductions in material use and environmental impacts.

This shift requires new ways of designing and implementing business models (Santa-Maria;Vermeulen;& Baumgartner, 2021) in which traditional roles of product manufacturers are reshaped to become service providers who are responsible not only for product sales but also take-back, refilling and reuse (Brown;Bocken;& Balkenende, 2019).Business model innovation—the process of changing existing business models in established companies or designing entirely new business models in a start-up companies to create, capture and deliver value in novel ways (Osterwalder and Pigneur, 2013)—is a core innovation to shift from single use to reuse packaging schemes. The challenge lies in offering a novel business model that is *feasible, desirable* and *viable*, while demonstrating its *sustainability* benefits.

3.1 Typology of reuse business models

In the packaging context, reuse circular business models (RCBMs) have emerged in recent years, aiming to slow down and close resource cycles (Bocken et al., 2016). These business models have been categorised in specific typologies detailed in Table 1 below.

Table 1. *Typology of Reuse CBMs*

Reuse CBMs	Source
· Refill at home · Refill on the go · Return from home · Return on the go	Ellen McArthur Foundation (2019)
· Consumer replenishes/reconditions · Consumer replenishes at home via service · Consumer replenishes on-the-go via service · Consumer brings and company replenishes/ reconditions via service · Company replenishes for consumer via service	(Tassell & Aurisicchio, 2020)
· Refillable by Bulk Dispenser · Refillable Parent Packaging · Returnable Packaging · Transit Packaging	(Coelho;Corona;ten Klooster;& Worrel, 2020)
· Exclusive reuse models o Exclusive reuse models o Exclusively reused products o Exclusively reused products with reuse-enabling infrastructure o Reuse-enabling infrastructure for exclusively reused products · Sequential reuse models o Sequentially reused products with reuse-enabling infrastructure o Sequentially reused products	(Muranko;Tassell;Zeeuw van der Laan;& Aurisicchio, 2021)

The Ellen McArthur Foundation detailed four archetypes for reusable packaging models: *refill at home, refill on the go, return from home, and return on the go* (EMF, 2019). This framework is built upon expected consumer behaviour (i.e. return or refill), and the location, (i.e. on the go or at home). Tassell and Aurisicchio (2020) introduced five reuse models based on crucial reuse-enabling behaviour of providers and consumers: (1) consumer replenishes/reconditions, (2) consumer replenishes at home via service, (3) consumer replenishes on-the-go via service, (4) consumer brings and company replenishes/ reconditions via service, and (5) company replenishes for consumer via service. The framework specifies both the role of the customer and the provider in the reuse process. In the first three categories, the customer keeps the packaging and is involved in replenishing (preparation for re-use) or reconditioning (recovery for reuse). The latter two categories require the customer to dispose of or bring back the reusable containers.

Coelho et al. (2020) introduced another simple classification of reusable business models based on the practical characteristics of such a system. These included: refillable by bulk dispenser (1), refillable parent packaging (2), returnable packaging (3) and transit packaging (4), the latter focusing on B2B operations. Muranko et al. (2021) made a distinction between two categories of reuse business models: exclusive reuse models in which reusable packaging is owned and kept by the customer who can control the reuse journey; and sequential reuse models in which reusable packaging is owned by the company and access is offered to the customer. Both reuse options entail three operations: preparation for reuse, reuse, and recovery for reuse. The exclusive and sequential reuse systems are also subdivided into different reuse models that require low to high amounts of consumer effort.

3.2 Examples of reuse business models

Several companies have been experimenting with Reuse business models in recent years (EMF, 2019) and several larger pilots are currently ongoing.

In partnership with **Algramo**, retailer **Lidl** has launched a new refill station at its UK-based Kingswinford store. The station is an automated, touchscreen, liquid refill machine. The machines can be found in-store in the laundry detergent section. The refill machine supports four laundry detergents. Customers can pick up a specially designed refill bottle; these can be found next to the machine. The automated refilling stations offers customers a streamlined and intuitive approach to save on single use plastic. First, the customer picks up a refill bottle in store. At the station, they select which Formil laundry detergent product they want to refill. After placing the refill bottle in the machine, the station will automatically recognise the Formil refill bottle. Once the refill process is complete, the customer simply collects a ticket printed with a barcode for the product.

The first time a bottle is filled, the customer pays for the refill bottle and laundry detergent at the till with the ticket. The next time, after the laundry detergent is used, the customer brings back the empty bottle to refill and starts saving. The refill bottles are made of HDPE. HDPE is a sturdy and durable plastic which will allow for the continued refill of laundry detergent. The refill bottle is 100% recyclable. Using the laundry detergent refill bottle after the first time saves 59g of plastic per use, the weight of a single use Formil bottle of the same product. The cost of purchasing the refill bottle and laundry detergent is £1.69 for concentrated detergent (bio and non-

bio) and £1.89 for concentrated fragrance detergent (Tropical Lily and Honey Petals). Once the bottle is reused, the price of just refilling will be £1.49 and £1.69 respectively. This is a saving of 20p per use.
Source: https://www.lidl.co.uk/refill

Loop is another relevant example of Reuse Circular Business Model applied at scale. Loop is a global platform for reuse, which collaborates with brands and manufacturers to enable refillable versions of their conventional single-use products, and partners with leading retailers to embed these offerings into their online eCommerce and physical retail stores. Loop is working with category-leading brands, retailers, restaurants, and more to activate a circular reuse ecosystem offering thousands of products—from cups of coffee to shampoo bottles—with the aim to make reuse as convenient and accessible as single use. Loop's reuse platform was announced in 2019 at the World Economic Forum in Davos, and is now available in the United States, the United Kingdom, Canada, Japan and France. Now partnered with over 200 consumer product companies and more than a dozen major retailers, Loop continues to launch innovative new platforms to offer reuse across a broad spectrum of categories, from restaurants to reusable diaper services. Loop's model is built to scale the impact of reuse across a cross-category global ecosystem of products, and to make these products as accessible and convenient as possible for consumers by distributing them through a network of existing channels and retailers. When shopping at the retailer, Tesco for instance, the customer visits the Loop Reuse Station to buy a wide selection of products from leading brands in zero waste, refillable packaging. Products can be taken home using a waste-free return bag. What's more, the returnable bag allows customers to drop off multiple containers at once and makes returns even simpler. Once the product is consumed, the customer simply drops off the empty container at the nearest Loop Return Point using the Loop Deposit App and gets the deposit refunded. Loop collects the empty packaging to be professionally cleaned and refilled, before arriving back in the stores for the next customer. Source: https://exploreloop.com/Tesco

Vytal is a digital reusable packaging system for **take-away** and delivery food. After registering on the application, customers get a personalised QR code in the Vytal app. This code can be used to borrow containers free of charge from participating partners (restaurants, canteens, caterers) for 14 days to avoid packaging waste. The caterers scan the QR code on the Vytal container and the one in the user app to link the packaging and the user. When the container is returned, the QR code on the container is scanned and the container is booked out of the user account. The Vytal system is completely free of charge for the customer. The containers are financed by the caterers who pay a small fee per filling the containers. This saves them disposable packaging costs, which are higher than the filling fee. If a Vytal Bowl or Cup is not returned within a 14-day return period, customers automatically buy a bowl for 10€ and a cup for 4€. Vytal reusable containers from MEPAL are made of BPA-free polypropylene (PP) and with a lid made of PP and thermoplastic elastomer (TPE), so they are light, stable and 100% leakproof. The divided container and the coffee cups are 100% PP. A Vytal container can be reused up to 200 times if used properly. According to Vytal, from 10 fillings upwards they are more environmentally friendly than disposable packaging and save up to 30 kg of CO2 over their life cycle compared to disposable packaging made of polystyrene or aluminium. Source: https://en.vytal.org

3.3 Opportunities and challenges for reuse business models

From a producer perspective, developing reuse business models can offer several opportunities:

- *Consumer loyalty:* Business models focusing on selling parent dispensers (ie: pouches) as well as return business models associated with a refund system can expect an increased consumer loyalty.
- *Sustainability image:* Several companies have introduced reusable packaging systems as part of their corporate sustainability strategy (e.g. in cosmetics) as consumers may associate reusable packaging with a stronger sustainability performance.
- *Emotional factors*: A bond with a particular product or package, can also be of importance for selected products (Bakker et al., 2014).
- Product customisation: The use of low-cost refills or a reusable system provides the potential for increased product customisation, as the costs for offering customised products decrease.

From a consumer perspective, reusable packaging systems can also offer a variety of benefits: reduced costs and price incentives (discounts for reusing), increased variety and customisation, convenience of delivery and pickup, and reduced waste.

The implementation of such business models is however not without challenges. Reuse business models require a systemic change, whereby all players of the value chain are involved, and all elements of the system are rethought. A new reuse business model requires the development of new (reverse) logistics, product designs, investments in new production steps or even complete lines, as well as communication strategies to optimise the impact of the system. Reorganisation of the supply chain and the relationships within the supply chain can become a major barrier within the current complex and global supply chains. The following challenges have been identified:

From the producer perspective:

- *Increased logistic complexity*: Reuse business models require reorganising supply chains to ensure that packaging is available and returned through better management of distribution, returns, brand recognition and loyalty, as well as stocks.

- *Upfront investments* in a new reusable packaging system
- *Product safety* especially for food and cosmetics.

From the retailers' perspective:

- *Additional* space to store reusable containers or dispensers.
- *Hygiene risks* due to contamination or spoiling through improper use or cleaning of bulk dispensers.
- *Ma*intenance and cleaning *of dispensers* as an added activity and hence barrier within current retail concepts.

From the consumer perspective:

- *Inconvenience* of a reusable packaging system such as having to bring empty containers to be refilled or the ease of use of refilling.
- *Unavailability* of refills, which would make the system inefficient.
- *The* first cost of a parent dispenser in a refill system.
- *Ineffective* communication, which may result in the disposal of reusable systems.
- *Poor* pricing *policy* by retailers or producers (resulting in equal or higher costs for a reusable system).

4. Material solutions for reusable packaging

The amount of packaging generated and used has increased in Europe during 2009–2019, and in 2019 the packaging waste volume reached the highest value since 2009. The highest increases have been experienced in plastic, paper and carboard and wooden packaging. In Europe, 40% of plastics and 50% of paper is used for packaging, and packaging represents 36% of the municipal solid waste (Coelho;Corona;ten Klooster;& Worrel, 2020). On average, a European consumer uses packaging approximately 177.2 kg per year, which totals up to almost 500 g of packaging waste generated each day (Eurostat (a), 2022).

In Europe, 89.2 million tonnes of packaging waste was generated in 2018 (Figure 3). Over 40% of the packaging waste was paper and cardboard packaging (36.7 million tonnes), and approximately 20% (17.2 million tonnes) is plastic waste.

Figure 3. *Waste amounts generated by packaging type in Europe in 2018 (Eurostat)*

The recovery (recovered plastic waste, including incineration), recycling and repair of different types of packaging in Europe (2018) is presented in Figure 4. Of the collected packaging waste, almost 83% of the paper and cardboard packaging is recycled. For plastic packaging waste, only about 75% is recovered and furthermore, only 41% is recycled. For glass and metal packaging, almost all of the recovered materials are recycled. Wooden packaging types of packaging have a recovery rate of 60%, and only about 35% are recycled. Eurostat also records repair activities, and as can be seen from the Figure 4. The repair is aimed at repairing wooden packaging for reuse.

By retaining the functional qualities of materials, reusable models provide the opportunity to reduce the need for virgin materials, reduce the increasing amounts of generated packaging waste, and reduce the environmental footprint of materials used.

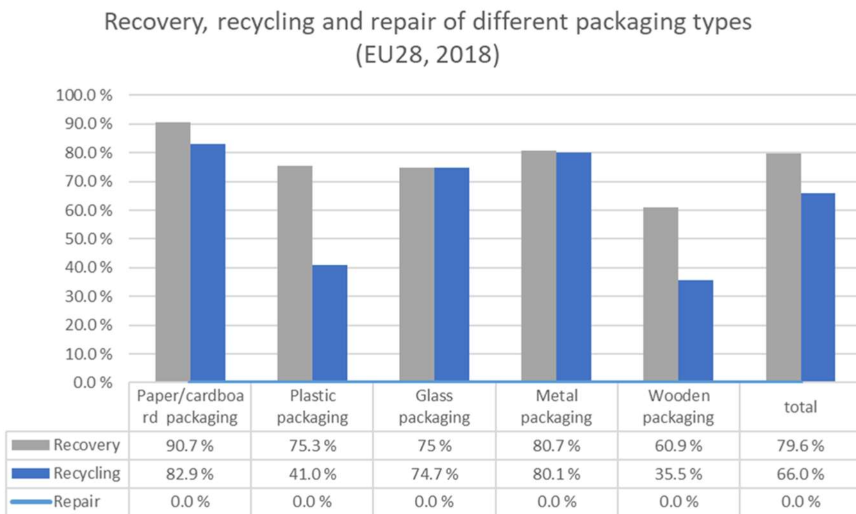

Figure 4. *Recovery, recycling, and repair of different packaging types in Europe in 2018 (Eurostat)*

Even though reuse is a key circular economy solution for mitigating the environmental impacts of packaging, data is not collected on reusable packaging systematically on an EU-level. There are proposed actions to include calculation methods for increasing reuse and recycling targets for packaging waste in the new proposals amending Directive 2008/98/EC on waste and Directive 94/62/EC on packaging and packaging waste. The reuse method would include municipal waste directed for reuse and reused products and components. The new proposal for Packaging and Packaging Waste Regulation (to be implemented in 2024-2025) presents several targets for reuse. For example, reuse for hot and cold beverage packaging (horeca) needs to be at 20% by 2030, reusable packaging for food takeaway 10% by 2030, and beverages (alcoholic and non-alcoholic) should be at 10% by 2030.

4.1 State-of-the-art of reusable packaging

It is common that the available reuse packaging solutions for FMCGs are similar to the single-use packaging used. Single-use packaging has been designed to fit the product’s technical requirements such as protection needs (especially different barrier properties), product volume and facilitating consumption, hence, it is a natural baseline for designing reusable packaging. However, it seems that typically more materials, especially with plastics, is used in reusable packaging to make them more rigid and durable. Additionally, material changes may occur, e.g. to replace expanded polystyrene containers or thin flexible films with more durable materials from plastics and metal-based packaging solutions. In addition, design changes to facilitate return logistics can be seen for example in redesigning the packaging to facilitate nesting or stacking. The type of packaging developed and used seems to depend a lot on whether the brand or retailer has invested in the reuse packaging and operations themselves or if they buy the packaging as a service from a third-party provider.

As an example, Kamupak’s deposit-based reuse containers for take away and coffee cups are branded under Kamupak, who offer the packaging and reuse related logistics and operations in Finland (Figure 5).

Figure 5. *Kamupak's deposit-based returnable takeaway and cups*

Another globally acting reusable packaging provider is Loop. Loop is a global reuse platform enabled by a multistakeholder coalition of manufacturers, retailers, and consumers and they are operating currently in the United States, United Kingdom, Japan and France. Loop has refillable packaging solutions for different types of consumer products like food, beverages, and other consumer products. Loop utilises durable materials in their reusable packaging like stainless steel, aluminum, glass and engineered plastics.

Different service providers offer commonly standardised packaging and container types and sizes that can be tailored for the brands and retailers, e.g. with colours and labelling. Standardised packaging for standardised systems typically result in easier, higher-capacity and more cost-efficient (automated) operations. Especially in business-to-business (B2B) systems, standardised transport and shipping containers and their maintenance is functioning and feasible (Coelho;Corona;ten

Klooster;& Worrel, 2020). In business-to-consumers (B2C) markets, packaging are less standardised. Bottles can be seen as more standardised, but there is still a lot of variance in the bottles used even though standardised volumes are used. For example, Coca-Cola invested in 25 M$ (2018) to unify the design of their reusable refillable bottles, based on PET, to create the 'Universal Bottle'. Furthermore, they invested 400 M$ to expand their reuse infrastructure for bottle cleaning and refill. The universal packaging bottle design has significantly reduced washing, filling and return logistic costs. (Ellen MacArthur Foundation, n.d.).

A difference to single-use packaging is also that the whereabouts and the condition of reusable packaging is typically monitored and tracked. Packaging condition monitoring and maintenance are especially important to ensure safe use and maximise the number of reuse cycles. As a rule of thumb, it can be concluded that if the packaging integrity is compromised, for example due to physical damage or chemical exposure, the safety cannot be ensured. Reusable packaging performance can be evaluated by different methods, for example by evaluating the maximum reuse lifetime or total number of cycles. The number of cycles a package can complete has a direct effect on the feasibility and environmental sustainability of the reuse system.

As an overview of analysis done in the 4everPack, the following differences—purpose, system and packaging material and design—can be seen surfacing with single-use and reuse (primary) packaging (Table 2).

