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Sustainability of reusable packaging–Current situation and trends

Patricia Megale Coelho[a], Blanca Corona[a], Roland ten Klooster[b], Ernst Worrell[a,*]

[a] Copernicus Institute of Sustainable Development, Utrecht University, Princetonlaan 8A, 3584 CB, Utrecht, the Netherlands
[b] Department of Design, Production and Management, Twente University, Drienerlolaan 5, 7522 NB Enschede, the Netherlands

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ABSTRACT

Packaging plays an important role in safely distributing products throughout today's society and supply chains. With a consumption of about 40% of plastics and 50% of paper in Europe, the packaging sector is a large user of materials. Packaging has a lot of environmental impacts, while it also represents a significant cost in the current supply system. Reusable packaging has been suggested as an option to significantly reduce environmental impacts. In this paper, we review the trends in reusable packaging and the literature on reusable packaging to generate insights into the current state-of-the-art knowledge and identify directions for research and development. This can help to better understand the key factors underlying the design and impacts of more sustainable packaging systems.

1. Introduction

The increasing environmental pressure on the economic system requires a reconsideration of our economic paradigm. This urges societies around the world to increase the efficiency of natural resources use and to reduce the overall environmental impact of daily activities. This reduction needs to be absolute, and we, therefore, need a strong decoupling of economic activities, environmental impact, and resource use. However, virtually no society has achieved a strong decoupling of material use and economic development. Increased resource efficiency as part of a transition to a circular economy can help in achieving this new balance (Worrell et al., 2016). There are various ways to improve material efficiency, as depicted in Fig. 1.

The challenge of the circular economy is to close material loops. In practice, this means that the circle has to be as small as possible to retain the material qualities needed to serve its original function, which is also expressed in various approaches as closing material cycles, e.g. the 9 "R's" (see e.g. Potting et al., 2017) to retain the highest economic value. Reusing products and materials for as long as possible reduces the need for virgin (or primary) materials and reduces the environmental footprint of materials use, if the loops are closed in sustainable ways (e.g. with minimal energy use to close the loops).

Packaging is now a primary user of virgin materials, because of the needed material quality. For example, in Europe, 40% of plastics (Plastics Europe, 2018; Geyer et al., 2017) and 50% of paper is used for packaging (CEPI, 2018), while packaging represents 36% of municipal solid waste (Eurostat, 2019). A Dutch consumer uses about 400 g of packaging material a day (Ten Klooster, 2017). The amount of packaging material has been growing in past years, as a consequence of retail developments, including e.g. increased convenience. This is also the consequence of supply chains that have moved increasingly to single-use packaging. This move might be due to globalization of supply chains, as well as the growing importance of large retailers, and the simplified logistics of single-use supply chains. However, different trends towards single-use packaging are observed in sectors and countries, demonstrating that cultural factors also play a role in the choice of the packaging system. In the past decades, the focus has been on reducing the amount of packaging material per unit of packed volume. Typically, this includes light-weighting and other marginal improvements (Lofthouse, 2014; van Sluisveld and Worrell; 2013). However, in the hierarchy of the circular economy (e.g. Rethink, Redesign, Reuse, Repair, Remanufacturing, Recycling, Recover, or any of the "R" variations that are being discussed, see e.g. Potting et al., 2017; Reike et al., 2018; Kirchherr et al., 2017) a change from material recycling to product reuse is considered positive as more value is retained. Hence, 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. Reuse is not new. Reusable forms of packaging have historically been used in a lot of applications and are still found, both in B2B (Business-to-Business, including secondary or transport packaging, e.g. crates, pallets) and in B2C (Business-to-Consumer; also called primary packaging, e.g. beer bottles).

* Corresponding author.
E-mail addresses: p.m.megalecoelho@uu.nl (P.M. Coelho), b.c.coronabellostas@uu.nl (B. Corona), r.tenklooster@utwente.nl (R. ten Klooster), e.worrell@uu.nl (E. Worrell).

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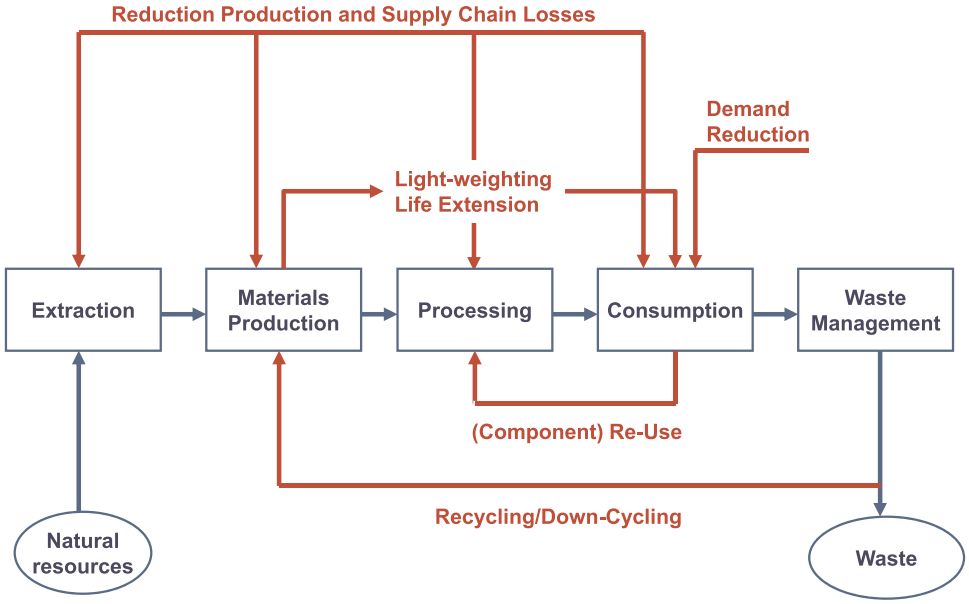

Fig. 1. Opportunities for material efficiency.
Source: Worrell et al., 2016.

However, in the past decades, we have observed a trend away from reusable packaging towards single-use in all countries without strict legislation on reuse (Golding, 1999), simplifying logistics for key product distributors and retailers. For example, in the Netherlands dairy products (e.g. milk, yoghurt, custard, and coffee creamer in glass and plastic bottles), vegetables (in glass jars), fruit juices (in glass bottles), were offered in reusable packaging, and were all replaced by single-use packaging. Also, the (recent) trend to smaller portion packs discourages reusable solutions. This development has resulted in increased materials use, a rapidly increasing waste volume and environmental impacts related to materials use (both in the production and at the end of life). The response strategies to reduce volume and impact of materials use have mostly been focused on light-weighting and recycling. Yet reusable packaging is recognized as a more efficient option in reducing the impact of the volume of packaging materials and energy used while preventing production emissions. It is estimated that at least 20% of plastic packaging could be replaced by reusable systems (Ellen MacArthur Foundation, 2017; 2019). The European Parliament has called for an increase in the share of reuse to 10% by 2030 (Morawski, 2017). The European Union has enacted the single-use plastics directive to limit the single-use of plastics including packaging, with an initial focus on disposables like plastic cutlery, coffee cups, stirrers and straws (EC, 2019), while various countries have implemented covenants or extended producer responsibility (EPR) schemes that include the reduction of single-use packaging. Various producers have developed refillable packaging, using refills that use less material (Lofthouse et al., 2009; 2017) while others are exploring more radical options, like packaging-free shops (Beitzen-Heineke et al., 2017). The latter has not been very successful yet. Well designed, refill/reuse systems can successfully result in material savings, e.g. refilling pouches for detergents in Japan represent 80 to even 98% of the market for some brands (Kao Group, Japan). Beer bottles have been successfully reused for several decades, due to high turnover rates, relative short transporting distances, and well-designed packaging systems. In practice, the impacts will depend on the design and the implementation of reusable packaging systems. However, switching to reusable packaging can also have negative impacts, if not carefully managed due to e.g. increased use of (currently) unrecyclable laminated materials used in pouches, increased transport movements, complex logistics, cleaning, food safety, and others. Hence, a reusable system is not necessarily a feasible or sustainable alternative for all supply chains and packaging.

As reusable packaging is already used in various applications and forms, Table 1 provides a simple classification of reusable packaging systems, based on the practical characteristics of such a system.

Table 1 shows that a change from single-use to reusable packaging may mean a change in the supply chain due to the introduction of reverse logistics (except e.g. for refill systems that are based on refilling by the final consumer). The introduction of reverse logistics may result in different economic optima, changing roles of stakeholders in the supply chain, changing logistics, and different forms of organization. A retailer can be seen as a funnel for the product flow from supplier to consumer, e.g. refillable and returnable packaging.

Due to marketing reasons packaging designs often vary. A company that supplies crates with filled bottles of a certain type, wants to receive the same crate with the same type of bottles when returned. However, consumers do not always return crates with one type of bottle and most bottles are brought back separately, not in a crate. This means that the retailer needs to invest in space and labour to sort the bottles and crates. Retailers compare the time needed of the activities related to secondary packages including sorting of bottles, filling crates and returning them to the brand owner to that invested in one-way packages (i.e. removing shrink film, flattening and stacking carton trays and boxes, and disposal). Often the one-way system is seen as less costly by producers or retailers, especially for primary packaging. Hence, the best solution depends on how the logistics are arranged with the supplier and retailer locations. The example shows that a shift to returnable primary packaging may involve more efforts than for secondary packaging. Hence, changing to reusable packaging may result in environmental and economic trade-offs, and redistribution thereof, especially in an era of global supply chains. A systems approach is necessary to evaluate the opportunities for reusable packaging.

Reusable packaging can be seen as a product-service system, in which instead of simply selling a product, a service is provided to the consumer. There is a wide body of literature on the opportunities and impacts of service systems, albeit with limited attention to packaging. This change is also considered as one of the viable business models within the transition to a circular economy. Yet, the role of consumer preferences for these packaging solutions needs attention. Currently, there is little data on the use and market shares of reusable packaging, volumes, and environmental and economic impacts (Golding, 1999, Rigamonti et al., 2019).

Table 1
A classification of reusable packaging

Type of packaging	Packaging description	Product examples
Refillable by Bulk Dispenser	Customers use their packaging or brand's refillable packaging in-store or at a mobile truck, making the use of further packaging unnecessary.	Cereals, grains, candy, wine, juice, mineral water, beer, olive oil, vinegar, detergent, soap, hair care products, perfume, body and face lotion
Refillable Parent Packaging	**Bottle, container, pouch, pod, tablet, powder**The refill packaging is made with less material than parent packaging. Parent packaging can be refilled by: - pouring product inside parent packaging; - placing container inside of parent packaging; - diluting concentrated product in water inside parent packaging.	Makeup, dental floss, tooth and mouth wash tabs, deodorant, perfume, cosmetics, cleaning products, hair care products, flavoured water
Returnable Packaging	**Container, bottle, cup, plate, bowl,…** Customers return empty packaging which will be cleaned and refilled for future use by the retailer/producer (can be combined with a deposit system to provide a financial incentive).	Beer, soft drinks, mineral water, perishables, detergent, soap, cosmetics, hair care products. Reusable cups, containers, plates. (for events, cafes, restaurants)
Transit Packaging	**Boxes, containers, soft packages** Customers receive the product in reusable packaging which is returned by door delivery/pick up, or through the post office. **Crates, pallets, wrappers** Customer reuses packaging multiple times before being returned to the producer or disposed of.	Reusable packaging for transport or shipping of perishables or non-perishables. B2C: for moving home or office location or e-commerce delivery of apparel, furniture or perishables. B2B transport from producer-warehouse-store.

In this paper, we review the background, opportunities for and experiences with reusable packaging. The review will help to not only provide an overview of the state-of-the-art but also help identify potentials to reduce the environmental impacts, as well as the barriers to implementation of integrated reusable packaging systems. The review investigates current developments in reusable packaging by 1) surveying new developments in the packaging market and, 2) reviewing the scientific literature. The overview of recent developments (see Section 2) in the market builds on an extensive search on the internet, trade journals, contacts with developers of reusable packaging systems, and trade shows. We differentiate between the classifications of reusable packaging, as these show different dynamics and opportunities. Next, we discuss the opportunities, drivers and barriers of reusable packaging based on a literature review, with an emphasis on peer-reviewed scientific literature, including assessment of the environmental and economic impacts of reusable packaging vis-à-vis single-use packaging. There is also a wide body of grey literature, which is partially included in this review. However, corporate studies were not available for this study. We did literature searches in various databases (e.g. Scopus, Google Scholar, Web of Science) to find relevant scientific papers published in the past 20 years, independent of product type or geography.

Based on the review, we propose a research agenda to come to a better understanding of the possibilities, impossibilities, opportunities and impacts of a shift to reusable packaging to define parameters for designers, marketers and decision-makers to come up with proper reusable solutions. We end with a research agenda to further investigate the potentials and ways to reduce the barriers to realize reusable packaging systems.

2. Current developments of reusable packaging systems

2.1. Refillable by bulk dispenser

Bulk stores are not a new concept and can be found around Europe, Canada and the US, with rare examples in other countries such as Indonesia, Brazil, Chile, Colombia or South Africa (Bepakt, 2019). However, these are still a niche in retailing, and usually have a limited variety of brands available. Some retailers (e.g. Waitrose and Asda) have been offering mainstream brands in bulk dispensers. Reusable packaging for perishables is often limited to dry products such as cereals, nuts, and candy in-store bulk dispensers can also be found in regular supermarket chains. These systems allow consumers to reuse containers and bags, although currently, standard plastic bags are still offered. Ecover (a sustainable detergent company from Belgium) now offers refill systems in stores. Ecopod (U.S.) provides dispensers for personal care and cleaning products that can also be tailored by retailers. Algramo (Chile) sells basic necessity products in bulk in a dispensing machine and reusable containers. The brand is intended for areas of low-income families to have access to basic necessity products, making it possible to buy only the quantity needed, without paying for the packaging. The reshaping of retailing through home delivery also offers new ways of distribution and hence, of packaging. In Italy, Casa Quick, a service operating since 2001 by the detergent and cosmetics manufacturer Allegrini S.p.A., offers home delivery of detergents using a refillable container that can be filled at a mobile dispenser (Manzini and Vezzoli, 2012).

However, bulk dispensers are usually avoided by retailers due to hygiene demands, as determined by the industry standards (e.g. ISO 22000 Food Safety Management, Regulation (EC) No 178/2002), which demand that risk assessment, management, and communication is executed using a systematic methodology for the determination of effective, proportionate and targeted measures or other actions to protect health, mostly taken up on base of a Hazard Analysis and Critical Control Points (HACCP), and due to the necessity of a different operational system. Taking away from retailers the responsibility of cleaning and manipulating the food, MIWA (Czech Republic) developed an innovative dispensing system. The dispensers are sealed by the producer, cleaned and reassembled by MiWA. The containers can be registered in a mobile app, which allows the consumer to pay for the product, and to obtain information such as the expiration date and its traceability to the producer. Their first dispensing machines were available in Prague in September 2019, while a pilot with an e-retailer has also started. The company is planning to expand to Switzerland, Germany, France and the Netherlands in 2020 (M. Lizec, personal communication, July 19, 2019).

2.2. Refillable parent packaging

The use of refillable containers and refill pouches results in large reductions in material use and transport costs (Keoleian and Spitzley, 1999). These are more commonly used for cleaning, hygiene and beauty products. Experiences with such systems vary, as many factors determine the success of these systems. Natura (Brazil), L'Occitane (France) have pouch options for some of their products. Companies like Replenish and Truman's (both in the U.S.) offer refill pods of concentrated product, which once attached to the parent packaging at the consumer's house can be mixed with water. Blueland and Dazz sell solid tabs to be diluted in water. These options reduce transport costs since around 80% of the standard product is water, the overall weight

and space during transport is reduced, as well as the volume of packaging material, becoming a less impactful and cheaper alternative of the parent packaging.

Various cosmetics brands now offer refillables for products like blush, eyeshadow, lipsticks amongst others. E.g. Elate Cosmetics (Canada), Kjaer Weis (Denmark), Zao Cosmetics (France), Pure Anada (Canada) and RMS Beauty are some of the brands. Lush (U.K.) is known for having packaging-free products, and for those that packaging is required the company started recycling their packaging. Lush uses the same plastic for the container, lid and label facilitating the recycling process. Rituals (the Netherlands) has refill containers to be placed inside the parent packaging, keeping the luxurious image of the product while reducing its impact.