Table 2. *Comparison of single-use and reuse packaging attributes.*

Attribute	*Single-use packaging*	*Reuse packaging*
Purpose	Discarded after one use	Multiple use cycles. In reviewed related LCAs and case studies, the plastic-based packaging circulated or was estimated to be reused between 15–100 times. Steel-based solutions were estimated to be reused 100–1000 times.
System	No return logistics, no specific requirements on the packaging after use	Return logistics required. Requirements on packaging after use, condition monitoring and preparation for new cycle like washing and refilling.
Packaging materials	Plastics, fiber-based, aluminium, tin, stainless steel (in higher cost products), glass	The same materials are also used in reusable packaging, but the amount of material used can be higher and packaging tends to be thicker or more rigid. Focus is more on plastics, stainless steel, aluminium.
Packaging weight	Typically, lighter than reuse packaging	Typically, heavier

		Exceptions exist, e.g. when reusable packaging is made out of plastic and replaces single-use glass packaging.
Packaging type and design	Plastics: flexible packaging, rigid packaging. Multi-material combinations and multilayer materials. Not typically possible to open and close multiple times, and designed for one-time action or one-time/rather quick product consumption. Fiber-based packaging: kraft paper and speciality, cartonboard, container board. Metal-based, more focused on aluminium and tin-based packaging due to lower cost. Stainless steel in higher value food packaging.	Plastics: Reusable packaging tends to be more rigid, but flexible reusable packaging is also used, e.g. refillable pouches. Redesigned to facilitate multiple openings and closings. Fiber-based packaging: the same type of packaging is used, but the use of fiber-based solutions for reuse is more limited than plastics. Challenges exist in cleaning and washing. Stainless steel is seen more in reusable applications than single-use, very durable material choice, which is easy to clean and wash.

4.2 Packaging types

Primary packaging is the packaging that is in direct contact with the product itself, it is also often referred to as retail or consumer packaging. The main purpose of primary packaging is to store, protect and/or preserve the product, particularly against contamination as well as deliver the product. This type of packaging is often intended for the end user or consumer. Primary packaging can be designed to improve desirability and the user experience; hence, the packaging can be also used for communication and marketing purposes.

As an example, Kotipizza's cardboard single-use packaging box is illustrated in Figure 6. Furthermore, examples of primary packaging for household products and takeaway food are illustrated in Figure 7.

Figure 6. *Kotipizza's packaging solution for takeaway pizzas*

Figure 7. *Primary packaging examples for household products and takeaway food containers*

Secondary packaging, also referred to as transport packaging, includes containers or boxes to store the primary packaging. Secondary packaging collates primary packaging into a single pack and facilitates the handling of smaller products or packaging. Secondary packaging provides additional protection for the primary packaging. It can also be used as a shipping container or box for smaller shipments, which makes it quite popular for example in e-commerce. Secondary packaging is standardised to facilitate efficiency, which enables faster loading times and lean production processes, for example.

Tertiary packaging is also referred to as bulk or transit packaging, and it is used to group larger quantities of primary and secondary packaging for transport. Tertiary packaging includes for examples pallets and shipping containers, which can be used for both shipping and storing. This type of packaging makes it easier and more secure and safe to transport large and/or heavy loads.

Reuse is quite common for secondary and tertiary packaging. Easier reuse is supported by standardised design of for example crates and pallets (Figure 8).

Figure 8. *Examples of reusable transport packaging sourced from the Reusable Packaging Association* (Reusable Packaging Association, 2022)

Wood is commonly used for secondary and tertiary packaging, also cardboard is used in these packaging types. Plastic and steel are used widely in different applications—from primary to tertiary packaging. Glass is used mainly in primary packaging solutions. Metal-based packaging is commonly seen in all categories—primary, secondary and tertiary packaging.

The secondary and tertiary packaging do not fall under the main scope of 4everPack project, but as there are more reuse applications within these packaging categories (typically B2B), the state-of-the-art was reviewed for ideas and scalable solutions for FMCG primary packaging.

4.3 Conventional packaging materials and their fit for reusability and recycling

Metal packaging is usually made from stainless steel, aluminium, and tinplate, and it is used in a variety of application forms and structures such as cans and closures. Metal packaging provides excellent barrier properties to light, gas, and moisture. It is easily converted into many shapes, it can be formed into rigid structures, and it is highly recyclable. It is easy to separate due to its magnetic properties, which enables also high recyclability. Metal manufacturing is however rather emission and energy-intensive; it can also be a source of leaching chemicals from containers to food and result in the depletion of finite resources when resourced from virgin or primary resources. Shipping metal-based packaging can be also more costly as it is a bit heavier.

Stainless steel is an expensive material solution and is used in returnable and reusable systems such as kegs (for drinks) and large storage or transport containers. Stainless steel is typically categorised into three main types by their crystalline structure: austenitic, ferritic, and martensitic. Aluminium and tin are more cost efficient than stainless steel. Aluminium is used in seamless containers (as it cannot be welded) and also in light-weight packaging applications such as foil, cans, bottles, tubes, caps, and closures. Also, combinations of materials are seen in packaging, where laminated and metallised packaging films are combined with plastics and paper. Aluminium is subject to dents, but for example, by adding manganese will enhance the strength-properties of aluminium. (Deshwal & Panjagari, Review on metal packaging: materials, forms, food applications, safety and recyclability, 2020)

Metals as such are not inert to food products, they are typically coated with protective lacquers to prevent metal-food interaction and the migration of metal components. For example, tin plate packaging is usually steel that is coated by tin on both-sides, also polymer-coated steel is used. Stainless steel has very good corrosion resistance and chemical inertness. This is due to the chromium content, which forms a protective inert layer on the steel surface. The main health and product safety concerns typically related to metal packaging are the migration of bisphenol A, lead, cadmium, mercury, aluminium, iron, nickel, bulging of cans, tin dissolution, blackening and corrosion. (Deshwal & Panjagari, Review on metal packaging: materials, forms, food applications, safety and recyclability, 2020)

Paper-based packaging is made from renewable resources like wood, bamboo, bagasse, wheat straw and so on. These types of packaging are lightweight, renewable, customisable, low-cost and allows tailoring of functional packaging. They are also widely recyclable and, in many cases, compostable.

The packaging types can be divided into paper-based packaging and paperboard packaging, where paperboard solutions are thicker and heavier than paper. Types of paper-based packaging include various types of solutions: *kraft paper*, which is made from unbleached pulp and is the strongest form of paper and is used in package e.g. flour, sugar, and dried fruits; *sulphite paper*, which is relatively weaker and lighter, typically glazed to improve appearance and properties, it is used to wrap for example biscuits and sweets; *greaseproof paper and glassine*, which contain densely packed cellulose fibres, and where the glassine version is further upgraded by further hydration to improve the paper's oil resistance. This packaging type is suitable to pack e.g. snacks, biscuits, fast foods, and greasy foods; *parchment paper*, which is acid-treated paper, which renders it impermeable to fluids but not to air and vapour and is thus used in packaging butter and lard; *paper laminates*, which are coated and have enhanced barrier properties used e.g. in soups, spices. (Deshwal;Panjagari;& Alam, An overview of paper and paper based food packaging materials: health safety and environmental concerns, 2019)

Paperboard packaging include also a wide range of different packaging types: *whiteboard*, which is a paperboard that is used also for primary packaging; *solid board*, which is typically coated and provides a strong and durable paperboard used to package milk, fruit juices and soft drinks; *chipboard*, which is the cheapest form of paperboard, made of recycled paper, and is used for the outer layers of food cartons, such as cereals and tea; and *fibreboard,* which is used to ship bulk food due to its strength and resistance to impact scratching and crushing damage. (Deshwal;Panjagari;& Alam, An overview of paper and paper based food packaging materials: health safety and environmental concerns, 2019)

Plastics play a significant role in the packaging industry from the functional and technical, and economic perspective. Plastics used in packaging are low-cost materials, typically very light-weight, are highly versatile, have high functionality, and can be shaped into different applications, shapes and formats. Plastic packaging is typically divided into rigid and flexible packaging. Rigid packaging types include containers, jars, bottles, trays, cans, cups, tubs, pots, and so on. Flexible packaging includes various different types of packaging like sachets, bags, pouches, packs, and so on.

Plastics can be clear or coloured, they are durable, have high barrier properties, as well as can be subjected to different temperatures, for example, suitability for frozen goods, vs microwavable food. Plastic packaging, depending on the design itself, is typically well recyclable if the packaging is monomaterial or the polymer types can be easily separated from others. There are further advantages that can be gained by utilising engineering plastics, which have even higher performance and allow technical improvements. An overview of typical packaging plastics is depicted in Table 3.

Table 3. *Characteristics and applications for different packaging types. Sources: extended from* (Nahladakis & Iacovidou, 2018), (Advanced Circular Packaging, 2022).

Plas-tics type	Characteristics and properties	Associated chal-lenges	Applications	Benefits
PET	"Semi-crystalline, high density, very hard material that is very tough, strong, and rigid, has very good sliding friction properties, very good dimensional stability, highly stiff with brittle behaviour at temperatures below zero, with good thermal stability, minimal thermal expansion, sensitivity to hot water and steam, relatively high thermal conductivity, low electrical conductivity, good insulation properties, high chemical and wear resistance, and low moisture absorption." (Nahladakis & Iacovidou, 2018)	Low heat resistance, susceptible to oxidation, scuffing and scratching. Very susceptible to heat degradation, sensitive to hot water and steam.	Bottles, films, food packaging. "Replacement for glass in beverage bottles due to its dimensional stability, strength and resistance to chemicals; widely used in food and personal care packaging applications as it is an excellent barrier to flavours and is usually transparent." (Nahladakis & Iacovidou, 2018)	Ideal for food packaging, can be used with oils, strong and clear. Also approved food contact recyclates (EFSA), light weight, high recyclability, low cost, durable, good moisture and gas barrier properties, good resistance to most solvents. Ideal for injection moulding, optically smooth surfaces for oriented films and bottles. Suitable for ovenable film and microwavable food trays.
HDPE	"Semi-crystalline, translucent, low density and hardness characteristics, but tough with low strength and very low rigidity properties, relatively stiff with low thermal stability and high thermal expansion, high thermal conductivity, low electrical conductivity, relatively good insulation properties, poor chemical and wear resistance, and very low	"Poor barrier against gases, oxygen, odours, and flavours." (Nahladakis & Iacovidou, 2018)	Containers, bags, wrappings and films, milk bottles, detergent bottles. Normally used in consumer bags, thermoformed trays for packaging frozen food, films for a variety of uses.	Low cost, recyclability, good chemical resistance

	moisture absorption.” (Nahladakis & Iacovidou, 2018)			
LDPE	“Semi-crystalline, translucent, with low density and hardness characteristics, very tough (no breaks), but low strength and low rigidity, sensitive to temperature with low thermal stability, no thermal conductivity, high thermal expansion, low electrical conductivity, relatively good insulation properties, poor chemical and wear resistance and low moisture absorption.” (Nahladakis & Iacovidou, 2018)	Not for rigid containers and flexible packaging, not good with oily products (especially natural oils). (Nahladakis & Iacovidou, 2018)	Pallet films, agricultural films, bags, coatings for bottle cartons, squeezable tubes and bottles, wrappers and bags, frozen food containers. Not practical for rigid containers and flexible packages and is not recommended for oily products. (Nahladakis & Iacovidou, 2018)	Low cost, good recyclability. Especially good for food packaging due to its stiffness and moisture barrier capacity as well as high transparency. Good resistance against acids, bases, vegetable oils. Heat-sealable.
PP	“Semi-crystalline, low density, material with better strength, hardness, rigidity, stiffness and thermal stability than PE types (HDPE-LDPE) with sensitivity at temperatures below zero, low thermal conductivity, low electrical conductivity, relatively good insulation properties, good chemical and wear resistance, and low moisture absorption.” (Nahladakis & Iacovidou, 2018)	High thermal expansion coefficient which limits its high temperature applications.	Film, microwave-proof containers, crates. “Has the lowest density of all thermoplastics, which combined with its excellent fatigue and chemical resistance can make it attractive in many packaging applications such as closures of all kinds, several boil-in-bag food packages and containers exposed to high levels of thermal and chemical stress.” (Nahladakis & Iacovidou, 2018)	Good resistance to fatigue and chemicals, high melting point (ideal for hot-fill liquids). Can also be foamed which results even more lightweight solutions. Good recyclability, low cost. Good optical clarity in biaxially oriented films and stretch blow moulded containers, low moisture vapor transmissions. Inert towards acids, alkalis and most solvents (not chlorinated).

PS	“Amorphous, optically transparent, high density, hard, brittle material, very tough, relatively strong and rigid, low thermal stability, low thermal conductivity and electrical conductivity, excellent insulation properties, poor chemical and wear resistance to hydrocarbon solvents, good electrical insulation properties and relatively low moisture absorption.” (Nahladakis & Iacovidou, 2018)	Brittle Challenging to recycle.	“PS is available in a range of grades which generally vary in impact strength from brittle to very tough. It is used for low strength structural applications when impact resistance, machinability, and low cost are required, such as in vending cups, yogurt containers, bottles for pharmaceutical tablets and capsules, and packaging of fragile products” via foam insulation. (Nahladakis & Iacovidou, 2018)	Rigid and foamed versions. Clear and hard.
PVC	“Amorphous, optically transparent, high density, hard, brittle material that is tough, relatively strong and rigid with very good sliding friction properties, very good dimensional stability, relatively stiff with low thermal stability, low thermal expansion, low thermal conductivity, low electrical conductivity, good insulation properties, good chemical and wear resistance, and very low moisture absorption.” (Nahladakis & Iacovidou, 2018)	Health hazard (emits hydrogen chloride), not clear, challenging for recycling.	The most widely used of the amorphous plastics. It is available in two forms, plasticised (flexible) or unplasticised (hard, tough), and is used in blister packaging for pharmaceuticals and capsules.	Good resistance to chemicals and oil, easily formed and shaped, hard and durable

4.4 Innovative and emerging packaging materials

Smart, intelligent and active packaging are packaging systems that integrate active and intelligent functions to the packaging. A typical example of smart packaging is packaging that has embedded sensors. The aim of smart, intelligent, and active packaging is to enhance wanted properties or enable tracking, monitoring, and new business models. Advantages can be gained for example from being able to extend the shelf life, monitor freshness, and to display information on aspects such as quality or on the temperatures that the packaging has experienced during supply chain, improve product safety, and enhancing customer safety. More about smart and intelligent packaging is presented in *Chapter 5 on Key Technologies for traceability and packaging monitoring.*

From the material perspective, newer, interesting materials from reuse perspective could be for example *self-cleaning* and *self-healing* materials. Additionally, issues relating to durability or washability and drying could be sought from the utilisation of high-performance engineering plastics as well as different additivation. A lot of high-performance solutions already exist on the market that are utilised in other sectors, where the material choice has not been optimised per se for cost efficiency or minimising material weight like the case typically is for single-use plastic packaging. Also, in many reusable systems, the ownership of the packaging remains at the business, which could also encourage investing more into the packaging.

Self-healing materials: The packaging sector does not really utilise self-healing materials at the moment, but that is mostly due to the single-use nature of packaging and the fact that with linear single-use systems, there is no reason to invest in expensive advanced materials. With reuse systems, there could be potential advantages with self-healing materials as the packaging needs to withstand potentially more stress than typical single-use packaging due to multiple use cycles and reverse-logistics.

In principle, self-healing polymers are types of plastics that are capable of recovering their original properties if damaged. Currently, the self-healing materials market size is evaluated at USD 1.28 billion and it is expected have a very strong compound annual growth rate of 25.5% from 2022 to 2030. Self-healing materials have on a microscopic level automatic repair and restorative functionalities without human intervention. The automatic repair and restoring functionalities are triggered by different stimuli such as UV light, pH, or by mechanical damage like microcracks. Self-healing materials are designed to repair damage at the micron scale, effectively impeding the propagation of the damage and extending the shelf-life of the material. (Grand view research, 2021)

Both physical and chemical approaches are used in self-healing polymers. For example, there are diffusion and flow, shape-memory effects, heterogeneous self-healing systems, covalent-bond reformation and reshuffling, dynamics of supramolecular chemistry or combinations of the different approaches (Wang & Urban, 2020). Microcapsules are also used in self-healing materials that rupture when exposed to mechanical dents, causing healing agents and other chemicals to be released to the damaged site. The released healing agents and the chemicals mix and polymerise, which fixes the caused microdamage and helps to reconstruct the structural and functional integrity of the material and product. Microcapsules are robust enough to withstand manufacturing processes (Grand view research, 2021)

Utilisation of self-healing polymers could support the extended lifetime of reusable packaging and reduce the need for maintenance. Currently, self-healing materials are seen mostly for example in mortar and cement in the building and construction industry, and in electronics like phones, laptops, as well as the automotive sector in exterior coatings. Growth in self-healing coatings is expected as coatings are used by several industries such as machinery manufacturing, automotive sector, oil and gas, marine sector, aerospace sector, and consumer goods. (Grand view research, 2021)

Self-cleaning systems and antimicrobial materials: Self-cleaning systems are systems that are capable of controlling wetting properties with inherent washing characteristics such as super-hydrophobic surfaces, which lower the surface tension and reduce contact points. Self-cleaning systems can be created by using silicon, titania nanoparticles and graphite, for example.

Superhydrophobic materials are found in a suite of scientific and industrial applications (not at fully industrial scale):

- Gene delivery, self-cleaning surfaces, fluidic drag reduction, nonwetting liquid transfer, microfluidic channels, lab-on-a-chip devices, and for anti-icing and anti-bio adhesion purposes,
- Transparent surfaces for solar cells and building windows,
- Plastic containers that can be washed without using detergent or can be completely drained of liquid.

The medical, food, and textile industries are three major areas of applied antimicrobials, especially used in medical devices and equipment. In these applications, passive antimicrobial polymers preventing bacterial adhesion and growth provide a more promising strategy than that of killing microbes directly by using active antimicrobial polymers. Bound or leaching polymers, polymeric biocides, biocidal polymers, and biocide-releasing polymers, the biocide-releasing system demonstrates potential because of the controlled release characteristics. Current challenges include the development of long acting or reusable antimicrobial polymers, which would also be important for reusable packaging. (Corrales;Fernandez;& Han, 2014)

Antimicrobial packaging shows potential for implementation as an innovative solution to reduce the microbial growth in food systems. For plastic-based packaging, polymers can be functionalised with antimicrobials such as enzymes, bacteriocins, natural extracts, organic acids, chelators and metal ions, showing excellent controlled release opportunities (Corrales;Fernandez;& Han, 2014). It is important to acknowledge when utilising these types of material innovations to always evaluate the efficiency of the antimicrobial approach and possible effects on the food case-by-case.

Self-heating and -cooling materials: Depending on the reuse application, added value could be gained from self-heating or self-cooling materials as well. Self-heating packaging is active packaging that has the ability to heat the food content, for example, without external heat sources or power. These types of packaging can be seen in the military, during natural disasters and for camping when conventional cooking is not available. Self-heating materials are typically based on exothermic chemical reactions, which initiate after the consumer pushes the bottom of a package, such as a coffee cup. For safe chemical reactions, which is key for consumer packaging, lime (calcium oxide) is reacted with water. This generates a sufficient substantial heat (up to around 54 °C), the ingredients are low cost and readily available. The heater components increase the packaging weight by 10–15%. (Poonia & Singh, 2015) These types of enhanced properties for reusable packaging would have to be developed further as these are mostly currently used in and as single-use applications.

4.5 Food packaging—food safety and requirements

Food comes into contact with different materials, both directly and indirectly, during its production, processing, storage as well as transportation, preparation, serving, and consumption. Food contact materials (FCM) are materials that are in contact with or materials that are intended or can be expected to be in contact with food. To keep food safe and for safe consumption, there are restrictions on the type of materials that can be used for food contact and these are evaluated, for example in the EU, by the European Food Safety Authority (EFSA). If an FCM is not tested for food safety or does not meet the requirements, then there may be a risk to consumer health through the migration of hazardous chemicals. Migrating chemicals from the packaging could also change the composition, appearance taste and smell of the food product. European Framework Regulation (EC) 1935/2004 on materials and articles intended to come into contact with food specifically requires that food contact materials must not release their constituents into food at levels harmful to human health or which would change the food composition, taste and smell in an unacceptable way. (European Commission, 2004)

In addition, all FCMs should be manufactured according to the principles of good manufacturing practices (GMPs) stated in Regulation (EC) 2023/2006 on good manufacturing practices for materials and articles intended to come in contact with food. (European Commission, 2006) The aim of the legislation on food contact materials is to ensure and protect consumers' health as well as ensure functioning internal markets.

For food contact approved materials, an international food safe symbol is used (Figure 9). Food safety assurance is given to packaging materials which are free of any toxic contaminants and will not potentially become a source of toxic contamination through use. The food safe symbol does not ensure food safety under all conditions, as the food safe logo only covers food safety from carcinogens. For example, some packaging materials should not be used to hold hot food. It is important to check the packaging specifications for the intended use of the material. Additionally, for reuse systems, the conditions and operations, e.g. the time stored in the packaging or logistics, might be different and bring additional matters to consider to protect food safety when setting up a reuse system.

Figure 9. *The international symbol for food safe material.*

The main properties for food packaging are gas (especially oxygen), grease and water vapour barrier properties, and the mechanical, thermal, rheological, morphological, optical, and physical properties. The gas barrier property is often considered the most important factor to ensure the shelf-life of food products. (Kim;Min;& Won Kim, 2014)

When choosing materials for food-contact applications, it is important to consider several aspects, but more importantly with the reuse system there are additional points-of-view that might not have been considered for single-use packaging.

- What type of food or drink will be packaged, and how long will the product remain in the packaging? What are the main properties needed, especially for barrier requirements?
- What temperatures need to be tolerated and how long? Is there a need to package hot food and for example heat the packaging?
- What environmental conditions will the packaging be subjected to? Especially with reuse, the reverse logistics and washing steps are new compared to single-use packaging and need to be considered how they affect the material.

In most commercial food products, paper and paperboard and plastics are the primary materials used. Metal and glass are also widely used for various liquid and semi-solid food products. Typical material types and their possible limitations for food contact applications are described below.

Ceramics are regulated under (EC) 84/500/EEC which highlights the limits for lead and cadmium transferred from ceramic articles. Depending on the type of article, there are 3 different categories and limit values which vary for lead from 0.8 mg/dm^2 to 4.0 mg/l, and for cadmium 0.07 mg/dm^2 to 0.3 mg/l. Ceramics are not separately collected and smaller quantities are placed in the mixed waste for incineration, at least in Finland, which hinders their recycling. (Suomen Kiertovoima ry, n.d.)

Glass is a good material for long shelf-life foods as it is moisture and heat resistant. With glass, it is possible to heat treat the product after filling, and it will not let air in providing the seal remains intact. Glass does not react with the food and can be made transparent to view the food inside the packaging. Glass can also be coloured, which is typically done to protect the product from light, which might affect the product quality. Glass is widely recyclable. However, glass packaging is heavy and bulky to transport and is subject to breaking and damaging especially if dropped.

Metals The interaction of metal and food can result in corrosion, perforation, loss of coating, deterioration and discolouring. Stainless steel is used in the food industry, especially for food processing and storage equipment. Austenitic types of stainless steel are food grade approved and mostly used in food grade applications. For products that require excessive corrosion resistance surfaces, austenitic 316 grades are used, which contain 16% chromium, 10% nickel and 2% molybdenum. (Deshwal & Panjagari, Review on metal packaging: materials, forms, food applications, safety and recyclability, 2020)

Paper and cardboard are lightweight and low cost in comparison to metal and glass. They are widely recyclable and also typically compostable materials. However, the barrier integrity of paper-based packaging is compromised when in contact with moisture and humidity, making it easier to tear or damage. **Regenerated cellulose films** are regulated under the Commission Directive 2007/42/EC relating to materials and articles made of regenerated cellulose film which are intended to come into contact with foodstuffs. Especially diethyleneglycol and ethanediol are identified as substances that can migrate extensively to certain foodstuffs. Direct contact between food and printed surfaces of regenerated cellulose films should be avoided. (European Commission, 2007)

Active and intelligent materials are utilised to maintain or improve the condition of food in its packaging by for example releasing or absorbing substances to or from the food and its environment. Since they are not inert, these materials in food contact are regulated under the Commission Regulation (EC) No 450/2009 on active and intelligent materials and articles intended to come into contact with food. Specific rules of the regulation apply to also active labelling that indicate for example the expiry of food or conditions experienced through colour changes of the label. (European Commission, 2009)

Food grade plastic packaging is one of the mostly used materials for the food safety and quality of a product. Plastic has good barrier qualities, and it is easy to shape into different forms. The good barrier properties of plastic typically increases the shelf life of a food and prevent it from spoilage or reducing in quality. Some food grade plastics are also recyclable, (see Figure 10).

- PET (1) is often used to make soft drink bottles, salad and biscuit trays. PET is a popular choice for its lightweight, strength and the fact that it is highly recyclable.
- HDPE (2) is used to make milk bottles, ice cream containers and freezer bags. HDPE is slightly more rigid and is also widely recycled.
- PVC (3) is used to make film and rigid bottles and containers. It is not a widely recycled plastic, and it is something that is phased out from packaging due to its hazardous nature.
- LDPE (4) is used to make flexible film-type packaging like squeezable bottles, grocery bags and shrink wrap.
- PP (5) is used to package different types of foods either in rigid or film packaging. PP is commonly microwave safe and is well recyclable.
- PS (6) is used for hot drink cups, takeaway food packaging and plastic cutlery. PS is not widely recycled as PS typically ends up in mixed plastics, and recycling of that is case-dependent. Expanded PS, EPS, is used in packaging as well, but it is does not really get recycled.
- Other (7) includes all other forms of plastic, such as multimaterial, multilayer, and composite packaging. Additionally, bio-based plastics typically end up in this category. Currently, these types of plastics do not get recycled.

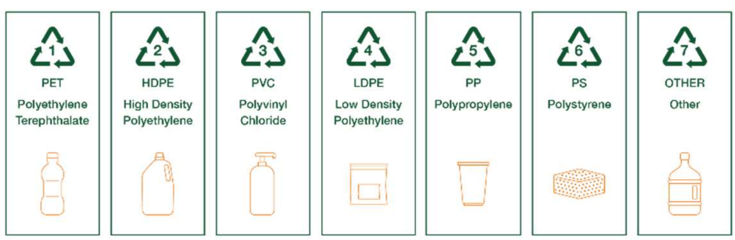

Figure 10. *Plastic recycling symbols.*

4.6 Household products—requirements

Household products are typically packaged in HDPE, PET and PP based packaging solutions as they have a good resistance to chemicals used in products such as detergents, cleaners, bleach and so on. PP is commonly used for caps and closures. The packaging is required to have good resistance to store products that contain (strong) chemicals so excellent resistance to solvents is needed. Additionally, the products in many cases remain for quite a long time in the packaging, so longer-term storage should be facilitated.

For household products containing chemicals are regulated under the EU CLP Regulation No. 1272/2008 on the Classification, Labelling and Packaging of Substances and Mixtures. Most cleaning and maintenance products are mixtures and therefore they must comply and be classified, labelled, and packaged accordingly.

For consumer products, the labelling must be on the packaging. The packaging of hazardous substances must prevent the contents from spilling or otherwise escaping from the packaging, and they must be made from materials that are resistant to the product contents. The packaging materials must also be strong and solids as well as have sealable fastenings. Furthermore, in some cases, child-resistance fastenings and tactile warnings are required.

4.7 Indicated challenges related to reuse packaging materials

Migration of flavours and scents: Strongly flavoured or scented products may migrate into the packaging and carry on to the new filled product. A case study by Lemos Junior (2019) investigated the reasons behind the affected flavour in soft drinks packaged in refillable PET bottles and the main factor was down to the consumers' inappropriate use of the packaging. Consumers were packaging perfumed or scented liquids in the bottles. A maintenance step, sniffer devices and chemical sensors to identify the presence of possible contaminants reduced the number of complaints related to altered flavour. Chemical residues were also associated with chemical additives that were added or carried on raw materials or used in the food manufacturing process (incl. cleaners and sanitising). (Lemos Junior;Pereira do Amaral dos Reis;Sales de Oliveira;Oliveira Lopes;& Signori Pereira, 2019)

High durability but decreased hydrophobicity: Jetten et de Kruijf (2002) investigated the quality and safety aspects of reusable plastic packaging for food applications: PET and PC bottles and PP vending cups. They investigated the effect of repeated use on the migration of plastic constituents, degradation products of plastic additives, barrier properties and surface characteristics. The investigated properties were not significantly influenced by repeated use. Only the hydrophobicity of the refillable PC and PP bottles were influenced by repeated washing—PC bottles washed 15 times were significantly less hydrophobic (ability to repel water) than unwashed bottles (Jetten & de Kruif, 2002). Decreased hydrophobicity can be linked to increased potential adhesion of microbial contamination such as bacteria. The number of cycles studied was however quite low, but this gives an indication that repeated washing might be one of the major steps which could wear down the packaging.

Subject to scratch and abrasion: Especially with PET and PP packaging, the packaging is subject to scratches and abrasion. Different approaches could be tried to improve scratch-resistance. There are multiple additives (both masterbatch as well as coatings) on the markets, used for mainly different purposes than reuse, that could be utilised to improve the scratch-resistance of packaging. The scratch performance of polymers is of great importance in electronic, optical, household, and automotive applications, where long-term aesthetics are important. High performance polymers such as polybenzimidazole (PBI), polyparaphenylene (PPP), polyetheretherketone (PEEK), and polyimide (PI) seem to have higher scratch resistance than classical engineering plastics (Friedrich;Sue;Liu;& Almajid, 2011). Improving the scratch-resistance in reusable packaging will most likely result in higher durability and better washability and safety.

5. Key technologies for traceability and packaging monitoring

Intelligent packaging represents a step forward in improving product safety, logistics, traceability, and brand protection (Yam;Takhistov;& Miltz, 2005). Intelligent in this context means that the package communicates the identity and status of its product(s) to its end users. There are three main ways to realise intelligent packaging systems: 1) indicators that visually inform consumers about the product quality, 2) sensors that provide a quantification of the product quality, and 3) machine readable data for identity, such as bar codes and electronic markers.

Smart Tags (Figure 11) are visible or electronic markers with environmental sensing functions combined with software intelligence (machine vision, user information, location, etc.) (Gligoric, ym., 2019) (Hakola;Vehmas;& Smolander, 2021). Previous features provide context aware services to the end users and enable the connectivity to the Internet of Things (IoT).

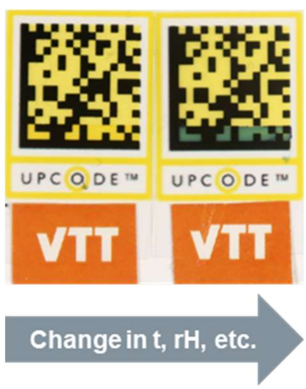

Figure 11. *Principle of a smart tag*

The rapid take up of smart tags can be expected only if global acceptance by large stakeholders happens. This requires standardised data encoding/decoding capabilities to avoid multiple codes on packages. For this purpose, the GS1 Digital Link Standard (https://www.gs1.org/standards/gs1-digital-link), ratified in August 2018, was created. This standard substitutes the current 1D barcodes for Web-based enabled 2D barcodes or RFID tags, while preserving the current GS1 identification system for accessing any webpage with a consumer device, such as a smartphone. To support monitoring of package conditions, the standard includes condition parameters along with identification parameters.

5.1 Identification technologies

Linear or 1D bar codes are widely used on product packages to identify the product. However, due to the limited amount of data they encode–typically less than 20 numerical characters–they are not suitable for item-level identification. Additionally, the need for a specialised reading device presents issues in consumer targeted use cases.

2D barcodes are used for traceability, information, entertainment and even for payment solutions. 2D barcodes, such as QR Codes and Data Matrix codes consist of black and white squares, called cells. They provide a large information capacity, even up to 7,336 numbers or 4,464 alphanumeric characters per code. A sophisticated error correction algorithm is included, which means that information is readable even if up to 30% of the code is destroyed. 2D bar codes can serve as a link to a database similar to linear bar codes, but they can also serve as an independent database. The physical size of the code is scalable without affecting the information capacity, meaning that the cell size of a particular code can be scaled. QR Codes can be easily detected and decoded with many devices such as mobile phones, thus providing a link to digital media and additional information. The first 2D bar code type, Code 49, was published already in 1988. Nowadays there are over 20 different bar code types used for different purposes in logistics, manufacturing, and information transfer. Some 2D bar code types are in the public domain, which means they can be used freely, such as the two most popular code types, Data Matrix and QR Code with GS1 standards.

Radio Frequency Identification (RFID) uses electromagnetic fields to automatically identify, and track tags attached to objects (http://www.rfidlab.fi (in Finnish)). RFID tags can be passive, active or battery-assisted passive. A passive tag is the cheapest and smallest solution, and it uses the radio energy transmitted by the reader for power. An active tag transmits its ID signal periodically and has a battery to provide power. Battery-assisted passive tags also have a battery on board, but they are activated only in the presence of an RFID reader. RFID tags can be read-only or read-and-write. Read-only tags have a factory-assigned serial number used as a key in a database. On read-and-write tags, the user can write data.

Near field communication (NFC) is a short-range, smartphone-readable form of RFID technology that operates at a standard carrier frequency of 13.56MHz (https://nfc-forum.org/). NFC transmissions typically span a few centimetres (0–4 cm), which allows for a secure link between two NFC capable devices. NFC technology is included in more than one billion smartphones in use worldwide. It provides a common link between service concepts use cases ranging from mobile payments and public transportation to pairing/sharing and tag reading. RFID and NFC antennas are printable, thus making them thin and flexible devices that can be attached to a variety of products.

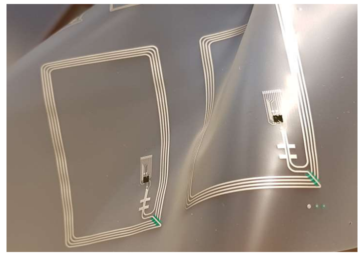

Figure 12. *Data Matrix and QR code, and printed NFC antennas.*

Digital Watermarks are information embedded into digital media, such as image or video. These watermarks are invisible to human eye, but readable by a specialised reading device. There are also digital watermarks that be read by smartphones from an image, where extra pixels have been added to serve as the watermark.

The different identification technologies are compared in Table 4.

Table 4. *Comparison of the different identification technologies*

	1D bar code	**2D bar code**	**Digital watermark**	**RFID**	**NFC**
Package compatibility	Printing	Printing, labels	Printing	Labels	Labels
Interpretation / decoding	Bar code reader	Bar code reader, smartphone	Smartphone	RFID reader	NFC reader, smartphone
Integration of monitoring capabilities	-	Smart tags	-	Sensors	Sensors
Physical size	Scalable	Scalable, min. ca. 1 cm x 1 cm	Scalable	Scalable, min. ca. 1 cm x 1 cm	Scalable, min. ca. 1 cm x 1 cm
Information capacity	<20 numerical characters	Up to ca. 7000 characters		MBs, typically ca. 2 kB	MBs, typically ca. 2 kB
Cost range	<1 cent	< 1 cent	< 1 cent	>1€	>1€, also alternatives for a few cents
Expected lifetime	Unlimited	Unlimited	Unlimited	12 months	12 months

Other identification technologies with the potential for package integration include machine vision technologies (e.g. identification of fiber structure or physically unclonable functions), and the integration of invisible features (e.g. micro holes or magnetic particles) into the packaging material to make each package unique. Micro holes refer to the addition of a few tens of micrometres particles during printing or varnishing pseudo-randomly to give an item a unique smartphone readable identity. Magnetic particles can be added similarly, but they require a reader with magnetic detection capabilities. Physical unclonable functions take advantage of the individual features of any fabricated item.