2.3. Returnable packaging

In the Business-to-Consumer market (B2C), examples of new reusable packaging are limited. Historically, deposit systems for bottles and other containers represent the major B2C experience with reusable packaging, e.g. beer (although some brewers increasingly offer single-use glass bottles and cans), (carbonated) soft drinks and spring water (especially in those countries that regulate the use of single-use containers, such as Denmark and Germany), and dairy. The systems often include crates for the bottles, although bottle labels and caps are single single-use.

With the increase of takeaway food in the past 10 years, the number of companies providing alternatives to single-use cups for offices, restaurants, cafes, events and festivals has been growing. This is the case of CupClub (U.K.), Meu Copo Eco (Brazil), Globelet (Australia), ReCup (Germany) and Revolv (Indonesia). As an alternative for single-use takeaway containers, GoBox (US), reCIRCLE (Switzerland), Returnr (Austria), Ozarka and Sharepack (The Netherlands) lease reusable containers to restaurants, cafes, bars and food trucks. Ozzi (U.S.) offers take away containers that are returned by the consumer through deposit system machines, placed in dining service areas such as university campuses. Fresh Bowl (U.S.) sells fresh products (e.g. salads) in returnable glass containers through vending machines.

Loop, a circular shipping platform, launched in May 2019, works as subscription-based e-commerce for major brands such as Unilever, Nestlé, Proctor and Gamble, amongst others. The ownership of the packaging is retained by the brand, being, therefore, of the brands' interest to make the packaging as resistant and durable as possible. After home delivery and use by the consumer, the packaging is picked up, cleaned and refilled by Loop before being resold. So far Loop offers perishables and high-margin products such as personal care and cleaning products.

In the cosmetics sector, companies that were already devoted to vegan, organic or cruelty-free products tend to reflect their sustainability aims also in packaging. After initial experience with refilling more than 15 years ago that failed due to lack of consumer acceptance, The Body Shop, now under the leadership of the Brazilian brand Natura, is accelerating their sustainability strategy and re-introducing reusable and also refillable packaging. The Body Shop joined Loop using reusable packaging and is reintroducing refillable machines in London. The brand aims to offer products in reusable packaging online and in stores by 2020 (S. Locke, personal communication, April 5, 2019).

Plaine Products (U.S.) sells hair and body care products in aluminium bottles (fully recyclable). After the product is used, a second product is delivered, and the first one can be returned in the same box by mail to be cleaned and refilled by the company. Due to the costs of the packaging material, shipping and washing, the product becomes more expensive. Still, the company has been steadily growing, reaching 18.000 orders by the second year of operation. The founder, Lindsey McCoy, believes that their consumers are looking for products with reusable packaging because they want a more sustainable option. Around 70% of the packaging gets returned even though consumers do not get a refund for it, although the return shipping is paid by Plaine Products (L. McCoy, personal communication, April 4, 2019).

2.4. Transit packaging

Reusing packaging in Business-to-Business (B2B) can result in significant long-term cost savings. For this reason, there is already a wide use of reusable packaging systems in the B2B market. Pallets, crates, dunnage, drums, intermediate bulk containers, and big bags are commonly used by many industries. Standardization allows for automatization and cost reduction, reaching larger markets. Indeed, the globalized world of trade would be impossible without standardized containers. New concepts are developed by many companies. Shrink film is an example of single-use plastics that are also hard to recycle. Various companies have introduced reusable pallet wrappers (e.g. Reusa Wraps, Envirowrapper, Dehnco Pallet Wrapz).

In the automotive industry, reusable packaging systems are an integrated part of one of the most sophisticated just-in-time[1] supply chains around the world. Other sectors also use similar systems for parts of their internal supply chains (e.g. supermarket retailers). These concepts are based on standardization, pooling and repair systems around the globe or a continent. One example is Euro Pool Group, which leases pallets and crates for the European food supply chain. With over 150 service centres around Europe, the company has recently introduced a train connection from Rotterdam to Valencia to transport fruits and vegetables and the return of empty crates and pallets. Euro Pool Group also offers return service for some of their customers, taking crates, pallets, but also beer bottles, and other materials that are either returned to the producers (in case of beer bottles for example) or taken to recyclers (e.g. paper and plastic). The B2B company has been analyzing how to enter the e-commerce sector for its food supply chain clients. Standardization of reusable packaging for e-commerce is essential to introduce reusable packaging at scale, as was done for pallets and crates in the past. This would make logistics more efficient for companies and carriers, and also facilitate automation (F. Smoes, personal communication, June 7, 2019). Another example is the carts used at flower auctions across Europe owned by Container Centralen. The shelves and carriers can be taken apart to optimally stack the cars for return.

New B2B developments are identified and realized as companies are trying to find ways to improve the sustainability of their supply chains. For example, Ghirardelli Chocolates from California (United States) has introduced reusable totes to replace cardboard boxes for Internal distribution. Assuming a 5-year life of the totes, the company expects to save up to $2 Million, due to reduced waste management costs (Stopwaste, 2005).

In the United Kingdom, the publicly sponsored WRAP Program has supported the development of reusable packaging systems for furniture, kitchen appliances, and kitchen top shelves. Outpace developed the Carrierpac, a reusable transit packaging for kitchen worktops replacing cardboard boxes. After 10 reuses, the Carrierpac breaks-even cost-wise compared to cardboard boxes. An Outpace customer makes on average 50 trips with the same packaging. The company has been saving around £1 million a year, avoiding over 1000 tonnes in cardboard boxes while reducing damage to the kitchen worktops. For some of the packaging, there is a repair service, keeping the material in the loop for longer (T. Hutchinson, personal communication, April 29, 2019). However, in the beginning, bags did get lost due to inadequate communication of new staff and third-party logistics, demonstrating that training of users is needed as well as monitoring of the bags (WRAP, 2007). Furthermore, the initial investments (including e.g. additional storage space) remain a hurdle to introduce reusable systems, despite the significant cost

[1] Just-in-time is a management strategy that minimizes inventory with increased supply chain efficiency, decreasing storage and surplus material costs.

savings over the lifetime of the system.

Moving companies in The Netherlands commonly reuse corrugated cardboard boxes, while used boxes are traded in many countries. Various companies, e.g. Rebox (Canada) and Dozenhal (The Netherlands), offer reusable corrugated cardboard boxes that after use, can be refolded, picked up and redistributed (all at a single day notice), basically moving from a sales-based product to a service system. Also, standardized reusable carton boxes are used e.g. for flower transport. Other companies rent plastic boxes specifically for house and office moving. This market has been expanding, especially in the United States in the last 10 years, focusing not on the moving service itself, but primarily on the rental of boxes. Usually made from HDPE or recycled plastic, the boxes are rented by the customers or businesses, delivered and picked up after use. In the U.S. companies such as FrogoBox, BungoBox, Rentacrate, Rent a Green Box, Bin it, Green Go Box and Rent a Moving Box offer boxes for rent, while Plus Crates offers the same service in the U.K.

Specifically in apparel, e-commerce is an increasing market. This trend is also observed for second-hand clothing, changing the way second-hand items are perceived and consumed. Still, the use of cardboard boxes is the primary option for e-commerce delivery. To counter the growing use of single-use cardboard boxes in e-commerce, two companies developed reusable packaging systems and are operating in different business models. The Finnish company Repack leases packaging for products that do not need hard packaging protection in B2C e-commerce, such as clothes, towels, backpacks. Once the consumer receives the product, the packaging, which comes with a return label offered by RePack, is folded and sent to the company by regular mail. Repack then cleans and checks the quality of the packaging before directing it back to stores. Repack offers its customers a discount coupon towards the next purchase in any partner store. The brands choose how the reusable packaging is offered to customers, e.g. as a paid option at checkout, for free over an expended amount or for free with the company absorbing the delivery cost (J. Berbee, personal communication, April 17, 2019). Returnity (US) sells reusable boxes, bags and envelopes to different brands. The company focuses on B2B, such as warehouse to store, in which the packaging is kept in circulation, saving costs compared to single-use. It is also tested in two B2C market segments, i.e. e-commerce lease of apparel (resulting in significant financial savings for the company since the packaging will be returned at the end of the leasing period), and return of unwanted products in regular e-commerce (which is around 30-40% of the products sold online). In the last case, since 60–70% of the packaging is not returned, some brands invest in a reversible tote bag with an appealing design that can be reused by consumers afterwards. This cost is seen by brands as a marketing investment.