5.2 Monitoring technologies

Monitoring technologies make it possible to create dynamic Smart Tags that enable changing the achieved information and its meta-information content due to the changing environmental conditions when scanning the codes by smartphone.

Functional inks react with a colour change to changes in the surrounding conditions. The colour change can be reversible or irreversible. The most popular and readily available functional ink technologies are thermochromic (changing colour with temperature) and photochromic (changing colour with ultraviolet/sunlight). Other commercially available ink technologies include invisible fluorescent inks (seen under UV or IR light), phosphorescent inks (glow in the dark after exposure to a source of light), hydrochromic inks (changing colour after contact with water), and touch'n smell inks (aroma released when rubbed with a finger), among others.

Sensors are devices that detect and respond to some type of input from the physical environment, and the output is generally a signal that is converted to a human-readable display (Chansin, 2015). Printed sensors are sensors that are manufactured by utilising printing methods providing benefits such as possibility to use flexible substrates resulting in thin and light-weight devices. The most intensively evolving types of printed sensors include biosensors, capacitive sensors, piezoresistive sensors, piezoelectric sensors, photodetectors, temperature sensors, humidity sensors and gas sensors. There are, for example, RFID tags available with integrated temperature sensors.

Indicators are sensors based on optical reading, such as colour changes. In the simplest form, they are functional inks reacting to environmental conditions such as temperature or lighting (Sipiläinen-Malm & Hurme, 2008). More complex indicators are systems that involve multiple processing steps, such as activation and encapsulation. Most often, the information is displayed by immediate visual changes, e.g. different colour intensities or the diffusion of a dye along the indicator geometry. Indicators can be based on mechanical, chemical, electrochemical, enzymatic or microbiological changes (Ghaani;Cozzolino;Castelli;& Farris, 2016). Indicators with applications for food packaging are time temperature indicators, oxygen and integrity indicators, and freshness indicators. Printed indicators are manufactured by utilising printing technologies, thus enabling easy integration with 2D bar codes and direct attachment to products or packages. VTT has demonstrated multiple printed indicator technologies for oxygen, volatile organic compounds (e.g. nitrogen), and humidity.

Figure 13. *A 2D bar code with an integrated temperature sensing element (green bar), and visual indicators for oxygen to check package integrity.*

5.3 Scenarios for the circular economy

During the EU Horizon 2020 project TagItSmart, the recycling behavioural change of consumers using Smart Tag components and functionalities was promoted[1] (www.tagitsmart.eu). This service concept use case was based on the implementation of several Smart Tag components on top of a cloud platform. The Smart Tags were implemented for communal recycling bin placed in the streets, in particular, unique NFC tags combined with unique QR codes. For the pilot, 3 Smart Tags were placed on 3 different recycling bins, simulating a real environment that allowed the end users complete their recycling actions and get rewards. The Smart Tag consisted of a unique and combined label with a QR code and NFC capabilities. The consumers were able to use just one method, QR code or NFC tag, to make the ‘virtual’ interaction with the bin. Consumers scanned the shopping receipt by their mobile phones and got additional information of the products purchased in addition to guidance how to sort the waste items. When the consumers brought their waste to the bin, they scanned the code or used the NFC tag and got the reward.

[1] www.tagitsmart.eu

Figure 14*. Smart codes implemented on recycling bins (Image: TagItSmart).*

The Spanish company recycl3r was then formed to commercialise the white label application for mobile or web that provides useful service to easily engage brands with consumers and provide tools to recycle easier. They have so far worked with e.g. Carrefour (French retail chain) and brands such as Magnum and Fairy (https://recycl3r.com/). The idea could be transferred also for reuse scenarios.

5.4 Discussion on package recycling

Package recycling at the end of the lifetime of reusable packages might be affected from the traceability and monitoring technology perspective because of the following reasons:

- Integration of electronics onto packages, such as RFID tags
- Embedding of tags (electronic or visual) inside package material through use of in moulding or similar technologies
- Protective layers on top of tags (electronic or visual) when the layer is a different material than the package itself

The simplest way to manage electronic components among package waste would be to remove a label that contains the electronic components, and then redirect the electronic labels for electronics recycling. However, if the electronics are embedded inside a packaging material, the situation would be more difficult. Electronic components when attached to packages, can influence the composition of solid and liquid residues in the paper recycling process, and thereby affect disposal costs (Furuta;Tonooka;& Kobayashi, 2008) (Erdmann;Hilty;& Althaus, 2009). Another recycling challenge are fossil-based ICs (i.e. RFID chips). Those are shown not to significantly increase the fibre rejects during paper recycling, and properties of the recycled paper, since they become blocked in the sieving systems and require disposal by burning or landfill (Aliaga;Zhang;Hortal;& Beneventi, 2015). In these cases, the electronic materials and components are lost and the amount of harmful electronic and electric waste increases. Since it is expected that almost 21 billion packages sold in 2030 will contain an electronic feature to enhance the package (Das, 2019), electronics recycling among packaging waste is a growing concern and electronic material recovery should be considered. In mixed waste the substrates would oxidize generating energy, and metals could be potentially recovered from the ashes. From plastic waste electronics could be separated during the washing process before extrusion and be potentially recovered from the rejects. However, suitable methodologies do not yet exist.

The use of protective layers, but also use of any label to attach different tags to packages, might be a recyclability issue since use of multiple materials in a single package is always more challenging than using just one material. The package recycling process aims to separate different materials so there would be a need to separate glued / laminated tags and their protective layers from the bulk of package material. Since the tag materials would be designed to endure even 100 events of usage with heating and washing, the separation process would need to be a robust one. The same issues might also arise when embedding visual tags inside the package material for durability.

From the package recycling point-of-view, making visual tags via package surface modification (e.g. laser patterning) would be the best way. However, the integration of monitoring functionalities would not be possible. Furthermore, small grooves on the material surface might also create the potential for bacterial growth, thus increasing demands for package hygiene.

To summarise, there is no simple answer to managing the recycling of packages with integrated durable tags.

5.5 Technology gaps and ongoing research and development

There are several identification and monitoring technologies available for the manufacture of different kinds of tags. However, in the context of reusable packaging, the technologies are exposed to different, even harsh, conditions during their lifecycle, such as transportation, low and high temperatures, washing, and microwaves. Thereby, it is important that the tags are attached to packages in a way that provides tolerance towards wear, temperature, humidity etc. during multiple uses. Furthermore, an advanced cloud-based digital platform is required for data and stock management, and for communication throughout the value chain. Finally, the tag solution should also be designed taking into account end-of-life management requirements of packages.

6. Optimising logistics

6.1 Reusable packaging logistics needs

To establish functioning logistics systems for reusable packaging, the traditional linear supply chain must be extended to include reverse logistics. In its simplicity, reverse logistics includes the operations that are required to move the used package from consumers, through washing, back to being reused. In addition to transportation, the operations that are required are at least the collection of used packages and storing and cleaning them (Accorsi et al. 2020). Cleaning is necessary due to contamination and dirt building up on the reusable packaging. It might also cause difficulties in organising the supply loop if new and used packaging should not be in contact for example during shared transportation. It should be noted that a well-functioning reusable system includes recycling of materials at the end of their use cycles. (Accorsi et al. 2020)

According to Coelho et al. (2020), the main barrier for producers to implementing reusable systems is the complexity of logistics to establish proper circulation of packaging. The complexity arises from having to reorganise current supply chains. This is not only limited to extending reverse logistics and all operations involved with that aspect, but in addition having to potentially modify the linear supply chain's characteristics (Azzi et al. 2012). This means for example, when a reusable packaging is introduced, the suppliers' manpower must learn what equipment to use with them and how many of them can be stacked compared to disposable ones. In addition, storage facilities might require reorganisation if the packaging differs from previously and the shelves must be then adjusted.

To establish a logistics system for reusable packaging, more coordination is required between stakeholders (Tornese et al. 2021). Gardas et al. (2019) identify stakeholders' acceptance as the main barrier to implementing reusable packaging systems. This is related to the complexity of the logistics as at least a few of the stakeholders are responsible for or otherwise have a connection with logistics. Stakeholder acceptance can be resolved using a slow approach and implementing pilot projects, so that beginning from the manufacturing level, each participant can learn and gain confidence in the new system. (Gardas et al. 2019)

In addition to the logistics operations, washing the packages is an essential part of the reusable packaging supply loop, especially when delivering consumer goods. As it is yet not too familiar amongst the other logistics operations in the loop, the washing phase is discussed more in detail in its own chapter (Chapter 6.2.3).

6.2 Logistics models for reusable packaging

There are a few logistics models for reusable packaging with numerous variations each having their own special characteristics such as deposits or form of collecting the packages. Overall, current logistics models for reusable packaging include the ownership of the packaging in addition to a variety of responsibilities regarding cleaning, collecting, transporting, storing, and overall managing the package through its reuse cycle.

Mahmoudi and Parviziomran (2020) divide reusable logistics models into three main categories which are switch-pool systems, systems with return logistics and systems without return logistics. Within the three main categories there are additional options to organise the system.

A switch-pool system is where the packages are divided so that each participant has a share and each participant is then responsible for controlling, cleaning, maintaining and storing their packages. This can be either organised as a sender-recipient system, where sender has the return logistics responsibility, or as a sender-carrier-recipient system, where the carrier has the return logistics responsibility. (Mahmoudi and Parviziomran, 2020)

Systems with return logistics are based on a central agency (3PL) that is responsible for collecting emptied packages from recipients after the recipients have stored a certain number of packages so that collecting them is cost efficient. There are two options to organise these systems, a transfer or depot system. In a transfer system, the sender has the responsibility for every other phase of circulation, but a central agency is responsible for returning the packages from the recipient back to the sender. (Mahmoudi and Parviziomran, 2020)

A depot system can be arranged in two ways, booking and deposit. Common to both options is that the packages are stored and cleaned at the central agency's depot. In a booking system, the central agency keeps accounts for other participants and as the packages move between the participants, debits are charged and refunded in the participants' accounts. The last participant receives their refund when the central agency collects the packaging. In a deposit system, the sender pays a deposit to the central agency which is equivalent to the number of packages. The sender charges a deposit from their recipient and so on. The last participant receives the deposit back as the central agency collects packaging back from them. The deposit system's greatest benefit is that the deposit works as an incentive for the participants so that packages are returned quickly in addition to them not staying in one place for too long. (Mahmoudi and Parviziomran, 2020)

Systems without return logistics operate so that a central agency owns the packages and rents them to senders, and after this, the senders are responsible for each phase of the package's circulation (Mahmoudi and Parviziomran, 2020).

The system can also be organised so that in each phase of the reusable packaging's circulation, the ownership changes to the phase operator (Tornese et al. 2021). Another option is that the package owner has ownership over the packaging through its supply chain and circulation, including reverse logistics, but cargo owners use these packages. The form of use could consist of renting or leasing (see e.g. Loop[2]) (Tornese et al. 2021), for example.

These systems are usually referred to as pooling networks. A pooling network is built around multiple facilities and an internal infrastructure to manage packages. These are owned and operated by the pooling company. However, pooling networks are operated in cooperation with participants of the supply chain. For example, retailers and suppliers play a crucial role in diminishing transportation costs/emissions and optimising the network's logistics as they offer a storage phase in their facilities for the poolers' packages to be collected and again collected by the pooler in larger "bulks" at regular intervals (Accorsi et al. 2020).

Muranko, et al. (2021) divide reuse systems into five main categories as follows: exclusively reused products, exclusively reused products with reuse-enabling infrastructure, reuse-enabling infrastructure for exclusively reused products, sequentially reused products with reuse-enabling infrastructure and sequentially reused products.

[2] https://buydurable.com/

6.2.1 Operations and actors in a reusable packaging supply chain

The main operations regarding reusable packaging return logistics are, cleaning, control, maintenance, and storage (Mahmoudi and Parviziomran, 2020). In this section, the operations are divided as follows, first- and last-mile deliveries, collection, transportation, handling, storing, and washing. Control, as in tracking the packages and their condition was discussed in Chapter 5. The requirements for washing/sanitising varies greatly depending on the use of the reusable packaging. It is a necessary part of reusable packaging supply chain. However, due to its different nature as an operation and the depth of the subject, it is discussed separately in Chapter 6.2.2.

There are currently an increasing number of companies offering reusable packaging solutions. There are companies offering logistics services for reusables and the actual reusable packaging as well as those who can provide both. Due to the reusables business current state, utilising existing actors to some of the activities can be managed partly depending on the packaging size and form. However, as the time comes to scale the reusable packaging operations, current facilities of the operators might be insufficient for higher volumes and centralised logistics and washing service might need to be established.

For example, WELL PACK[3] offers centralised washing services for reusable plastic crates. They offer other logistic services as well as in collecting used crates and delivering them back to the client after washing. Washing is done in large facilities in eight countries in Europe, and the company washes 300 million packaging annually (WELL PACK, 2022).

The collection of used packages can be organised in multiple ways. On the consumer level, it is necessary to organise the collection of used packages s, that packages are used as efficiently as possible and returned to circulation as quickly as possible. The alternatives for collection differ especially regarding end user's contribution to the collection phase in addition to the steps in the washing phase and how they are organised. Collection can be organised by companies retrieving the packages from consumers (see e.g. GreenToGo,[4] and Good Club[5]) or consumers dropping packages at a drop point. (Long et al. 2020) Dropping packages can also be organised either with collection boxes (see e.g. Ozzi Group[6]) or to partnership company's facilities (see, e.g., Vytal[7]). If the collection is organised so that there are multiple small collection points, irregular emptying may cause allocation issues of the packaging (McKerrow 1996).

[3] https://wellpack.org/
[4] https://durhamgreentogo.com/
[5] https://www.goodclub.co.uk/
[6] https://www.planetozzi.com/
[7] https://en.vytal.org/

Sanitising refers to the washing step in the supply chain, which depending on the chosen model and where the packaging is refilled can be organised by different actors. There are two main models for this; either having consumers wash and refill packages themselves or organising the collection of used packaging and handling the washing and refilling phases in company facilities, or the washing can be organised by a third-party. Refill can be implemented with refill products in consumers' homes or consumers can take empty packaging to centralised refill stations (see e.g. Algramo,[8] Unilever[9]).

Transportation in this case is the movement of the packages between participants in the supply chain (e.g. collection-wash-retail) and potentially to consumers as well. Utilising existing logistics providers (see e.g. DPD[10] for Good Club[19]) can save resources. Utilising the empty capacity of existing logistics providers could increase economic and environmental efficiency.

First- and last-mile logistics include the last activity to get the packaging to and from the consumer. Here, return transportations could also be utilised. Depending on the packaging type and chosen collection form, this phase does not necessarily require large vehicles but can, for example, be executed with electric bikes with a delivery box attached (see e.g. SwapBox[11]).

Handling of the packages includes the manpower that is used to move the packages in addition to the equipment that is required to handle them, such as trolleys (see e.g. Ozzi Group[20]).

Quality control is a crucial step in the reusable packaging supply chain, where the quality of the packaging is checked and either sorted for further use or removed from circulation for recycling. It can be organised in different parts of the supply chain depending on the needs. In most cases, a quality check after washing might make most sense, but it could also be organised before washing, to ensure that a food package has not been used for something else making it no longer possible to be used for food even after washing.

The role of and necessity for **storage** varies greatly depending on the type of logistics system that is chosen. For example, storing can be organised in restaurants (small participants) where the 'shelf life' of the packaging is short and as an opposite to having a central agency that stores multiple packaging for a long time. Drop points are not usually willing to store large quantities of empty packaging (McKerrow,

[8] https://algramo.com/en/
[9] https://www.unilever.com/news/news-search/2021/reuse-refill-rethink-our-progress-on-refill-and-reuse-continues/
[10] https://www.dpd.com/nl/en/
[11] https://www.swap-box.com/

1996). Therefore, if possible, on same delivery route when new packaging is distributed, the excess packaging from drop points should be collected (and redistributed to other participants) by the same vehicle.

6.2.1.1 Usability of existing actors and infrastructure

The needs vary for different types of packaging, for example, as the washing solutions are different depending on packaging size and shape.

There is a limited amount of information regarding existing actors with reusable bottle packaging in comparison to other reusable packaging types, although reusable beverage bottles are still in use. However, for example, Hartwall[12] has an existing system of 17 million glass beverage bottles that circulate from the company's facilities, to retailers, consumers, back to retailers, where Hartwall picks them up (during their other deliveries) and washes and refills the bottles at their facilities. The return rate for bottles is 97 percent and one bottle is used up to 33 times (Hartwall, 2022). In addition, there is an existing collection system for deposit bottles, organised by Palpa,[13] that could potentially be utilised to collect reusable bottles if they are to be washed and refilled by the producer and not the consumer. There are four diverse types of beverage packages that can be recycled through the deposit-return systems in Finland: aluminium cans, PET plastic bottles, ring recyclable glass bottles and refillable glass bottles. Returning a bottle or can during your shopping is a small act. But when all the small deeds of each consumer are added together, up to 2 billion containers are returned each year—a figure that makes a difference. Besides the ease of return, also the number of points located where people move is important to encourage consumers to return used containers. Additionally, the targeted volumes should be on the same scale.