FuturumShop, a Dutch company that sells gears for cyclists, triathletes and mountain bikers, has been working together with PostNL to reuse packaging for e-commerce. In 2018, a pilot of a reusable packaging designed and owned by PostNL was used in the delivery of 400 shipments from FuturumShop in and around the city of Zwolle (NL). According to FuturumShop, the pilot was well accepted by consumers and a new pilot is currently being developed. The retailer highlights the importance and financial benefits of reusing packaging for e-commerce. The delivery of e-commerce is now another way in which companies can take back the packaging (E. van Kampen, personal communication, April 10, 2019).

Another e-commerce sector that has been growing is the food market. The delivery of groceries from supermarkets or meal kits is usually done with cardboard boxes. The meal kits are a relatively new market (growing since 2010), accompanying the growing trend of e-groceries, and also offered by regular (“brick and mortar”) retailers. However, so far there are few developments in reusable packaging for food delivery. Liviri Fresh (U.S.) is one of the first providing insulated reusable boxes developed especially for the delivery of food, maintaining food quality at the consumer's door for hours.

Finally, the use of reusable packaging systems can be supported by the use of modern monitoring systems, as it is now feasible to add radio-frequency identification (RFID) chips to the package, allowing for remote reading and automated handling. A unique example is the development of refillable and micro-chipped containers for soft drinks that are used with a central dispenser at festivals by Coca Cola and the University of Reading. The chip allows for direct billing. Also making the supply chain more efficient is the Dutch company Tconsult that created TellApe, an app and online platform that gives real-time insights to all of those involved in the supply chain. The app is developed for dockworkers and truck drivers, to register the quantity and type of reusable packaging that is being handled in every pickup and delivery of goods. In the portal, the administrator has real-time insights into the load balances of all its clients. The platform provides users to trade in crates, pallets and trollies online, reducing unnecessary empty transports and CO_2 emissions. This allows TellApe users to optimize their reversed logistics (E. Tjaden, personal communication, April 10, 2019).

The initiatives above, and the ones presented in Table 2,[2] are examples of new developments in the field of reusable packaging. It shows the growing interest around the world in addressing the sustainability challenges of reducing material use and packaging waste, through the development of reusable packaging systems. It is important to remark that one product can fit two categories at the same time e.g. a brand's container used for bulk dispensing can be refilled several times before being returned to the company to be cleaned and reused by another consumer.

3. Economics of reusable packaging

There are limited (life cycle) costing studies comparing the costs of reusable packaging systems vis-à-vis single-use packaging systems in the scientific literature. The overall costs of a reusable packaging system could be lower than that of single-use packaging, although a variety of factors influence the benefits. Table 3 summarizes studies that addressed the economics of a reusable packaging system.

Key factors that affect the economics (and environmental impact; see below) are *transport distances and logistics*, the *total volume of the market, fitting in a standardized system, return rates* of reusable packaging, *cleaning,* and *labour* involved in these steps. Return rates vary between different systems and are positively affected by deposit fee systems. Economics is most affected by logistics (both organization and transport distance). While longer transport distances (in global supply chains) may make a reusable system more expensive, they may still result in cost savings if well organized. Reusable containers tailored to the product may reduce product damage and loss (Chonhenchob and Singh, 2003; Chonhenchob et al., 2008). This may be a major factor in the cost analysis (Welcome, 2011), especially for transporting valuable products. Yet, because of data lacks on product damage and losses, it is often not included in the environmental and economic analysis. An exception is the study by Singh et al (2017), comparing reusable plastic crates with carton boxes for fruit and vegetables. They incorporated the experience of people in the supply chain, from the distribution centre to the shop floor, and also considered other aspects like food waste, microbial contamination, time for stacking, to evaluate all the impacts of a shift to reusable packaging.

Note that even when the overall costs of a reusable packaging system may be lower, the financial incentive for a producer or retailer may be different, as the distribution of costs and benefits varies. Today, not all costs of packaging waste management are borne by the producers of packaging, see e.g. Ferreira da Cruz et al. (2012). Hence,

[2] The information about the products and companies presented in this table were found online during the research period of this article. Products, packaging and categorization might change over time.

Table 2
Overview of developments for the different categories of reusable packaging. The listing of brands introducing reusable packaging are just examples and do not represent the totality of re-usable packaging initiatives.

Type	Description	Brands
Refillable by Bulk Dispenser	**Reusable packaging** Customers use own packaging or brand's refillable packaging in-store or at a mobile truck.	**Beauty and Personal Care**: All Things Hair Refillery, CoZie, Eden Perfumes, Mugler (Perfume) **Cleaning and Hygiene:** Allegrini, Ecover, Common Good Dispenser provider: Algramo, Ecopod **Perishables**: Dispenser provider for own brand or multiple brands: Algramo, Aquafina Water Station, Bevi, Coca-Cola Freestyle, Desani Purefill, Jean Bouteille, MiWA, Pepsi Spire, Soda Stream, The Milk Station Company
Refillable Parent Packaging	**Bottle, container, pouch** Bottle, container or pouch used to refill parent packaging.	**Beauty and Personal Care:** By Humankind (deodorant), DentalLace, Eco Lips, Elate Cosmetics (Makeup), Georganics (dental floss), Hairstory (shampoo), Hourglass (lipstick), Kjaer Weis (makeup), Lucky Teeth (dental floss), L'Occitane, Mugler (perfume), Myro (deodorant), Natura (body lotion), Olay (moisturizer), Poh (dental floss), Pure Anada (makeup), Rituals (body cream), RMS Beauty (makeup), Tevra (dental floss refill), Twenty (shampoo tablets), Zao Cosmetics (makeup). **Cleaning products:** fillgood.co, Saponetti
	Refill pod, tablet or powder Pods, tablet or powder to diluted in water in parent packaging.	**Beauty and Personal Care:** Bite (tooth tablets), By Humankind (mouthwash tablets), Dent tabs (tooth tablets), Georganics (mouthwash tablets). **Cleaning products:** Blueland, Cif, CleanPath, Dazz, Jaws, Method, Replenish, Splosh, ThreeMain, Truman's, Twenty **Perishables**: Drinkfinity (Flavoured water pod)
Returnable Packaging	**Container, bottle, cup, plate, bowl,…** The packaging is cleaned and refilled for future use by the retailer/producer.	**Beauty and Personal Care:** Plaine Products, Funky Soap Shop, Le Labo, Loop, fillgood.co **Cleaning and Hygiene**: fillgood.co, Hepi Circle, Loop **Perishables**: Flevosap, Fresh Bowl, Just Salad, Loop, Pieter Pot, Refill LLC., Breweries: Heineken, Quilmes, Grolsch,... Replacement of disposable cups/ plates: Billie Cup, CupClub, CupForCup, Ecoverre, Festicup, Globelet, Green Globlet, Happy Cups, Less Mess, Meu Copo Eco, Newcy, Plastic Free Plux, r.Cup, ReCup, Revolv, Shrewsbury Cup, Stack Cup Take away containers: Bûmerang, EcoBox, GoBox, Ozarka, Ozzi, reCircle, Returnr, Shared Packaging, Sharepack, Tiffin, Wisebox.
Transit Packaging	**Boxes, containers and soft Packages** Used to transport goods from warehouse to store (B2B) and/or store to consumer (B2C).	**Apparel**: RePack, Returnity, PostNL, The Lime Loop, ReusePac, Living Packets - The Box **Furniture:** OutPace (Carrierpac), Returnity **Moving:** Plus Crates, BungoBox, Rent a Crate, Rent a Green Box, Bin it, Green Go Box, Redi-Box, Rent a Moving Box, Zipp Go, FrogBox,… **Perishables**: For meal box kits or groceries: Liviri Fresh For fresh supply chain: Euro Pool, IFCO, Multitank
	Crates, pallets, wrappers Pallets, wrappers used to transport good (B2B).	**Transport of good and non-goods:** CHEP, Svenka Returnsystem, Enrivowrapper, Interior Packaging Design, Pallet Wrapz, Plastic Packaging Solutions, Returnable Packaging Resource, Reusa Wrap, Reusable Transport Packaging, Tconsult, Use Reusables,…

Table 3
Summary of studies on the economics of reusable packaging systems

Market	Packaging System	Key Findings	Reference
Generic	Generic Containers	Modelled relative costs of a single vs. multiple-use system generically, suggesting that expendable containers are more economic for smaller packages than for larger packages, whereas reusable containers are more feasible for larger packages. The trade-off will change as reusable containers become less costly. Other key factors are the daily volume (the larger the system the more attractive multiple-use containers become), while delivery, distance and cycle time seemed to be less important cost factors, as well as the daily variations in volume shipped.	Mollenkopf et al. (2005)
B2B	Drums (55 gallons)	Costs of reusable steel drums may be between a factor 3 or 4 lower than single-use drums	Franklin Associates (1999)
	Bucket for cut flowers	Evaluated the costs of a multi-use system to transport cut flowers and found cost advantages in the multi-use system. Costs were mainly affected by logistics	Menesatti et al. (2012)
	Reusable containers for LCD-panel (parts)	Showed that a reusable container for transporting LCD panels (or parts) within the international supply chain is economically beneficial.	Kuo et al. (2019)
	Reusable packaging system for a regional catering company	While the reusable system was environmentally superior to the current single-use system, it led to increased costs (0.058 €/kg delivered).	Accorsi et al. (2014)

Table 4
Summary of environmental impact studies of reusable packaging systems.

Market	Packaging system	Key Findings	Reference
B2B	Drum (55 gallons)	Energy use over the life cycle of multiple-use drums is 65% lower, 75% reduction of solid waste.	Franklin Associates (1999)
	Steel drums, Steel IBC	Greenhouse gas (GHG) emissions of reusable steel drums are 64-66% lower, 9% for reusable plastic drums (polyethylene), and 69–71% for steel IBC (Intermediate Bulk Container) crates. Also, lower footprints in other categories.	Ernst and Young (2015)
	Drums for chemicals	Compared single-use fibre drum and a reusable steel drum for the transport of chemicals, showing that the reusable system is environmentally more attractive.	Raugei et al. (2009)
	Beer keg vs. bottle	Beer in keg causes a lower environmental impact along the life cycle than beer in bottles.	Cordella et al. (2008)
	Food (catering)	Evaluation of the environmental impact of a reusable packaging system for a regional catering company showed that the reusable system was beneficial compared to the current single-use system.	Accorsi et al. (2014)
	Crates (for loaves of bread)	Reusable plastic crates for the transport had a better environmental performance than single-use cardboard boxes, though an effective recycling system can also improve performance, dependent on transport impacts and logistics.	Koskela et al. (2014)
	Pallet or crate for small yoghurt packs	Compared wooden pallet (and cardboard boxes) for transportation of consumer yoghurt packages with a plastic reusable packaging system. The reusable system has a lower environmental impact than the wooden pallet, because it is lighter in weight, has more reusable parts and can transport more yoghurt pots per trip. It has a long service life and is virtually fully recyclable.	Lee and Xu (2004)
	Cardboard boxes for fruits & vegetables	Compared corrugated cardboard boxes with reusable plastic packaging systems to distribute fruit and vegetables. Environmental impacts are primarily dependent on the energy to make the materials and transport. Over transport distances of (one way) 1200 km, the single-use cardboard box was preferable.	Levi et al. (2011)
	Crates for automotive parts in internal supply chain	Evaluated impacts of Volvo's internal transport system for automotive parts that uses reusable crates. It found that geographical distances and fill rates were most influential in determining impacts and that geographically long supply chains or low fill rates can tip the balance, and make single-use systems more attractive.	Pålsson et al. (2013)
	Plastic crates	Reusable plastic crates for vegetables and fruits were already environmentally beneficial after reusing the crate three times. Crate manufacturing is the dominant impact until 20 trips.	Tua et al. (2019)
	Display trays for fruit & vegetables	Compared reusable plastic containers to single-use display-ready corrugated board trays for vegetables and fruits distribution, for 10 produced items. Reusable plastic containers require 39% less total energy, produce 95% less total solid waste and generate 29% less total greenhouse gas emissions.	Singh et al. (2006)
B2B/B2C	Thermal packaging for biologic/ Pharmaceuticals	Compared single-use insulated containers to reusable vacuum-insulated packaging. Reusable packaging has a much lower environmental footprint (75% in global warming potential (GWP), 60% in eutrophication and 95% reduction in waste).	Goellner and Sparrow (2014)
B2C	Bottles	Refillable bottles emit less greenhouse gas emissions than one-way bottles. The usage of refill systems has to be deeply analyzed to estimate the number of refills and transport distances, which allows maximizing its environmental benefits.	Simon et al. (2016)
	Soft Drink and Water Bottles	The study compared refillable plastic bottles, improved refillable bottles and single-use bottles. For virtually all impact areas, refillable bottles demonstrate a better environmental performance than single-use bottles, even when the single-use bottle uses 50% recycled material.	Stajcer et al. (2001)
	Coffee cups	Reviewed various studies on reusable and disposable coffee cups. Results depend strongly on assumptions in the study. Disposable cup scenarios often do not account for film sleeves, lids, printing, and use conservative shipping weights and distances, reflecting a best-case scenario. Impact for reusable cups will decrease as the electricity mix becomes less CO_2-intensive and dishwashers get more efficient.	Woods and Bakshi (2014)

financial accounting methods and boundaries favour packaging systems that offload costs from the producer but may increase overall societal costs. Hence, full *environmental life cycle costing* methods are essential to determine the economics of sustainable packaging systems, as these internalize some of the current externalities in packaging systems.

4. Environmental impacts of reusable packaging

Earlier work has shown that significant reductions in packaging material use are possible, both in primary consumer packaging or B2C (e.g. Hekkert et al. 2000a) and in secondary packaging or B2B (e.g. Hekkert et al., 2000b). These studies included various reuse options, but did not study reuse in detail, nor did these studies evaluate environmental impacts across the whole supply chain. Table 4 summarizes the studies on environmental impacts. The vast majority of the environmental studies use commonly accepted Life Cycle Analysis (LCA) methods. In fact, LCA is rooted in the comparison of reusable against single-use containers (Hunt and Franklin, 1996).

Table 4 shows that there has been more emphasis on studying case studies in B2B packaging, than for B2C products. The few studies in the B2C market focus on items that have received recent (public or policy) attention. This suggests that reusable packaging systems are more common in B2B supply chains and receive more attention within the drive to more sustainable packaging than in the B2C market. Also, studies are often done in response to market pressures, instead of working from a pro-active independent research agenda. Only a small number of studies address economics impacts.

Key factors that affect both the economics and environmental impacts of reusable packaging are transport distances (affected by (reverse) logistics), return rates, and the impact of sorting, cleaning and maintenance (Dubiel, 1996), as well as impacts on product damage (Welcome, 2011). Return rates vary between different systems and are positively affected by deposit fee systems.

Environmentally, the available studies show that (generally) a reusable packaging system has a lower environmental impact than single-use systems. The key trade-offs are the impacts associated with materials production and disposal on the one hand, and the impacts of increased transport on the other hand. Furthermore, the disposal and recycling of both reusable and single-use system are important. A special factor affecting B2C systems may be the failure and disposal of a

parent dispenser (in the case of refills) that may result in a higher environmental impact (Lofthouse, 2014).