Food packages could be washed more easily due to utilising existing washing facilities for regular dishes. Actors that have these facilities include large restaurant groups that include lunch restaurants, e.g. Compass Group[14]) and student restaurants (e.g. UniCafe[15]). These facilities are not currently used around the clock hence, it could be a win-win situation. In addition, smaller restaurants have washing capacity as well and they could be part of the collection process too, if it was to be organised as a drop off collection. Regarding first- and last-mile deliveries, there are existing actors that offer solutions for this part of the logistics chain but currently mostly for the last-mile (e.g. Wolt[16], Foodora[17], Kavall[18] and Fiuge[19]).

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[12] https://www.hartwall.fi/kestopullo/
[13] https://www.palpa.fi/
[14] https://www.compass-group.fi/
[15] https://unicafe.fi/
[16] https://wolt.com/fi/fin
[17] https://www.foodora.fi/en/?r=1
[18] https://kavall.co/fi/
[19] https://fiuge.com/en/frontpage/

Food couriers could have a role in reusable food packaging logistics. Food couriers operate and earn money by delivering food and orders from local restaurants and businesses to customers. Especially those couriers with motorised vehicles such as cars could be provided with a second earning option when returning from customer deliveries by using the reverse logistics of those deliveries bringing back reusable packages from their customers. Couriers could collect used packages from customers or from other locations such as containers where packages have been placed. Couriers could collect small batches during their normal operations and bring them to the nearest dishwashing contract operator, selected from an operational app. Several aspects need to be considered in this concept such as the earnings model, deposits, hygiene risks, software application, security etc.

Food service companies make regular deliveries to each food service unit that they serve. This enables take back opportunities for reusable packaging. The most potential would be transportation of clean reusable packaging to locations where they are used or stored.

Regarding grocery home delivery packaging, the packaging is larger in size compared to the other packaging models. Here, the above mentioned first- and last-mile delivery options might not be as efficient due to the vehicle's capacity. However, almost all grocery stores chains have their own home delivery service. When new home deliveries are made to a certain area, empty packaging from that area could then be claimed by the delivery person. There is also an existing supply loop that is in close connection to retail stores currently: companies offering reusable bread and bakery trays and logistics services to manage them (e.g. IFCO[20], Lännen Teollisuuspalvelu Oy[21]). In addition, as these packages are a form of secondary packaging, and hence should not be in direct contact with products, there could be a possibility to sanitise them instead of washing them. Sanitising could be organised in retail stores' own facilities with an automated or semi-automated sanitising machine.

6.2.2 Washing integration

6.2.2.1 Critical factors for dishwashing hygiene

Hygiene is important in all areas of daily life where food is involved. Food safety and hygiene risks may jeopardise consumers, restaurants, kitchens, hospitals and even communities, if hygiene is neglected. Professional dishwashing plays a crucial role in avoiding food related risks. When it comes to reused food packages, each consumer is entitled to have hygienically clean food packages and cutlery. Dishwashing is a means of preventing the spread of potentially pathogenic microorganisms that may be present on dishes and cutlery to break the chain of infection. This is also

[20] https://www.ifco.com/fi/ratkaisut-elintarvikkeille/leipa/
[21] https://ltplogistics.fi/yritys/lannen-teollisuuspalvelu/

highly valid in the development, verification and use of reusable food containers, cutlery and transportation containers that are targeted for food deliveries for any context.

A key requirement for the wide adoption of reusable food packaging is their unquestionable washability, cleanability and verified hygiene after which they can be refilled and used again. Improperly cleaned and sanitised packages and containers with stuck-on debris will leave customers dissatisfied and could make customers sick. This necessitates *professional dishwashing integration* for targeted food related concepts, which is the only solution ensuring clean and hygienic packages for recurring uses. Professional dishwashing refers to food industry and food catering adopted and validated professional dishwashing and hygiene standards, practices, expertise, and infrastructure. In exceptional cases it might be possible to allow consumers to clean their own food packaging and bring the packages to refill for their own use if there is no risk of mixing them with third party packages or any other contamination risks.

Professional dishwashing procedure requirements need to be fulfilled to ensure consumers obtain clean dishes and utensils. This is necessary for all packaging used for serving or delivering food. This will happen if all four critical factors of dishwashing are in balance to ensure dishwashing hygiene and quality. These factors are temperature, mechanical work, chemicals, and time.

Temperature plays and essential role in the dishwashing process. Heated water loosens and dissolves stuck-on food, melts fats, and distributes the chemicals for cleaning and sanitisation. Each step in a dishwasher’s cycle requires that water is heated to a certain minimum level and the temperature is heavily involved also in drying. In comparison to legacy ceramic wares, reusable packaging material may have remarkably different thermal properties that may affect the targeted dishwashing quality and hygiene.

Mechanical work means motion which is created by the physical motion of the water as it hits the wares being washed, working to loosen stuck-on food debris and fat. The water is distributed via wash arms, which are either stationary or spinning, depending on the type of commercial dishwasher in question.

Chemicals in detergents help to remove food debris from wares during the washing cycle. They help to dissolve all forms of food debris and oils. Rinsing aids are used to enhance the drying process and protect glassware from etching. Chemicals must be mixed with water in the proper ratio during the dishwashing cycle. Too low a concentration may mean that your machine fails to get wares clean and sanitary. Too high a concentration of chemicals not only wastes money but may linger on plates after the wash cycle is complete and impart an unpleasant taste and odour to the food served. Similarly, as in the case of temperature, reusable packaging materials need to be suitable for chemical processing.

Time contributes to dishwashing quality in that a sufficient time spent inside a dishwasher will determine if the reusable packaging becomes thoroughly cleaned and sanitised.

If any one of the four factors is lacking, dishes may not get thoroughly cleaned. Reusable food packages do not necessarily behave like traditional dishware, e.g. ceramic, glass and metallic plates, bowls, and cutlery. Instead, reusable packaging may change the balance of critical factors in the dishwashing process. According to expert interviews, the most critical aspects might be temperature and chemical resistance. The chosen materials need to tolerate temperatures and chemicals to ensure proper sanitisation. Chemical resistance might bring out unwanted effects on the surface of the materials. The washability and hygiene of the materials need to be tested and validated carefully during the development process and controlled carefully during the lifetime.

Initially, the most critical reusable food packaging dishwashing related factors are associated with thermal and chemical suitability allowing dishwashing-based hygiene. The packaging design will need to ensure that it is suitable for dishwashing, collection and transportation. Washability and hygiene must be verified through testing during the material and packaging development. Specific design rules are most probably also needed to ensure washability and transportation, e.g. some of these might relate to surface properties, design details, durability, and stackability.

6.2.2.2 Applicable dishwashing technology

Commercial dishwashing machines can be classified into three basic types:

- **Undercounter dishwashers** are designed for small and medium size cafes and restaurants,
- **Hood-type dishwashers** with stainless steel entry and exit tables are made for larger volumes, and
- **Conveyor-type dishwashers** are for high-volume dishwashing where racks of crockery are automatically channelled through a large chamber.

All existing commercial dishwashing machine types can be used for reusable food packaging dishwashing, bearing in mind that the material may be different to traditional ceramics. Potential new material-based concerns to watch are temperature and chemicals, sufficiently high temperature durability and detergents. Careful evaluation of the efficacy of the dishwashing process is needed in conjunction with the reusable packaging development process. According to expert opinion, if there are hygiene-based food safety risks with dishwashing results, existing dishwashing technology can be extended with extra technologies that are already used in basic dishwashers for sanitisation purposes. For example, this could mean additional infrared technology may be required to ensure high quality dishwashing results.

6.2.2.3 Usability of existing actors and infrastructure for dishwashing

Mapping existing actors showed that there are potential actors and infrastructure available that could be used for reusable packing dishwashing purposes. The most potential candidates for the dishwashing operator role are food service companies and their dishwashing-related infrastructure in the facilities where they operate. Food service companies are professionals in food-related issues such as food safety and dishwashing hygiene. There is typically some excess dishwashing capacity, which is based on the design traditions in terms of planned customer volumes and the business idea. So, in some cases there is room to take some extra dishwashing crockery.

It is also acknowledged that food service companies struggle with the availability of a dishwashing workforce. An advantage could be that by providing extra dishwashing services to external customers dishwashers could be employed for a full day instead of part day. Large food service operators have a wide coverage of units especially in larger city areas making it possible to dishwash collected packages from nearby neighbourhoods. For example, the globally operating food service company Compass Group[22] operates in Finland in approximately 500 units. Initially, it was estimated that the reusable dishwashing needs for the whole of Finland could be covered by carefully selected units.

Food service companies operate under various service contracts. Some restaurants are open for every citizen, whereas some only for staff working in the building. Nevertheless, it is possible to organise a professional and safe operational dishwashing service model for reusable packages. A question remains concerning how to compensate the extra dishwashing costs to the facility owner in case the amount of dishwashing is great. This should be doable in terms of credible compensation to the facility owner. There are customer organisations where this kind of sustainable and shared resource concept would fit the organisations and their sustainability values. If a food service company would also use reusable food packages, it would make things a bit easier to avoid security concerns if the food service company can operate with their own staff.

The food service reusable dishwashing concept consists of a number of units with free dishwashing capacity. Dishwashing needs are centralised and optimally located units providing sufficiently short distances for food deliveries, use packaging collection and delivering to dishwashing and clean package deliveries to food service operators. Hospital reusable dishwashing volumes make it a bit more challenging. Should this consist of one centralised unit, or several decentralised units? And would there be free capacity for one centralised unit?

[22] http://www.compass.fi/

Besides food service companies, a second option for reusable dishwashing service operators would be event crockery service companies. Crockery service providers base their business on providing crockery for a large number of people in events. They have a dishwashing infrastructure and even mobile infrastructure to operate close to the events. The number of such companies and the coverage in Finland is limited, and their dishwashing capacity is unknown.

In Finland there are some event type catering services available, that offers tableware and dishwashing services. Ware renting services also provide dishwashing services, but not in such volumes that are available in other areas such as clothes, mats and textiles.

In the future, the dishwashing for food service operators is heading in the direction where dishwashing will be taken care of by dishwashing service providers, whereas food service companies will concentrate on their own core tasks of food production and customer serving activities. This transition has already started in Europe and this may affect dishwashing services in the food business in Finland. It is assumed, that these future dishwashing service operators could also take care of reusable dishwashing.

6.3 Efficient and economically viable sustainable circular logistics in reusable packaging

There are multiple variables that impact circular logistics economically. For example, Mollenkopf et al. (2005) list the container unit cost, cycle time, pack quantity, delivery distance and daily volume (average daily volume and peak volume).

The efficiency of circulation will be disturbed if there are not enough packages in circulation. Lack of efficient tracking of the packages can lead to disruptions in their quantity in addition to their poor allocation between phases, which causes a rise in the total costs (Twede and Clarke, 2004) and can cause delays. In addition, optimising the package quantity so that the full capacity of vehicles is used during transports reduces costs and improves efficiency. This can be further applied so, that in return routes, empty packages are nested, therefore more packages can be transported, or smaller vehicle used. (Gardas et al. 2019)

To optimise the packaging quantity and daily volumes, the ability to forecast the returns of reusable packaging to at least some level is necessary (Glock, 2017). Regarding the packaging and its use purpose, the return intervals can vary greatly which makes demand forecasting more difficult. In addition to planned intervals within the system (such as collections done at regular intervals), variables such as consumer behaviour and the packaging's current condition have an impact on returns. Tracking technologies have a strong positive impact on this (see Chapter 5).

However, a simple forecast is necessary to plan shipments of packaging, to purchase new packaging from the manufacturer, and to be able to replace lost/damaged packaging in circulation (Glock, 2017).

Delivery distances vary greatly between participants and different phases of the supply loop. Dividing deliveries into long distance/large capacity transportations and first- and last-mile deliveries can provide economic and efficiency value. This is due to aspects such as utilising short range electric vehicles for first- and last-mile deliveries instead of regular vans.

Unit costs are high at the beginning due to the initial investment in the packaging. However, the more times the packaging circulates the less expensive its unit cost will be in the long-term. The initial investment per packaging should be returned after 1–1.5-years after the package begins its first circulation (Gardas et al. 2019).

Automatisation is also a great source of efficiency. When establishing a new system that plans to utilise new technologies, some activities from different phases of the circulation are likely to be automated. It is recommended to evaluate whether there will be issues with implementing automatisation in the system later on, if it is not examined in the design phase for the system and packaging characteristics (Azzi et al. 2012).

6.3.1 Supporting technologies

Using automation is a prerequisite for organising efficient logistics of reusable packages if the package is not under the control of and on the premises of the consumer all the time. The basis for increasing the automation level is the automatic recognition of the packaging. This is the only way to ensure automatic movement of the package and receiving the package from consumer in a return machine. The recognition can be realised by visual scanning of the form of the item. However, in this case, the required technology might be rather expensive as the requirements for recognition accuracy are high. Therefore, for bottle recycling, for example, the bottles have identifiers which enable efficient and relatively simple recognition if the identifier is readable.

As an example, the Palpa return machines that Alko Inc[23] uses recognise the form of the bottle. Due to this, some of the returned bottles that are outside the product portfolio of Alko and are outside Alko's deposit scheme might be refunded. These bottles go to recycling, not reuse.

The identifier can be unique for each type of package, or each package could have its own unique identifier (Holmström et al., 2009). A large majority of the current recyclable packages have a package-type-level identifier. This will help to keep

[23] Alko is the national alcoholic beverage monopoly in Finland

count of different types of packages and enable fast dispatch and retrieval of them. A unique identifier enables item-level identification. This would offer many additional benefits for logistics, but it is also more expensive to realise and gaining the benefits from item-level recognition requires a considerable amount of processing and storing capacity in the system (Holmström et al., 2009).

A unique identifier enables item-level tracking (Zhou and Piramuthu, 2013). The item-level tracking of single packages enables multiple benefits related to visibility compared to the package-type-level recognition and tracking, such as: 1) the ability to track the history of a single package; 2) the possibility to collect information about the movement of packages and circulation times; 3) better possibilities to calculate circulation costs of packages; and 4) possibilities to obtain information about missing packages. In addition to identifiers, the realisation of tracking requires the reading of identifiers and a connection to a database that processes the tracking data. Depending on software applications, tracking information can be used for a variety of purposes (Zhu et al., 2012; Raza at al., 2021).

Reading the identifiers may require visual contact or it might be based on wireless technologies. QR-codes or barcodes require visual contact, but they are cheaper to apply. On the other hand, NFC or RFID tags are more expensive, but reading them does not require visual contact, and it is also possible to read multiple RFID tags at the same time.

The use of unique identifiers in each object belongs to the wider Internet of Things (IoT) concept (Golpîra et al., 2021). The idea of IoT is to connect and exchange data between unique objects and controlling systems over the Internet or other communication networks. From the IoT perspective, returnable packages will be part of an smart store, restaurant or home, for example, depending on where they are used in that moment.

6.3.2 Packaging design and properties for efficiency in logistics

The characteristics of the packaging, including the size, shape, weight, and temperature resistance, have a great impact on the different phases of logistics and their efficiency. Nilsson et al. (2013) divide logistics requirements for packaging as follows, product protection, logistical information, volume and weight efficiency, quantity and size and handling.

Nesting and/or stocking provides efficiency and ease of handing the empty packaging (Hellström & Saghir 2007; Azzi et al. 2012). To be able to nest and/or stock packaging, it needs to be standardised. The standardisation of the packaging results in better vehicle capacity utilisation and standardised storage facilities and equipment (McKerrow, 1996).

Molina-Besch and Pålsson (2016) address the need to optimise unitisation to also maximise the used capacity of volume in transportation and storage. In addition, from the sustainability point of view, the packaging design has an impact on minimising cooling/heating needs in addition to reducing emissions. Lighter packages will not cause as many emissions (Hellström & Saghir 2007) and proper insulation properties will control packaging temperature (Molina-Besch & Pålsson 2016).

A necessity for reusable packaging is the package's durability. Going through the different phases of circulation, especially washing, the packaging must not be easily damaged. According to Koskela et al. (2014), a plastic crate can be used up to 700 times. However, the durability varies between the intended use of the package. For example, food packaging has to resist contact with cutlery in addition to being washed after every use (perhaps daily) compared to a delivery box being used perhaps once a week.

6.3.3 Physical Internet for reusable packaging

The idea of the physical Internet is to apply the concepts from digital Internet data transfer to real-world shipping processes. On the Internet, data is transferred in the form of packets with embedded information. The physical Internet vision involves encapsulation of goods in smart, eco-friendly and modular containers ranging from the size of a maritime container to the size of a small box. It hence generalises the maritime container, which succeeded to support globalisation and shaped ships and ports, and it extends containerisation to logistics services in general. The physical Internet moves the border of the private space to inside the container instead of the warehouse or the truck. These modular containers will be continuously monitored and routed, exploiting their digital interconnection through the Internet of Things. (Montreuil, 2011; Pan et al., 2017; Sternberg and Norrman, 2017)

The key issues of the physical Internet, modularity of shipments and tracking, will enable the efficient use of transportation capacity (Pan et al., 2017). When a shipment requires transportation between its origin and destination, modularity will help to find available cargo space of transport carriers. Like the digital Internet, the shipment may not go the shortest route between its origin and destination, but it uses a route where free capacity can be found. The use of tracking enables smooth transfers between transport carriers in logistics nodes and ensures that the package does not get lost.