5. Opportunities for reusable packaging systems

While (recent) history and packaging developments show many examples of reusable packaging systems, it is also clear that not all distribution systems and supply chains are suitable for the use of reusable packaging systems, or it may not result in environmental gains. Hence, for every group of products, supply chains, and delivery system, a critical analysis is needed to potentially develop a sustainable reusable package system. The transition to a reusable packaging system needs the development (or retooling) through a systems or a supply chain approach, including specifications of primary and secondary packaging, monitoring systems, ownership, reverse logistics, and service organization. Note that changes in trade patterns and retail concepts offer challenges as well as opportunities for new packaging concepts. For example, today there seems to be a growing acceptance in the market of a switch to service systems, instead of ownership, e.g. in transport (car sharing) and in lighting for commercial buildings and public spaces. The first service concepts in the B2C market, e.g. home laundry cleaning (including detergents) and coffee making, have also entered the market (e.g. in The Netherlands). This results in different delivery mechanisms of appliances and detergents, impacting packaging. In the past, Procter & Gamble wanted to sell diapers on large scale straight to customers, but the retailer Walmart objected. As new retail channels open up, we see that both retailers and producers develop home delivery services. It is easier for new companies to enter these markets, as these are not limited by existing relationships in the supply chain. For this reason, the Dollar Shave Club, an online seller of razors through a subscription service, was acquired by Unilever.

Next to the direct costs and benefits (see above), there are less tangible factors associated with packaging systems that may affect the potential opportunities of reusable packaging. Various producers have developed refill-concepts that use a parent dispenser in combination with light retail packaging. This might result in increased *consumer loyalty*. Also, the need to return the packaging (e.g. through a refund system) to the store may increase customer loyalty to the retailer.[3] Similarly, consumers associate reusable packaging with the *sustainability image of a brand*, and especially in brand-sensitive markets, companies introduce reusable packaging systems as part of their corporate sustainability strategy (e.g. in cosmetics). Emotional factors, as e.g. a bond with a particular product or package, can also be of importance for selected products (Bakker et al., 2014).

From a producer perspective, the use of low-cost refills or a reusable system provides the potential for increased *product customization*, as the costs for offering customized products decrease. When integrated into new retail concepts this could offer opportunities for customization and reaching new consumers.

Finally, the use of reusable packaging systems allows the low-cost introduction of *electronic tagging* (e.g. RFID) that could simplify and (partially) automate logistics, bringing down the costs of packaging and distribution. It could also simplify the monitoring of flows and stocks of packaging.

Seeing the impact of packaging in the environment, consumers have been asking for less wasteful, more eco-friendly options. Studies suggest that awareness, motive, and social behavior can greatly influence consumers choice for reusables and accentuate the importance of facilitating the access to reusables (Babader et al., 2016; Ertz et al., 2017). For consumers, reusable packaging systems can offer a variety of benefits, e.g. *reduced costs and price incentives* such as discounts for reusing, *increased variety and customization, convenience of delivery and pickup* and *reduced waste*.

6. Barriers to the introduction of reusable packaging

Experiences with the introduction of reusable packaging systems are mixed. For example, in beer distribution, reusable glass bottles are the norm in various countries in Europe (e.g. Germany, The Netherlands), while soft drinks and (spring) water distribution has shifted massively to single-use unless strong national policy prohibited this move. This shows the difficult interplay of the assessment of economics (e.g. breweries seem to find reusable bottles cheaper, while the soft drinks industry asserts the opposite), cost distribution (incl. externalities), organizational barriers, marketing, retailer relations, industry and national cultures, as well as regulation and policy.

The introduction of reusable packaging is a system change for the producer, retailer and consumer. Gardas et al. (2019) investigated the role of the different factors that contribute to realizing the change towards reusable packaging. Returnity, for example, develops reusable packaging for e-commerce and found that the biggest barriers to implementing reusable packaging are the change from the standard (one way) business practices and the restructuring of the business model. The new 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 optimize the impact of the systems. Reorganization of the supply chain and the relationships within the supply chain could be a major barrier within the current complex and global supply chains. Based on the experiences with reusable packaging systems, evidence of barriers in current systems that limit or hinder realizing the full potential of such systems have been identified.

The key main barrier for **producers** (and brand owners) identified in literature, is the increased logistic complexity, requiring reorganizing supply chains to ensure that packaging is available and returned through better management of distribution, returns, brand recognition and loyalty, as well as stocks. However, the use of *pooling systems* to enable sufficient supply may require a degree of standardization. This is evident in B2B systems (e.g. standardized shipping containers, pallets) but was also found in some B2C markets (e.g. bottles). *Return rates* and *turn-around*[4] of reusable packaging affect the system. Also in B2B systems, packaging (returnable packaging items, such as crates, pallets) return rates are a major issue for many companies. Deposits and refund systems (both in B2B and B2C) induce customers to return the packaging in good condition and in a timely manner. In global supply chains, *customs handling* of empty refillable containers has shown to be an issue (e.g. of IBCs), resulting in unnecessary handling costs and delays. Furthermore, the *upfront investments* in a new reusable packaging system are noted as a barrier to producers. While the *design* of a reusable packaging system is mentioned as key for a successful reusable packaging system, few studies have evaluated the design and impacts of policies specifically aimed at introducing or increasing the role of reusable packaging systems. Especially for food and cosmetics, *product safety* is a concern. Jetten et al. (1999) studied the impacts of reusable plastic packaging on food quality and safety. In general, it is concluded that reuse does not significantly influence any of the properties investigated. Neither the chemical, physical nor surface properties seem to be significantly influenced by repeated washing. Only the hydrophobicity of the refillable polycarbonate (PC) and polypropylene (PP) containers seemed to be influenced by repeated washing (Jetten and de Kruijf, 2002). Also, the characteristics of the plastic (incl. migration) did not significantly change after repeated washing. However, for strongly flavoured products, flavour may likely be carried over to a new filling. Lemos Junior et al. (2019) showed for a case study of reusable soft drink bottles in Brazil, that inappropriate use of the bottles by

[3] We have not identified studies that have been able to quantify the effects and role of sustainable or reusable packaging systems on customer loyalty.

[4] *Time required to prepare the packaging for a new cycle.*

consumers was the key factor for introducing components that affected the flavour. However, using HACCP to design a good management system for returned bottles helped to reduce the rejection rate to 1%.

For **retailers**, the additional *space and hygiene requirements* for receiving and storing reusable containers, or for dispensers, may be a barrier. Furthermore, the need for *maintenance and cleaning* of dispensers is an added activity and hence barrier within current retail concepts, which may also introduce risks and liabilities, e.g. due to contamination or spoiling through improper use or cleaning of bulk dispensers. Third-party companies that take the risk and responsibility from the retailers' hands can represent an innovative solution. This is the case of, for example, reusable takeaway container companies. These companies provide cleaning, maintenance and transport for retailers while bringing financial and green marketing for the company, removing most barriers that prevented innovation.

A number of factors affect **consumer** acceptance. The following barriers were identified in the literature: the *inconvenience* of a reusable packaging system such as having to bring empty containers to be refilled or the ease of use of refilling; the risk of *unavailability* of refills; the *first cost* of a parent dispenser in a refill system; ineffective *communication,* which may result in the disposal of reusable systems, and bad *pricing* policy by retailers or manufacturers (resulting in equal or higher costs for a reusable system). In the past, pricing strategies have not always reduced the retail price of e.g. refills. Even price premiums for refills or reusable packaging systems have been found, assuming that sustainable-conscious consumers are willing to pay extra. These pricing strategies negatively affect the introduction of sustainable packaging options. For the general public, the 'feel-good factor' is not enough, and hence a *financial incentive* may be important to change consumers to switch to a reusable packaging system. *Convenience* affects the acceptance of reusable packaging systems by consumers, including delivery (e.g. weight), the ease of use (e.g. in the case of refilling), home management, and the return of used packaging, as well as return opportunities (e.g. in-store, pick up). The impact of product hygiene concerns due to bulk dispensing was not reported in the literature and may be a factor for selected products (e.g. dairy or other products at risk of spoilage or contamination). Finally, while consumers take interest in environmental impacts of packaging, they have *limited understanding* to distinguish and rate the impacts of packaging concepts, which makes it hard for consumers to make an informed choice. In B2C e-commerce, cost allocation to return the packaging (either the retailer or the customer), is a decision of the retailer. Companies experimenting with reusable packaging in e-commerce highlight that consumers generally favour sustainable retailers. Yet, when given the option to pay more for a returnable packaging, the majority of customers will decline (M. Newman, personal communication, July 19, 2019; J. Berbee, personal communication, April 17, 2019).