If the principles of the physical Internet were applied in the logistics of reusable packages, the first thing would be the modular packages (Montreuil, 2011). Basically, if the number of different package types is limited, a single package could be the basic unit of a modular package. This would be a first-level packet. Reusable packages should be designed in a way that they can be easily packed in a box or similar standardised container. This would be the second-level packet. Possibly, several boxes could be packed in a bigger box, which would be a third-level packet.

To fulfil the requirements for tracking, all different packet levels require a unique identifier. If a single item is a first-level package, a level-type identifier is not enough, because otherwise there would be a risk that dirty and clean packages could mix.

Applying the principles of the physical Internet when organising reverse logistics of reusable packages from the user to the provider will be based on the idea of finding free transport capacity (Pan et al., 2017). Basically, shipments and goods flow from stores and take-away restaurants to the consumer. Therefore, there should be empty capacity when the consumers themselves or deliverers provide goods for users. The main thing is to find and define this empty capacity. For example, if a food deliverer is using a car for the delivery work, there will be most probably quite a lot free capacity for returnable packages, and that capacity increases every time one delivery is provided. Even if the deliverer does not go to the place where the empty packages are needed next time (e.g. a washing station), it probably helps in the organisation of the logistics, when the packages are no longer scattered amongst different consumers, but they are in a single place where various kinds of traffic exist (like in a store or restaurant). Therefore, organising the next route may have more options, as numerous food deliverers, consumers, and material suppliers visit that place during the day.

Applying physical Internet -based applications in the logistics of reusable packages requires open data exchange between different actors. The information about packages and free capacity to carry them needs to be available for different parties to enable smooth logistics. One option is to develop an Open Data Standard for reusable packaging. (Ellsworth-Krebs et al., 2022)

7. Consumers’ views on reusable packaging

Finding ways to maintain the use, value and worth of packaging is key to reducing plastic packaging waste. Reusable packaging systems are one way to achieve this (Greenwood et al. 2021). Novel, consumer-based reusable packaging models are emerging in the FMCG industry and consumer engagement is critical to ensure the success of businesses in this area (Muranko et al. 2021). As Greenwood et al. (2021, p.1689) put it:

“There is little point in creating a reuse system with low environmental impact if consumers are not willing to engage with the system, and vice versa a reuse system that consumers are willing to engage with that brings no environmental benefit, or worse brings more detrimental impacts”.

Some knowledge about consumers’ views on this domain exists. Consumers’ views have been studied in relation to a) *the reusable packaging idea in general without reference to specific products and\or packages* (e.g. Babader et al. 2016), b) *reusable packaging of food, personal care and home cleaning product categories* (Lofthouse et al. 2009, 2017, Bashir et al. 2020, Greenwood et al. 2021) and c) *reusable containers, such as shopping bags and warm drink cups* (e.g. Ertz et al. 2017, Poortinga & Whitaker 2018, Novoradovskaya et al. 2020, 2021). For clarity, the reusable container here refers to such packaging, which is not produced by the product manufacturer and is not an original feature of the product. Despite not being strictly in line with the reusable packaging definition (see the Introduction of this report, p. 11), some studies concerning reusable containers are included in this chapter anyway due to their potential relevance for reusable packaging domain.

The next sections of the chapter present and discuss findings from relevant studies as follows: Section 7.1 presents consumers' perceptions and attitudes toward reusable packaging. Section 7.2 presents factors shaping consumers' perceptions, intentions and behavior related to reusable packaging. Section 7.3 provides concluding remarks and future directions for consumer research on reusable packaging.

7.1 Consumers' perceptions and attitudes toward reusable packaging

Consumers' perceptions and attitudes toward the general idea of packaging reuse and reusable containers seem to be positive. For instance, an empirical study of UK consumers (Babader et al. 2016) indicated that the idea was perceived as a good approach from an environmental sustainability perspective, i.e., to tackle packaging waste. In another study, it was found that consumers' general attitudes toward reusable mugs, drinking bottles and shopping bags were positive among Western and Asian consumers (Ertz et al. 2017).

Convenience, quality and pricing of reusable packaging solutions are issues of concern for consumers. For example, products from several refillable packaging systems are expected to be cheaper than conventional solutions as it is generally perceived that they cost less in terms of production and transportation. (Lofthouse et al. 2009, 2017, Bashir et al. 2020)

Consumers seem to be positive, but also sceptical of certain types of reusable packaging types. A study in the UK found that for some consumers deposit-based refill systems felt better from the ethics and environmental sustainability perspective, while for others such systems did not fit in with modern life (Lofthouse et al. 2009). Consumers' first reactions toward certain reusable packaging solutions seem negative. For example, a home cleaning product offered in refillable packaging in Norway was perceived as burdensome by the study participants because it required greater time and excessive effort (Bashir et al. 2020). However, from the consumers' perspective, there was variation between five alternatives related to the above-mentioned solution in terms of expensiveness, environmental friendliness, overall advantage, convenience, and risks over privacy, functionality and product safety.

Negative attitudes toward some reusable containers have also been observed. For instance, US consumers who did not own and did not like having to carry reusable coffee cups were reluctant to bring their own reusable coffee cups for refills to relevant retailers, such as cafeterias. (Nicolau et al. 2022)

7.2 Factors shaping consumers' perceptions of reusable packaging, intentions, and related behaviour

Consumers' somewhat positive attitudes and perceptions towards reusable packaging do not seem to translate into increased intentions towards them. Generally, willingness to reuse packages (through repurpose, refill and return) seems to be low. A UK-based study (Greenwood et al. 2021) involving consumers' evaluations of ninety commonly sold products in supermarkets (e.g. food, personal care and home cleaning) showed that consumers were willing to return and refill only 7% of them. This was because consumers' reuse behaviour is relatively habitual and this translates into a willingness to return and refill products for which reuse systems already exist (e.g. milk in glass bottles) and reservation toward others (e.g. reuse of microwavable trays).

However, the research in the field has identified certain product, information, and consumer-specific factors which shape the relationship between consumers and reusable packaging.

7.2.1 Packaging related factors and product information

Some functional characteristics of products and packages influence consumers' perceptions of reusable packaging solutions. For instance, the ease of transportation and delivery, lightness, bulkiness, fit-for-purpose, product safety, ease of functionality, additional time and space resources, packaging availability, risk of discontinuity, complexity, and compatibility were noted by UK consumers when evaluating the convenience of certain packaging refill products in home cleaning, personal care and food categories. In addition, consumers have concerns that they may be forced to use only certain branded products because of lack of alternatives in the market (Lofthouse et al. 2009). Another study found that the packaging material, type, and closure mechanism moderated the consumers' willingness to reuse packages of frequently bought products at UK-based supermarkets (Greenwood et al. 2021). For example, the willingness to reuse packaging made of glass was higher than films, flexible plastic, or foil and the willingness to reuse was higher for jars, bottles and boxes or cartons, compared to wraps, cans and aerosols. Finally, a study among Norwegians found that those consumers who perceived a home cleaning refill solution as inexpensive, convenient and of high quality were more inclined to use it and to recommended to others (Bashir et al. 2020).

Some studies have tackled the information effect on consumers' views related to reusable packaging. Consumers' intentions to use and buy products in reusable packaging and reusable containers were positively influenced by information about the environmental benefits, packaging waste and safety (Bashir et al. 2020, Novoradovskaya et al. 2021). Exposure to either evidence-based information about negative environmental consequences of disposable coffee cups or information about environmental benefits associated with reusable coffee cups resulted in a significant increase in the intentions to use reusable coffee cups on a daily basis (Novoradovskaya et al. 2021). Additionally, a combination of explaining the environmental benefits and safety reassuring information about a home cleaning refill solution resulted in increased intentions to use and recommend the solution to friends and family (compared to those who received only environmental benefit information and to those who did not receive any information about the same solution) (Bashir et al. 2020).

7.2.2 Psychographics, demographics and socioeconomics

Certain psychographics predict intentions and behaviour related to the reuse of containers. The perceived behavioural control (i.e., the degree to which a person believes that he or she can perform a given behaviour) and motivation increase consumers' intentions to use reusable mugs, thermal bottles and shopping bags (Ertz et al. 2017). Higher perceived behavioural control and (favourable) attitudes contributed positively to consumers' intentions to increase the use of reusable drink cups (Keller et al. 2021) while another study (Novoradovskaya et al. 2020) showed that environmental values and past behaviour predicted the use of reusable drink cups. Finally, consumer-focused interventions toward increasing the usage of reusable containers (e.g. the provision of free reusable containers) have a significant and positive influence on participants' strength of habit (i.e., the extent to which a behaviour is habitual), personal norms (towards natural environment), environmental values, and the intention to use reusable cups (Novoradovskaya et al. 2021).

Demographics and socio-economics influence consumers' reusable packaging behaviour and their intention to use reusable containers. For instance, women and older people have bought products with reusable packaging and containers more than men and young people, respectively (Escario et al. 2020, Nicolau et al. 2022, Dorn and Stöckli, 2018). The education level has been associated with the reuse of packaging materials (Escario et al. 2020), but also with non-willingness to use reusable containers, such as reusable coffee cups for refills (Nicolau et al. 2022).

7.2.3 Social influences

The consumers' social environment has been found to influence their intentions and reuse behaviour in various ways. For instance, subjective norms (i.e., the belief that an important person or group of people will approve and support a particular behaviour) predicts the intention to use reusable mugs, thermal bottles and shopping bags (Ertz et al. 2017). Counterintuitively, it has been found that when an individual is the only person in a group behaving pro-environmentally they prefer buying products in reusable packaging (Escario et al. 2021). Finally, others' behaviour is likely to prompt others to follow. For instance, a study of reusable take-away boxes for food at restaurants showed that choices of reusable boxes are more likely to occur for individuals when others around them chose to buy or use their own reusable take away boxes (Dorn and Stöckli, 2018).

7.2.4 Financial incentives

The effect of financial incentives and counterincentives (i.e., charging for single-use packaging choice) on consumers' behaviour related to packaging and container re-use has been approached by one study. A study in UK-based cafeterias and restaurants (Poortinga and Whitaker, 2018) showed that standalone discounts did not lead to increased use of reusable coffee cups, while charges on disposable cups did. A major behavioural change was achieved with a combination of measures including a discount, on-site selling of reusable cups, and the distribution of free reusable cups to customers.

7.3 Concluding remarks and future directions for consumer research on reusable packaging

All in all, consumer understanding of the reusable packaging domain is still in its nascent. In total, the literature review carried out for this chapter identified fourteen research pieces, which scratched only a surface of potentially important topics. In this chapter, some criticism towards the existing literature is given and some future directions for research are offered to inspire the research and subsequent business development concerning reusable FMCG packaging.

7.3.1 Perceptions of reusable packaging

Until today, it seems that, only one empirical study with a relatively small sample (Babader et al. 2016, N=101) has taken place regarding consumers' perceptions of the general idea of reusable packaging (excluding repurposing). This naturally highlights the novelty of reusable packaging as a study domain, but at the same time calls for more attention. There is a need for a better understanding about what consumers think and feel regarding reusable packaging approaches (e.g. return and refill) where packages circulate for the same purpose they were originally conceived. In addition, there is a need for further studies in different domains. For example, it can be expected that consumers' views will vary between reuse solutions for food and detergents. There might even be variation within the domains. For consumers, less often used reusable take-away food packaging might be a different story than more frequently used reusable packaging for convenience foods.

Currently, research findings showcase consumers' views on potential cost, environment and waste-related values of reusable packaging solutions and containers (e.g. Ertz et al. 2017, Nicolau et al. 2021). However, it is unknown whether consumers associate more values than just environmental sustainability and waste reduction with reusable packaging in general and with specific solutions. For instance, values related to pleasure have not been explored yet despite earlier findings indicating that some packaging refill types were considered by consumers as "fun to use" (Lofthouse et al. 2009, Kunamaneni et al. 2019).

Consumers' views have been studied for three reuse models: refill, return and repurpose (i.e., reuse for other purposes than the original use). Notably, refill solutions are the most explored among the reviewed studies. The limited focus on solutions addressing return in consumer studies is odd given the fact that return models are being highly explored by the FMCG industry (Murnako et al. 2021).

7.3.2 Consumers' rational and affective decision-making regarding reusable packaging

The reviewed studies heavily focused on consumers' rational thinking about reusable packaging and containers as means to reduce their packaging waste and contribute to environmental sustainability. Evidence from research in ecological packaging suggests that consumers may not only be driven by rational thinking and logic when making ecologically responsible purchases. Additionally, affective reactions to ecological packaging may provide an important explanation of consumers' intention to buy such products (Koenig-Lewis et al. 2014). Measurement of the emotions evoked by the reusable packaging idea and\or certain solutions may offer additional insights into consumers' motives and barriers to adopting reusable packaging. In addition, understanding the affective influences could serve as valuable building blocks for the development of attractive reusable packaging solutions.

7.3.3 Self-reported behaviour

Some of the reviewed studies tried to tackle consumers' actual behaviour. However, the studies rely on consumers' self-reports. It is well known that self-reported behaviour might provide limited understanding of the actions taking place in real-life (Rantala et al. 2022). In addition, self-reported behaviour might be biased, especially if the behaviour in focus is socially desirable, such as reusable packaging use (Novoradovskaya et al. 2020). Consumers' perceptions and reuse behaviour have been mainly studied through self-reporting, either through the administration of questionnaires (e.g. Escario et al. 2021, Bashir et al. 2020, Ertz et al. 2017) or the use of an Ecological Momentary Assessment (EMA) solution developed for capturing consumers' behaviour in the actual moment of consumption (Novoradovskaya et al. 2021). Exceptions to self-reporting include two studies on container use that took place in real life environments, such as cafeterias, and were supported by direct observations and cashier data (Dorn and Stöckli 2018, Poortinga and Whitaker 2018). Studies of reusable packaging in real life contexts is suggested as a way to test how and to what extent reusable packaging solutions bring changes in peoples' use and buying behaviour.

7.3.4 Clarification of the context: Varying definitions of reusable packaging in consumer studies

The previous chapters introduced the state-of-the-art of consumer research in the reusable packaging context. However, it was evident that reusable packaging in consumer research holds for multiple definitions warranting further considerations on the generalisability of the results for specific reuse contexts. In many of the reviewed studies, no definition of reusable packaging or reusable containers was provided. Further, in those studies which included one, some differences emerged. This endangers the comparability of the studies and makes it difficult to interpret the results and form solid conclusions\an overall view of the topic as naturally consumers' views differ according to what they are prompted to evaluate.

Ertz et al. (2017) define reuse, in general, as "any activity that lengthens the life of an item" whereas Babader et al. (2016) and Greenwood et al. (2021) refer to the definition provided by the Packaging Waste Directive 94/62/EC where reusable packaging is described as:

"[An] operation by which packaging, which has been conceived and designed to accomplish within its life cycle a minimum number of trips or rotations, is refilled or used for the same purpose for which it was conceived with or without the support of auxiliary products present on the market enabling the packaging to be refilled: such reused packaging will become packaging waste when no longer subject to reuse."

In some studies, references are made to types of products sold in reusable packaging, and to reusable containers (e.g. shopping bags) either without further information regarding reuse or with short descriptions. For instance, Novoradovskaya et al. (2021) refer to the material properties of reusable hot drink cups as "made of durable plastic, glass, metal or other materials".

Furthermore, definitions of reuse models exist in consumer studies. For instance, Greenwood et al. (2021, p. 1689) define packaging return as to "where the containers owned and cleaned by a business (or group of businesses)" and packaging refill as to "where the container is owned by the consumer after the first purchase and then refilled with auxiliary products (at home) or taken to a refill station (on the go)". Additionally, Lofthouse et al. (2009) provide short descriptions of 15 common refillable packaging systems\models, differentiated by the delivery mechanism and level of consumer/business interaction.

8. Reusable packaging policy framework

This chapter summarises the current and upcoming European policies and regulation on packaging reuse, and highlights issues that may also hinder the uptake of such reuse systems.

8.1 EU policies and regulation on packaging reuse

8.1.1 European Green deal

The European Green deal (EGD) is a paradigm change in the European growth strategy as it aims to accelerate the sustainability transformation needed to tackle the severe challenges related to climate change and environmental degradation (European Commission, 2019). The goal is to transform the economy, including production and consumption, to better address planetary boundaries. The increasing packaging waste generation and related pollution, particularly related to plastics, as well as increasing CO2 emissions, are one of the key environmental challenges to be tackled.

In the Green Deal, the European Commission has set an ambitious goal that it will develop requirements to ensure that **all packaging in the EU market is reusable or recyclable in an economically viable manner by 2030.** (European Commission, 2019)This goal is a significant push to favour the uptake of reusable packaging at the European Union (EU). Even though packaging reuse has been identified as a means to reduce packaging waste generation in the Directive on Packaging and Packaging Waste (PPWD) (European Parliament, 2018), the new ambitious target brings reuse to the centre of policy attention. The EGD entails several strategies, initiatives and regulatory measures that target directly or indirectly packaging reuse, and this chapter will summarise these key approaches.

8.1.2 Circular Economy Action Plan

The new Circular Economy Action Plan (CEAP) (European Commission, 2020a) highlights the need to set a broader **sustainable product policy framework** and broaden the scope of the existing Ecodesign Directive to better address circularity in product design. The recent Commission proposal of this framework highlights the ambition to improve the environmental sustainability of products by setting ecodesign requirements for any physical good placed on the market, including packaging. The suggested ecodesign requirements, which shall be further elaborated by the Commission in delegated acts, relate to aspects such as product reusability and recycled content in products (European Commission, 2022a). In the CEAP packaging is identified as one of the key product value chains and the action plan set forward a review of Packaging and packaging waste directive (Directive 94/62/EC) to reinforce the mandatory essential requirements for packaging to drive the design for re-use and recyclability of packaging. Another key strategy within the CEAP is the **European Strategy for Plastics in a Circular Economy** (European

Commission, 2018) which aims to transform the way plastic products are designed, produced, used and recycled. This strategy lays foundations to improved plastics use in the CE highlighting the need for product design that respects reuse, repair and recycling.

8.1.3 Packaging and Packaging Waste Directive and Regulation

The revised Packaging and Packaging Waste Directive (PPWD) (Directive 2018/852 amending Directive 2008/98/EC (European Parliament, 2018) has set tighter recycling targets for all packaging. For example, by the end of 2030, 70% by weight of all packaging waste must be recycled. While the revised directive obliges Member States to increase the share of reusable packaging placed on the market, as well as set up systems to reuse packaging, quantitative targets for reuse are still missing. The PPWD also obliges Member States to set up systems for the collection, recovery and recycling of post-consumer packaging waste. National governments generally delegate this legally binding obligation to producers of packaging through the setting of extended producer responsibility (EPR) schemes.

Due to the insufficient effectiveness of the PPWD, the European Commission has been preparing a new legislative proposal. In November 2022, the Commission launched its proposal for Packaging and Packaging Waste Regulation (PPWR) (European Commission, 2022b). Instead of a mere amendment to the existing directive, the proposal is a regulation, which is seen to enable setting more harmonised rules across the EU. The proposal aims to tackle the growing amount of packaging waste, drive the design for re-use and recycling of packaging, reduce the complexity of packaging materials and introduce requirements for recycled content in plastic packaging.

Furthermore, the proposal sets the first progressive targets for packaging reuse. For example, 10% of primary packaging of takeaway food for immediate consumption should be reusable by 2030. The target is 40% by 2040. The proposal for PPWR also suggests bans on using single-use packaging for food and beverages filled and consumed on the premises in the hotel, restaurant and catering (HORECA) sector. The PPWR also defines the requirements for reusable packaging accordingly:

- the packaging must be conceived, designed and placed on the market with the objective to be re-used or refilled;
- it must be been conceived and designed to accomplish as many trips or rotations as possible in normally predictable conditions of use;
- it can be emptied or unloaded without damage to the packaging, which prevents its re-use;
- it is capable of being emptied, unloaded, refilled or reloaded while ensuring compliance with the applicable safety and hygiene requirements;
- it is capable of being reconditioned (in accordance with Part B of Annex VI of the proposal), whilst maintaining its ability to perform its intended function;

- it can be emptied, unloaded, refilled or reloaded while maintaining the quality and safety of the packaged product and allowing for the attachment of labelling, and the provision of information on the properties of that product and on the packaging itself, including any relevant instructions and information for ensuring safety, adequate use, traceability and shelf-life of the product;
- it can be emptied, unloaded, refilled or reloaded without risk to the health and safety of those responsible for doing so; EN 62 EN
- it fulfils the requirements specific to recyclable packaging when it becomes waste set out in Article 6 of the proposal.

While the current PPW directive acknowledges EU member states' role in supporting and setting up reuse systems, the proposed regulation puts more pressure on member states. The proposal requires states to: 1) actively encourage the re-use and refill solutions and consider establishing deposit and return systems also for reusable packaging, 2) support the establishment of systems for re-use and refill and monitor their functioning and compliance with the hygiene standards; and 3) strive for the maximum inter-operability of systems and cooperate to ease the return of packaging by consumers.

8.1.4 Directive on Single-use Plastics

The Directive on Single-use Plastics (SUPD) (European Parliament, 2019) sets out an ambitious reduction in the consumption of single-use plastic products and promotes a transition to a CE. The directive addresses 10 types of plastic items that contribute to (marine) litter and plastics pollution, including food containers and cups for beverages. In this directive, single-use plastics are defined to 'be made wholly or partly' of plastic and are typically intended to be used just once or for a short period of time before they are thrown away'. The directive entails market restrictions (bans), compulsory marking of SUP items and consumption reduction measures. Extended producer responsibility is also strengthened entailing the 'polluter-pays' principle, which means that producers must cover the costs of waste management clean-ups, data gathering, and awareness raising. **The directive gives priority to sustainable and non-toxic reusable products and reuse systems, including reusable packaging.**

Reuse is particularly highlighted in article 4 of the SUPD, which targets a reduction in the consumption of selected SUP items, i.e., packaging of single-portion food and drinks intended for immediate consumption either on site or on-the-go directly from its packaging without further manufacture (such as cooking, cooking or heating). The suggested measures include ensuring that re-usable alternatives are made available at the point of sale to the final consumer, as well as developing economic instruments, such as like making SUP products not free of charge at the point of sale. The member states have different approaches in the national implementation of this directive and the measures range from binding regulation to voluntary approaches. Examples of different approaches in connection to packaging reuse are discussed in Ch. 8.2.

8.1.5 Food contact materials framework regulation

The food contact materials (FCM) framework regulation address reuse through the materials intended to be in contact with food. Particularly plastics are regulated under this frame. For example, according to the EU regulation 10/2011, plastic materials and articles intended for repeated use in food contact must be tested and verified to ensure safety. Regulation 282/2008 addresses recycled plastic materials and articles intended to come into contact with foods. To better address the circular economy and the use of re-usable and recyclable materials in food contact applications, the EC initiated in 2020 the revision of EU rules on FCMs (European Commission, 2020b). Following from this, the EC published a draft regulation on recycled plastics in food packaging (Recycled plastic materials and articles intended to come into contact with foods and repealing Regulation (EC) No 282/2008), in December 2021. If this regulation were to be adopted, it would broaden the types of recycling, like for example a combination of mechanical and chemical processes, to be considered legal and potentially enhance the use of recycled plastic materials in food contact. However, so-called legacy materials, such as paper and board, are not regulated under the FCM frame.

8.1.6 Regulations on good manufacturing practices and the hygiene of food stuff

All actors throughout the value chain of food contact materials, such as materials and packaging intended for use or reuse in food applications, need to comply with the regulation 2023/2006 on good manufacturing practises (Finnish Food Authority, 2021) (European Commission, 2006). This means that companies (material and packaging producers, reusable packaging service providers and companies selling food) are obliged to place, implement and maintain a quality management system that is based on the Hazard Analysis and Critical Control Points (HACCP) principle. The system should thus cover the necessary expertise, quality assurance, control and documentation to ensure food safety. This self-monitoring procedure is also aligned with the requirements of the **EU regulation on the hygiene of foodstuff** (European Parliament, 2004).

Currently, there is no regulation prohibiting consumers from using their own reusable containers for food at restaurants or stores, if this can be done in a way that ensures food safety. However, national interpretations on the food hygiene legislation may differ. For example during the COVID19 pandemic, Finnish food authority recommended that take-away food should not be sold in customers' own containers, in order not to jeopardise the safety of consumers and restaurant workers (Finnish Food Authority, 2020).

8.1.7 Regulation on classification, labelling and packaging of substances and mixtures

A regulation on classification, labelling and packaging of substances and mixtures (CLP) (1272/2008 amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation No 1907/2006) addresses packaging reuse indirectly and is relevant for reusable packaging, for example, in case of bulk-dispensing systems for detergents. CLP regulation obliges manufacturers, importers and downstream users to classify, label and package substances and mixtures placed on the market. In practice, this means that a company/retailer selling detergents to consumers through bulk-dispensing, must ensure that even though the consumer is using a reusable packaging, the sold detergent is labelled and packaged as required by the regulations (Tukes, n.d.).

8.1.8 General Data Protection Regulation

Finally, a few words on the EU's General Data Protection Regulation (GDPR) and its linkages to packaging reuse. The GDP regulation lays down rules on the processing of personal data and the free movement of such data (European Parliament, 2016). The regulation aims at strengthening EU citizens' rights in the digital age and to facilitate business by clarifying rules for companies and public bodies. Thus, every company collecting, and processing personal data must comply with this regulation, as well as ensure that any third-party supplier, such as web developers and food delivery apps, are also GDPR compliant. The GDPR does not inhibit the use of customer data, but it requires receiving informed consents from customers on personal data collection and usage. Thus, companies have to give customers more control over their personal data and provide clear and concise information on why, what kind of data and for which purpose data is collected and processed prior to the consent.

8.2 National policies and regulations

This section provides an overview of national packaging policies related to reuse. The focus is on Finland, yet additional benchmarks of recent ambitious national regulations addressing packaging reuse are also presented.

8.2.1 Finland

The packaging and packaging waste decree sets the key requirements for packaging and packaging use. A recent update to this decree was made in 2021 related to the implementation of the EU waste package and SUP directive. The latest **Government Decree on packaging and packaging waste (1029/2021)** sets requirements for packaging following from the EU's Packaging and Packaging waste directive. According to the decree, reusable packaging must simultaneously meet the following requirements:

- the physical properties of the packaging must be such that it can withstand several transport and times of use under normal operating conditions
- it must be possible to handle the used packaging in accordance with the requirements regarding the health and safety of employees;
- when the packaging is no longer reused and becomes waste, the requirements regarding the usability of the packaging must be followed (e.g. recycling, composting and energy use).

All packaging producers, i.e. companies packing or importing packed products or selling products through e-commerce, with a turnover of over 1 million EUR are seen as packaging producers according to this regulation, and are obliged to organise the collection and recycling of packaging waste in its entirety and to bear the resulting costs. According to the decree, the extended producer responsibility costs should be eco-modulated, meaning that the EPR fee is recommended to be lower for packaging that is reusable, and the fee is charged only when the reusable packaging is put on the market for the first time. Furthermore, the share of reusable packaging can be taken into account in the material specific recycling targets. This is done so that the targets can be adjusted by a maximum of five percentage by reducing the share of reusable sales packaging placed on the market for the first time during the previous three years from all sales packages placed on the market containing the material in question. The decree (1029/2021) also obliges the producers (or producer organisations on behalf of producers) to annually report the volumes (tons) of reusable packaging, including:

- the volume of reusable packaging placed on the market for the first time;
- the reuse times (number of rotations);
- the volume of reusable sales packaging;
- the volume of all reusable packaging; and
- the achieved reuse rate

Regarding the implementation of the SUP directive, the required product bans and labelling requirements obligated by the directive have already been transposed into national law by the **Waste Act Amendment Act (714/2021, HE 40/2021 vp)** related to the implementation of the EU waste package and the **Government Decree on Certain Disposable Plastic Products (771/2021)**. Furthermore, regarding the implementation of consumption reduction measures (article 4 of SUPD), Finland has initiated a voluntary, collaborative measure approach. In the spring of 2022, the Ministry of the Environment, in co-operation with five key industry associations, set a green deal agreement to reduce the consumption of plastic disposable food packaging. The primary objective of this agreement is to replace plastic disposable single-portion packs with easily recyclable plastic-free disposable packaging, reusable single-portion packs and reusable containers. This year, the agreement aims to set a baseline for reduction targets and plans to set more precise national quantitative targets for reducing the consumption of disposable plastic packaging in the coming years.

8.2.2 Germany

The German Packaging Act (VerPackG, 2021) sets general requirements for packaging including requirements on reusability, recyclability, packaging volume and mass, and also the use of secondary raw materials. The act has been recently amended (BMU, 2021) to address the implementation Single-use Plastics Directive (EU) 2019/908. The recent amendment of the German Packaging Act states that from January 1, 2023, the final distributors of food packaging and beverage cups, that is restaurants, bistros and cafés selling on the go food or drinks are obliged to offer their products in reusable packaging as well as in single-use packaging. The reusable alternative must not be more expensive than the product in single-use, disposable packaging. In addition, the final distributors are obliged to inform consumers on the return options of the reusable packaging offered by them through readable information boards or signs. However, small businesses with five or less employees and a shop area of no more than 80 square metres are exempted. Small businesses must, however, provide the option of filling customers' own reusable containers.

The amended Packaging Act has set targets for increasing the share of reusable packaging for beverages to over 70% but it does not address the deposit scheme to other packaging, such as other foodstuffs and household items such as soap, shampoo, and detergent, which is seen to be necessary to further reduce single-use packaging and strengthen reuse systems (Kumar, 2020).

In 2020, the German city of Tübingen set a packaging tax on single-use, takeaway food and drink packaging to create an incentive to reduce the consumption of disposable packaging, to promote reusable packaging and to avoid high disposal costs. However, due to a lawsuit filed by local McDonald's, the Administrative Court of Baden-Württemberg declared the tax to be illegal (SWR, 2022).

8.2.3 Portugal

The main legislative framework on packaging is Decree-Law No. 152-D/2017 of 11 December 2017 (DRE, 2017). The law entails a deposit refund system (DRS) for reusable packages, in which the consumer pays a deposit at the time of the acquisition of packaging, which can be reimbursed when returning the same packaging.

Decree-Law No. 102-D/2020 updates the scheme for the management of specific waste flows and also addresses packaging reuse (DRE, 2020). For example, large retail outlets are required to have areas for the trade in bulk products and beverages in reusable packaging. In addition, from 2022 onwards, stores and restaurants offering ready-to-eat food, and retail establishments trading in bulk products, are obliged to accept customers bringing their own packaging.

The latest Decree-Law (78/2021) set to implement the SUPD, requires that establishments providing ready-to-eat, take-away or home-delivered packaged meals in single-use packaging are obliged also to make reusable alternatives available to their customers by charging a deposit to be returned upon return of the packaging from the beginning of 2024 (DRE, 2021). In addition, from the beginning of this year (2022), the points of sale of bulk products, such as for bakery products, fruit and vegetables, are obliged to provide consumers with reusable alternatives for packaging or, where this is not possible, alternatives made from a single material other than plastic.

To support the reduction of plastics the Portuguese Pact for Plastics has been established with the aim to ensure that 100% of plastic packaging is reusable, recyclable or compostable by 2025. The roadmap also identified the need to further incentives for packaging reuse, including tax incentives (Smart Waste Portugal, 2021). Consequently, in 2021, a ministerial order (331-E/2021) and a consequent law (75-B/2020) set a tax (0.30 € per package) on single-use packaging made of plastic, aluminium or multi-material with plastic or aluminium to be purchased in ready-to-eat meals, in ready-to-eat and take-away or home delivery.

8.2.4 France

France has set highly ambiguous targets to reduce plastics. Packaging reuse has been identified as a means to achieve this target. The recent Circular Economy Law (LOI n° 2020-105) has set several objectives for packaging reuse, including quantitative targets for reusable packaging: 5% in the market already by 2023 and 10% by 2027 (Ministère de la Transition Écologique, 2022). To reduce packaging, the law promotes selling bulk, loose goods, which, in turn, accelerates the uptake of reusable packaging. Since the beginning of 2021, consumers have been allowed to bring a reusable container to retail outlets. The container must be clean and suitable for the product purchased. However, it is emphasises that the consumer is responsible for the hygiene of the container. The establishment selling the food may, refuse to serve the consumer if the container brought is dirty or otherwise unsuitable. Furthermore, retailers with a sales area of more than 400 square meters will have to provide the customers with clean reusable containers. This service covers the sale of products without packaging and can be offered free of charge or for a fee.

Regarding takeaway food and beverages, venders must offer lower pricing when the beverage is sold in a reusable container brought by the consumer, and fast-food restaurants must, from January 1, 2023, use reusable tableware for meals and drinks served on site (cups, lids, plates, containers, cutlery).

8.3 Policy uncertainties

8.3.1 Defining reuse and reusable packaging

The definition of packaging reuse or reusable packaging is not straightforward in the European policy context. Currently, the definitions vary depending on policy document and regulation. For example, the PPWD states that reusable packing is 'packaging which has been conceived, designed, and placed on the market to accomplish multiple trips or rotations within its lifecycle by being refilled or reused for the same purpose for which it was conceived' (EU Directive 2018/852). On the other hand, the German Packaging Act defines reusable packaging as packaging that is intended to be used several times for the same purpose after use, and whose return and reuse is facilitated through adequate logistics and appropriate incentive systems, usually through a deposit (Kumar, 2020). The European standard EN 13429 on reuse defines different approaches to reuse: 1) a closed loop system in which packaging is circulated by a particular company or group of companies; 2) an open loop system in which packaging circulates amongst unspecified companies, or 3) a hybrid system, in which the end-user retains the reusable packaging and uses auxiliary one-way packaging to refill it (Eunomia, 2020).

8.3.2 Measuring reuse and sustainability impacts

The European Commission is committed to evidence-based or -informed policy making. The idea behind this approach is that policy decisions must be based on, or informed by, objective evidence and/or scientific frameworks. The policy ambition to increase the packaging reuse has several challenges from this perspective. As mentioned earlier, there are no clear definitions of packaging reuse. In addition, there are no common means to evaluate and measure how much reusable packaging is on the market and how many times these packages rotate. It is difficult to set binding targets for packaging reuse without having a clear understanding of the current reuse levels. This would require setting up a system to identify, measure and verify the flows of reusable packaging in Europe. However, setting up such a system requires resources and may increase administrative costs and burden. Yet, to be able evaluate the sustainability of reuse systems and to what extent reuse could replace single-use packaging, data on packaging rotations and volumes is much needed.

8.3.3 Uncertain policy landscape and implications

During the recent years, the European policy landscape for packaging and packaging waste has evolved rapidly. In the packaging sector, this change has been seen as a 'regulation tsunami' and has created major uncertainties to the entire packaging sector (Sundqvist-Andberg & Åkerman, Collaborative governance as a means of navigating the uncertainties of sustainability transformations: The case of Finnish food packaging, 2022).