The discussion on barriers shows also that e.g. current legal, accounting, waste management, and other societal systems, affect the selection of packaging. The literature on B2B systems shows that in this market there seems to be an autonomous driver for the increasing interest and introduction of more sustainable reusable packaging systems. However, **policy** plays a key role in the development of reusable packaging systems in B2C markets. Bans of single-use packaging (e.g. Denmark), taxing of single-use packaging systems (e.g. Belgium, Denmark, Finland), or compulsory deposit systems (e.g. Germany) are policy instruments that have been used. The Finnish case has shown that the use of reusable bottles, which was 73% for beer and 98% for carbonated beverages, decimated after the levy on non-recyclable containers was abolished in 2008 (i.e. it put the same tax on refillable container systems as in single-use systems) (Morawski, 2017).

7. Research needs and directions

7.1. Drivers and barriers of reusable packaging

In the past decades, we moved from reusable packaging to single-use packaging, while a good understanding of these drivers and how these are connected to e.g. economics, cultural, regulatory and retail concepts is still lacking. Helping to understand these drivers will help to develop strategies to introduce reusable packaging options when this would be environmentally beneficial. It is also essential to learn from the (failed or successful) introduction of reusable packaging systems, and the role of communication strategies (especially in B2C markets).

Research is needed to determine the usefulness of reusable packaging systems for different market segments, products and its relationship to supply chain. This would include the need to monitor the effectiveness and efficiency of current systems (Rigamonti et al., 2019), to better understand new opportunities for reusable packaging systems. The review has also shown that the organization of the supply chain is critical to the adoption of reusable packaging systems. Yet, it needs a better understanding of the factors that play a role in this adoption (Twede and Clarke, 2004). This, including the integration of reverse logistics, transport distances, the role of pooling, and the impacts of new tracking technology, such as RFID (Jansen and Krabs, 1999).

Design may also play an important role in the effectiveness and efficiency of a reusable packaging system, including factors such as (re-) sealability, user-friendliness of (refill) systems, choice of material (e.g. potential for uptake of aromatics in plastic), standardization and pooling, and reduction of product damage and losses.

7.2. Sustainability impacts of reusable B2C packaging

The literature has shown that economic and environmental analysis of B2C packaging is less prevalent. As large volumes of materials are used in B2C markets, further integrated life cycle analysis of the environmental (LCA) and economics (LCC) of reusable packaging systems is needed. Research would need to study and help to better understand the role of (reverse) logistics, return rates, the pooling (including sorting, cleaning and maintenance), actual transport distances, and impacts on product damage.

Specifically, to assess the environmental impacts of reusable packaging systems, the use of tools such as material flow analysis (MFA) and LCA can help to understand the impacts of assumptions, system boundaries and technological change, especially as many impacts are determined by energy use, which will change dramatically over the next decades (e.g. Woods and Bakshi, 2014). Behavioral aspects (e.g. consumers behavior concerning reuse and end-of-life disposal) are key to the environmental impact but need better integration in existing LCA methods. Furthermore, the optimization of (reverse) logistics for reusable packaging systems is an important area to be included in the analysis.

7.3. Retail concepts and reusable packaging: the opportunities of E-Commerce

The retail concept affects (to some degree) the choice and design of the packaging. Today, the retail market is changing, as e-commerce is increasingly becoming more popular, and the market of online ordering and home delivery of groceries is growing. Home delivery is now associated with excess packaging material use, and various concepts have been developed to reduce this. Yet, an analysis of the deeper opportunities for packaging due to a shift to e-commerce are not yet well understood. For example, the role of marketing in packaging design may become less important, and the design of primary packaging may be less optimal for e-commerce distribution (resulting in excess packaging for shipping to the consumer). E-commerce also offers the opportunity to move to service concepts and distribution.

7.4. Packaging policy

It has been shown that externalities (e.g. environmental impacts, littering) and costs allocation (e.g. waste management) play a role in the preference of packaging systems by producers and retailers. Furthermore, in a few countries policy changes played a direct role in the success or demise of reusable packaging systems. Producers and retailers are an important lobbying force in the development of future packaging policy, affecting packaging markets. We need to better understand (international, national or local) policy affecting packaging choices, and the role of policy in the dissemination and implementation of reusable packaging systems. This includes monitoring of the impacts, effectiveness and efficiency of packaging policy, as such analysis are still rare (Rouw and Worrell, 2011).

8. Conclusions

Over the past decades, we have witnessed a declining use of reusable packaging and increased use of single-use packaging. The increased environmental pressures (due to e.g. material use, waste generation, littering) of single-use packaging, demand a change in the trend towards single-use packaging. Reusable packaging systems seem to demonstrate environmental and potential economic benefits over single-use packaging systems. This paper presented a review of the literature on reusable packaging systems and tried to map current international developments. Reusable packaging systems are more often found in B2B markets, while in some B2C market segments there is a wide and long experience with reusable systems (e.g. beer, mineral water, soft drinks). We introduced a classification for reusable packaging systems and provide an overview of the developments of various types of reusable packaging systems.