While the current EU's environmental policies seem to favour reuse, the actual means and instruments are still limited. In practice, the only binding regulation supporting packaging reuse comes from national implementations of the SUP directive, as the cases of France, Portugal and Germany show. Additionally, in other countries, like in Sweden and Austria, the implementation of consumption reduction measures of certain single-use plastics (article 4 of SUPD) obliges restaurants, caterers and in certain countries also delivery services to offer reusable containers to customers. However, there are worries that this rule could be easily circumvented. Further uncertainties arise from the forthcoming update of the PPWD. Until this point, it is unclear how the update will address reuse.

8.3.4 Concerns on food safety and hygiene

Particularly on packaging materials, the safety aspects of regulation address chemical safety, instead of the process of packaging reuse. Regarding hygiene, there is EU hygiene legislation on food (European Parliament, 2004) that requires self-monitoring by companies according to HACCP principles, but beyond these obligations, there are no specific rules on packaging reuse processes.

Furthermore, there are no regulations prohibiting consumers to use their own reusable containers for food at restaurants or stores that ensures food safety. However, national interpretations on the food hygiene legislation may differ. In Finland, both public authorities and many companies have taken quite a strict approach against the use of customers' own containers. For example, during the COVID19 pandemic, the Finnish Food Authority recommended that take-away food should not be sold in customers' own containers in order not to jeopardise the safety of consumers and restaurant workers (Finnish Food Authority, 2020).

In general, EU rules and regulations are set for identified problems or needs. In the case of hygiene concerns on reusable packaging, these potential problems have not yet manifested, thus EU rules do not yet exist for them. The EC is, however, collecting information on the issue to be able to act swiftly if problems emerge.

9. Concluding remarks

The report aimed to provide an overview of the recent developments in packaging reuse in the FMCG sector. In recent years, the demands for more environmentally friendly packaging and sustainable consumption have been increasing and many public and private entities have reacted by designing policy interventions and new business models to meet public demands.

In the EU, the **policy** targets favour packaging reuse over single-use. Yet, the current mix of policy instruments for packaging reuse are still rather narrow and focus mainly on financial measures, such as EPR and waste taxes, and other regulations such as SUPD aim to ban and reduce the consumption of certain single-use plastic items. Despite of the ambitious policy goals, in practice, the current EU policies emphasise the recycling of packaging waste over reuse. This can be seen, for example, in that compared to packaging waste recycling, there are no quantitative targets for packaging reuse. However, some EU member states, such as France, have set more stringent national laws with binding packaging reuse targets. There are also policy challenges to be taken into account. For example, the current policy mix of packaging, and particularly food packaging, is rather complex. Thus, new packaging reuse systems needs to be designed so that they are compatible with existing legislation targeting packaging such as legislation on food contact materials, REACH, hygiene, packaging and packaging waste laws and regulations, among others. Furthermore, there are certain policy uncertainties that may even slow down the transformation, such as delayed regulatory changes, lack of an agreed definition on packaging reuse, and a limited data and evidence base on sustainability impacts. Despite these policy challenges, the current EU and Finnish policy mixes set a good starting point for a systemic change, yet further policy incentives need to be developed and studied to foster the transformation.

Material solutions for reuse applications in many cases follow the materials used for single-use packaging. The single-use packaging's functional design is designed around the product's requirements and typically the product itself is unchanged in reusable packaging applications. Further advantages could however be gained to redesign the product and rethink single-use packaging, for example, to remove excess space, water and so on, as well as ensure recyclability after reuse-cycles. In reuse cases, the packaging faces requirements from both the product requirements as well as the system design, which includes the reverse logistics, reuse related operations and maintenance, possibly intelligent elements such as sensors, and marketing needs. The materials used today in single-use packaging are seen also in reuse applications, and the materials are not the main hindering factor in setting up reuse systems. However, the number of cycles the packaging can withstand is an important factor for feasibility, and in many cases, it seems that the packaging solutions for reuse are made more rigid, for example by adding more material to the packaging. As the packaging, especially in return systems, may be of higher value, different advantages could be further sought from advanced materials such as intelligent packaging, self-heating or cooling, self-cleaning and self-healing materials. A key remark is that there is a wider opportunity that should be taken to create the maximum positive impact—as packaging is designed to fit reuse system and product requirements, it is important to re-evaluate the product design and system design and incorporate eco-design principles to design a total system and packaging solutions as sustainable, material efficient and fit for reuse and recycling.

There are several **tagging technologies** available allowing connectivity to digital traceability platforms. The selection of the tagging technologies depends on balancing between tag durability, compatibility with end-of-life management, need for condition monitoring, and connectivity. It is worth considering if the same tags used for package traceability and identity, could also be used for other purposes during the package lifecycle, such as for offering additional services for product safety and consumer engagement. Important digital platform features include access to data, data management, dynamic data, and data security that should be handled despite the selection of tagging technology. Thereby, the digital platform would need to be designed to be compatible with any identification, traceability, and monitoring technology selected. A common platform for all reusable packages with modular functionalities would be the best-case scenario.

Consumer engagement is critical to ensure the success of businesses dealing with reusable packaging of FMCGs. Some knowledge about consumers' views on reusable packaging and reusable containers exists but the domain is still nascent. Overall, consumers hold somewhat positive perceptions and attitudes toward reusable packaging. However, there are concerns by consumers over a number of issues (e.g. convenience, quality and pricing) and negative attitudes toward certain solutions and a low willingness to return and refill packages have been observed. The current literature shows that consumers' intentions and behaviour related to buying and using reusable packages are shaped by certain packaging characteristics, psychographics, demographics and socio-economics, social environment aspects and financial incentives. However, the limited amount of consumer studies on the topic compared to the abundance of solutions (e.g. see Muranko et al. 2021) can only point to certain directions rather than allowing for generalisations. Pioneering studies about consumers' perceptions and behaviour related to reusable packaging have just scratched the surface of this important topic. More research is required on values that consumers may associate with reusable packaging, emotions evoked by reusable packaging and possible variations in consumers' views within and across FMCG domains, such as food and home cleaning. Moreover, the lack of a common definition regarding the phenomenon of reusable packaging in consumer studies warrants further considerations on the generalisability of the results in specific contexts, such as reuse schemes where packages are reused for the same purpose they have been conceived. Finally, the study of reuse behaviour might be benefited by studying how changes in peoples' use and buying behaviour occur in real life contexts.

All circular solutions need their own **reverse supply chains** to enable circularity. The lacking infrastructure for collection logistics and washing solutions pose challenges for the uptake of reusable packaging. Depending on the packaging type, some existing infrastructure can be utilised, which facilitates taking the first steps, and is the case especially in takeaway food packaging. However, for many of the other packaging types and depending on the refill model, there needs to be an infrastructure for reuse. In the literature one of the main concerns are both the environmental and economic sustainability of logistics, which depends on both transportation distances and modes, but could be minimised by using the reverse flows of existing transports. There is a need to manage the flows efficiently, avoid bottlenecks to keep the packaging circulating and using the transportation capacity efficiently.

Well-performing **business models** are crucial in scaling up reuse systems. Despite the growing interest of the private sector in the circular economy, the implementation of circular business models is still low in practice. Today, only very few products with reusable packaging are available in the FMCG industry, although a portfolio of new reusable packaging business models is emerging. Various barriers and success factors can be identified depending on the type of reuse business model and the sector (food-home products...). Nonetheless, several generic conditions support the development and successful implementation of the new reuse business models: the tightness of collaboration between brand and retailers; the efficiency of operations in the whole value chain; the level of consumer participation and the associated strategies to make the user journey convenient, financially attractive, environmentally friendly; and the business model value capture strategy. An overarching condition is the establishment of an ecosystem that can integrate these different dimensions (material and product design, distribution, use, reverse logistics…). To achieve the required feasibility, desirability, profitability and sustainability thresholds to make the new reuse business model successfully scalable, business model experiments are required to validate and fine tune the various intertwined elements before reaching a market readiness-level.

This study also showed that the transition to packaging reuse systems is still at an early stage. Certain perceived risks are limiting the initiative to transitioning to reuse systems. These perception include the ideas that reuse is not allowed, reuse is not safe, reuse is not sustainable, or reuse is not economically feasible and so on. It is important to establish that there are no inhibiting regulations for reuse. However, a mix of policies and instruments are needed to support and incentivise establishing reuse systems at scale. Safety is a required baseline for operations that can be managed and maintained. Additionally, in principle, reuse is environmentally sustainable <u>when</u> the reusable packaging is circulating in an optimised reuse system as it supports decoupling extraction and the use of primary/virgin resources, reduces the amount of materials being recycled and furthermore, the amount of materials incinerated or landfilled or waste leaking into the environment.

Based on our reviews and project progress so far, we identify the main current key challenges and uncertainties concerning scaling solutions beyond demonstrations and pilots to relate to:

1. Missing key value chain actors—a limited number of enabling reuse operators or service providers who would take care of the system operations, logistics and washing.
2. How to increase the value of reusable packaging in the eyes of the consumers so that they uptake and keep on using the reusable alternatives.
3. Economic scale and feasibility—lack of infrastructure, standardisation and reuse networks/pools to enable scaling the reuse up and achieving economies of scale. At the moment, reuse is directly compared to single-use in terms of sustainability, efficiency and economics event though reuse is very marginal and far from the optimal scale.
4. Need for quantitative reuse targets and further policy incentives for packaging reuse.

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Title	**Operational environment review for reusable packaging used in fast moving consumer goods** 4everPack
Author(s)	Anna Tenhunen-Lunkka, Jussi Lahtinen, Liisa Hakola, Rosa Palmgren, Henna Sundqvist, Harri Luomala, Erwan Mouazan, Angelos Balatsas Lekkas & Kyösti Pennanen
Abstract	There are many requirements for good packaging - it needs to protect the product and enable a sufficient shelf life. However, over the recent years the demand for more environmentally friendly packaging has been increasing and many public and private stakeholders have reacted by starting to investigate and implement reusable packaging systems to mitigate the environmental effects and meet the public demands. Additionally, regulations have started to move towards supporting reuse with set targets. Consumer engagement is critical to ensure success for businesses dealing with reusable packaging of fast-moving consumer goods (FMCGs). Some knowledge of consumers' views on reusable packaging and reusable containers exists, but the domain is still in its nascency. Overall, consumers hold somewhat positive perceptions and attitudes toward reusable packaging. However, concerns by consumers over several issues (e.g. convenience, quality, and pricing), confusion between recycling and reuse, negative attitudes toward certain solutions and low willingness to return and refill packages have been observed. Well-performing business models are crucial to scale up reuse systems. Despite the growing interest of the private sector in the circular economy, the implementation of circular business models is still low in practice. Today, only very few products with reusable packaging are available in the FMCG industry, although a portfolio of new reusable packaging business models is emerging. Different barriers and success factors can be identified. For instance, reuse may be perceived as not allowed, unsafe, not sustainable, or not economically feasible. It is important to establish that there is no inhibiting regulation for reuse. However, a mix of policies and instruments is needed to support and incentivise establishing reuse systems on a large scale. Safety is an integral aspect that need to be managed, it can also be facilitated by material and packaging design. In reuse cases, packaging faces requirements from both the product side and the system, which includes reverse logistics, reuse-related operations and maintenance, possibly intelligent elements such as sensors, and communication and marketing needs. The materials used today in single-use packaging are seen also in reuse applications, and the materials are not the main hindering factor in setting up reuse systems. However, the number of cycles the packaging can withstand is an important factor for the overall feasibility. All circular solutions need their own reverse supply chains to enable circularity. The lacking infrastructure for collection logistics and washing solutions pose challenges for the uptake of reusable packaging, there are a lack of active operators in the field on a larger scale. To facilitate the reverse logistics and packaging monitoring, tagging technologies are available to allow connectivity to digital traceability platforms. Important digital platform features include access to data, data management, dynamic data, and data security. Tags and data can offer additional services for product safety and consumer engagement.
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Nimeke	**Katsaus uudelleenkäytetävien pakkausten toimintaympäristöön kulutustavaroiden osalta** 4everPack
Tekijä(t)	Anna Tenhunen-Lunkka, Jussi Lahtinen, Liisa Hakola, Rosa Palmgren, Henna Sundqvist, Harri Luomala, Erwan Mouazan, Angelos Balatsas Lekkas & Kyösti Pennanen
Tiivistelmä	Pakkaamiseen liittyy paljon vaatimuksia, sen tulee olla esimerkiksi turvallinen ja taata tuotteen säilyvyys. Viime vuosien aikana yhä tärkeämmäksi kriteeriksi on kuitenkin noussut pakkaamisen ympäristöystävällisyys. Yritykset ovat siirtyneet kohti paremmin kierrätettäviä materiaaleja, mutta mielenkiinto myös uudelleenkäytettäviä pakkauksia kohtaan on kasvanut. Uudelleenkäyttöön liittyvien kokeiluiden ja tutkimusten määrä on kasvanut ja lainsäädäntöä on lähdetty muuttamaan monessa maassa uudelleenkäyttöä tukevaksi. Kuluttajien sitoutuminen on ratkaisevan tärkeää, jotta uudelleenkäytettävistä pakkauksista voidaan luoda kannattava vaihtoehto korvaamaan kertakäyttöpakkauksia. Kuluttajien näkemyksistä uudelleenkäytettävistä pakkauksista on jo jonkin verran tietoa. Kuluttajilla on jonkin verran positiivisia käsityksiä ja asenteita uudelleenkäytettäviä pakkauksia kohtaan. Kuluttajien on kuitenkin havaittu olevan huolissaan esimerkiksi käyttäjämukavuudesta, laadusta ja hinnasta sekä halukkuus palauttaa ja täyttää pakkauksia vaihtelee. Hyvin toimivat liiketoimintamallit ovat kriittisiä uudelleenkäyttöjärjestelmien laajentamiselle. Kiertotalousliiketoimintamallien toteutus on käytännössä vielä vähäistä. Nopeasti muuttuvalla kuluttajatuotesektorilla on saatavilla vain vähän tuotteita uudelleenkäytettävissä pakkauksissa, vaikka uusia uudelleenkäytettävien pakkausten liiketoimintamalleja ja toimijoita tulee markkinoille. Tietyt mielletyt riskit saattavat rajoittaa siirtymistä uudelleenkäyttöjärjestelmiin, kuten uskomukset että uudelleenkäyttö ei ole sallittua, se ei ole turvallista, se ei ole kestävää tai taloudellisesti kannattavaa. On tärkeää huomioida, että uudelleenkäyttöä estävää säätelyä ei ole olemassa. Tarvitaan kuitenkin erilaisia toimintatapoja sekä poliittisia ohjauskeinoja, jotta voidaan tukea ja kannustaa uudelleenkäyttöjärjestelmiä. Tuote- ja pakkausturvallisuus on edellytys uudelleenkäytettäville pakkauksille. Tätä voidaan edistää myös materiaali- ja pakkaussuunnittelulla. Uudelleenkäytössä pakkauksiin kohdistuu sekä tuotevaatimuksia että järjestelmävaatimuksia, kuten käänteinen logistiikka, pesu ja uudelleentäyttö, älykkäät elementit sekä viestintä- ja markkinointitarpeet. Kertakäyttö-pakkauksissa käytettyjä materiaaleja käytetään myös uudelleenkäyttöpakkauksissa - materiaalit eivät ole varsinainen hidaste uudelleenkäyttöjärjestelmien rakentamisessa. Kuitenkin pakkauksen kestävyys ja mahdollisten kiertojen määrä on tärkeä kannattavuuden tekijä. Uudelleenkäyttöratkaisut tarvitsevat käänteisen toimitusketjun. Keräyslogistiikan ja pesuratkaisujen puutteellinen infrastruktuuri asettaa haasteita uudelleenkäytettävien pakkausten käyttöönotolle, alan toimijoista on pulaa laajemmassa mittakaavassa. Käänteisen logistiikan ja pakkausten seurannan helpottamiseksi on merkintätekniikoita, jotka voidaan liittää digitaalisiin jäljitettävyysalustoihin. Tärkeitä digitaalisen alustan ominaisuuksia ovat data ja siihen pääsy, tiedonhallinta, dynaaminen data ja tietoturva. Samoja tunnisteita voidaan käyttää myös tuoteturvallisuuden parantamiseen ja kuluttajien sitouttamiseen.
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Operational environment review for reusable packaging used in fast moving consumer goods

4everPack

This publication outlines an overview of the operational environment for reusable packaging used in fast moving consumer goods. The report has been developed as a part of the Business Finland funded 4everPack research project. We cover the key drivers for reusable packaging, reuse business models, material solutions and key technologies for traceability and packaging monitoring, ways to optimise logistics, policy framework and veri importantly, highlight on the current knowledge of consumers' views on reusable packaging.

Over the recent years, the demand for more environmentally friendly packaging has been increasing and many public and private stakeholders have reacted by starting to investigate and implement reusable packaging systems to mitigate the environmental effects and meet the public demands. Additionally, regulations have started to move towards supporting reuse with set targets. The report aims to provide an overview of the recent developments in packag-ing reuse in the fast moving consumer goods sector.

4everPack consortium partners: VTT Technical Re-search Centre of Finland (coordinator), University of Vaasa, Berner, Borealis, Brightplus, City of Helsinki, HUS, Kamupak, Kesko, Kiilto, Kotipizza, Metsä Board, Nordic ID, SOK, Tomra and UpCode.

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