There are still several areas that need further research to better understand the opportunities for packaging reuse and to estimate the potential environmental and economic impacts. While there are opportunities in both B2B and B2C markets, the review has shown that there is more knowledge on B2B than on B2C reusable packaging systems. Moreover, few studies have proactively investigated the potentials, leading to a lack of knowledge on future potential opportunities. Future research will need to discern different market segments to explore and map reuse opportunities, starting with distinguishing B2B-packaging, B2C consumer products (for short and long lifetimes), and B2C food packaging. Developing decision support models that consider alternative design options for B2B and B2C reusable packaging systems seem to be promising. Research should be done in collaboration with stakeholders (e.g. producers, trade, retail, logistics) in the various supply chains to get realistic insights, yet also allow for independent study of new options.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Accorsi, R., Cascinia, A., Cholette, S., Manzini, R., Mora, C., 2014. Economic and environmental assessment of reusable plastic containers: a food catering supply chain case study. Int. J. Production Econ. 152, 88–101.
Babader, A., Ren, J., Jones, K.O., Wang, J., 2016. A system dynamics approach for enhancing social behaviours regarding the reuse of packaging. Expert Syst. Appl. 46, 417–425.
Bakker, C., den., HM., van Hinte, E., 2014. Products That Last: Product Design for Circular Business Models. BIS Publishers, Amsterdam, The Netherlands.
Beitzen-Heineke, E.F., Balta-Ozkan, N., Reefke, H., 2017. The prospects of zero-packaging grocery stores to improve the social and environmental impacts of the food supply chain. J. Clean. Prod. 140, 1528–1541.
Bepakt. (2019). Retrieved May 7, 2019, fromhttps://www.bepakt.com.
CEPI, 2018. Key statistics 2018 European pulp & paper industry. In: Confederation of European Paper Industries. Brussels, Belgium.
Chonhenchob, V., Singh, S.P., 2003. A comparison of corrugated boxes and reusable plastic containers for mango distribution. Packag. Technol. Sci. 16, 231–237.
Chonhenchob, V.D.K, Singh, S.P., 2008. Comparison of reusable and single-use plastic and paper shipping containers for distribution of fresh pineapples. Packag. Technol. Sci. 21, 73–83.
Cordella, M., Tugnoli, A., Spadoni, G., Santarelli, F., Zangrando, T., 2008. LCA of an Italian Lager Beer. Int J LCA 13, 133–139.
Dubiel, M., 1996. Costing structures of reusable packaging systems. Packag. Sci. Technol. 9, 237–254.
Ellen MacArthur Foundation, 2017. The New Plastics Economy: Catalysing Action. Isle of Wight, UK.
Ellen MacArthur Foundation, 2019. Reuse – Rethinking Packaging. Isle of Wight, UK.
Ernst & Young, 2015. *Life Cycle Assessment of Newly Manufactured and Reconditioned Industrial Packaging* (revised version). Rotterdam, The Netherlands October 2015.
Ertz, M., Huang, R., Jo, M.S., Karakas, F., Sarigöllü, E., 2017. From single-use to multi-use: study of consumers' behavior toward consumption of reusable containers. J. Environ. Manage. 193, 334–344.
European Commission, 2019. In: EU 2019/904, Directive on the Reduction of the Impact of Certain Plastic Products on the Environment. Brussels, Belgium.
Eurostat, 2019. Municipal Waste and Packaging Waste Statistics. Eurostat, Brussels, Belgium.
Ferreira da Cruz, N., Simões, P., Cunha Marques, R., 2012. Economic cost recovery in the recycling of packaging waste: the case of Portugal. J. Clean. Prod. 37, 8–18.
Franklin Associates, 1999. Life Cycle Inventory of Single Trip and Multi-Trip Steel Drum Systems in the U.S., Europe and Japan. Prairie Village, Kansas, U.S.
Gardas, B.B., Raut, R.D., Narkhede, B., 2019. Identifying critical success factors to facilitate reusable plastic packaging towards supply chain management. J. Environ. Manage. 236, 81–92.
Geyer, R., Jambeck, J.R., Law, K.L., 2017. Production, use, and fate of all plastics ever made. Sci. Adv. 2017 (3), e1700782.
Goellner, K.N., Sparrow, E., 2014. An environmental impact comparison of single-use and reusable thermally controlled shipping containers. Int. J. Life Cycle Assess 19, 611–619.
Golding, A. 1999. *Reuse of Primary Packaging – Final Report.* Abfallberatung, Müllvermeidung & Recycling, Tübingen, Germany.
Hekkert, M.P., Joosten, L.A.J., Worrell, E., Turkenburg, W.C., 2000a. Reduction of CO_2 emissions by improved management of material and product use: the case of primary packaging. Resour. Conserv. Recycl. 29:, 33–64.
Hekkert, M.P., Joosten, L.A.J., Worrell, E., 2000b. Reduction of CO_2 emissions by improved management of material and product use: the case of transport packaging. Resour. Conserv. Recycl. 30:, 1–27.
Hunt, R.G., Franklin, W.E., 1996. LCA- How it came about - personal reflections on the origin and LCA in the USA. Int. J. Life Cycle Assess 1, 4–7.
Jansen, R., Krabs, A., 1999. Automatic identification in packaging – radio frequency identification in multiway systems. Packag. Technol. Sci. 12:, 229–234.
Jetten, J., de Kruijf, N., Castle, L., 1999. Quality and safety aspects of reusable plastic food packaging materials: a European study to underpin future legislation. Food Addit. Contaminants 16, 25–36.
Jetten, J., de Kruijf, N., 2002. Quality and safety aspects of reusable plastic food packaging materials: influence of reuse on intrinsic properties. Food Addit. Contaminants 19 (1), 76–88.
Keoleian, G.a., Spitzley, D.V., 1999. Guidance for improving life-cycle design and management of milk packaging. J. Ind. Ecol. 3 (1), 111–126.
Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: an analysis of 114 definitions. Resour. Conserv. Recycl. 127, 221–232.
Koskela, S., Dahlbo, H., Judl, J., Korhonen, M-R., Niininen, M., 2014. Reusable plastic crate or recyclable cardboard box? A comparison of two delivery systems. J. Clean. Prod. 69, 83–90.
Ten Klooster, R., de Koeijer, B., de Lange, J., 2017. Towards a generic set of packaging material key figures. In: Proc. IAPRI Conference. Lausanne. pp. 2017 Proceedings IAPRI.
Kuo, T-C., Chiu, M-C., Chung, W-H., Yang, T-I., 2019. The circular economy of LCD panel shipping in a packaging logistics system. Resour. Conserv. Recycl. 149, 435–444.
Lee, S.G., Xu, X., 2004. A simplified life cycle assessment of re-usable and single-use bulk transit packaging. Packag. Technol. Sci. 17:, 67–83.
Lemos Junior, W.J.F., do Amaral dos Reis, L.P., Sales de Oliveira, V., Lopes, L.O., Pereira, K.S., 2019. Reuse of refillable PET packaging: approaches to safety and quality in soft drink processing. Food Control 100, 329–334.
Levi, M., Cortesi, S., Vezzoli, C., Salvia, G., 2011. A comparative life cycle assessment of

disposable and reusable packaging for the distribution of Italian fruit and vegetables. Packag. Technol. Sci. 24, 387–400.
Lofthouse, V.A., Bhamra, T.A., Trimingham, R.L., 2009. Investigating customer perceptions of refillable packaging and assessing business drivers and barriers to their use. Packag. Technol. Sci. 22, 335–348.
Lofthouse, V.A., 2014. A Creative Approach to Investigating Refillable Packaging Systems. Loughborough University, UK.
Lofthouse, V.A., Trimingham, R.L., Bhamra, T.A., 2017. Reinventing refills: guidelines for design. Packag. Technol. Sci. 30, 809–818.
Manzini, E., Vezzoli, C., 2012. Product Service Systems and Sustainability: Opportunities for Sustainable Solutions. UNEP, DTIE, Paris, France.
Menesatti, P., Canali, E., Sperandio, G., Burchi, G., Devlin, G., Costa, C., 2012. Cost and waste comparison of reusable and disposable shipping containers for cut flowers. Packag. Technol. Sci. 25, 203–215.
Mollenkopf, D., Closs, D., Twede, D., Lee, S., Burgess, G., 2005. Assessing the viability of reusable packaging – a relative cost approach. J. Bus. Logist. 26 (1), 169–197.
Morawski, C., 2017. The push for reusable packaging. Resour. Recycl. July 2017, 68–70.
Pålsson, H., Finnsgård, C., Wänström, C., 2013. Selection of packaging systems in supply chains from a sustainability perspective: the case of volvo. Packag. Technol. Sci. 26, 289–310.
Plastic Europe, 2018. Plastics – the Facts 2018. An analysis of European Plastics Production, Demand and Waste Data. Plastics Europe, Brussels, Belgium.
Potting, J., Hekkert, M., Worrell, E., Hanemaaijer, A., 2017. Circular Economy: Measuring Innovation in the Product Chain. PBL, The Hague, The Netherlands January 2017.
Reike, D., Vermeulen, W.J.V., Witjes, S., 2018. The circular economy: New or Refurbished as CE 3.0? — exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. Resour. Conserv. Recycl. 135, 246–264.
Raugei, M.P.F-i-P, Puig, R., Torres, A., 2009. A comparative life cycle assessment of single-use fibre drums versus reusable steel drums. Packag. Technol. Sci. 22, 443–450.
Rigamonti, L., Biganzoli, L., Grosso, M., 2019. Packaging re-use: a starting point for its quantification. J. Mater. Cycles .Waste Manage. 21, 35–43.
Rouw, M., Worrell, E., 2011. Evaluating the impacts of packaging policy in The Netherlands. Resour. Conserv. Recycl. 55, 483–492.
Simon, B., Ben Amor, M., Foldenyi, R., 2016. Life cycle impact assessment of beverage packaging systems: focus on the collection of post-consumer bottles. J. Clean. Prod 112, 238–248 c.
Singh, J., Saha, K., Geiger, S., 2017. Economic and social sustainability assessment of reusable plastic containers in the agricultural-food supply chains; In: 28th IAPRI Symposium on Packaging. Lausanne, Switzerland. pp. 303–313.
Singh, S.P., Chonhenchob, V., Singh, J., 2006. Life cycle inventory and analysis of reusable plastic containers and display-ready corrugated containers used for packaging fresh fruits and vegetables. Packag. Technol. Sci. 19, 279–293.
Stajcer, D., ten Houten, M.R., Wiegersma, S., Kok, I.C., Alfers, A.L.E., 2001. LCA voor meermalige en eenmalige verpakkingssystemen met statiegeld voor frisdranken en waters. TNO, Delft, The Netherlands (in Dutch).
StopWaste, 2005. Ghirardelli Chocolate Company – Reusable Totes Case Study. StopWaste, Oakland, CA, US.
Tua, C., Biganzoli, L., Grosso, M., Rigamonti, L., 2019. Life cycle assessment of reusable plastic crates (RPCs). Resources 8, 110.
Twede, D., Clarke, R., 2004. Supply chain issues in reusable packaging. J. Market. Channels 12, 7–26.
Van Sluisveld, M.E.A., Worrell, E., 2013. The paradox of packaging optimization – a characterization of packaging source reduction in the Netherlands. Resour. Conserv. Recycl. 73, 133–142.
Welcome, J., 2011. Using reusables to the max. Packag. Digest 46–48 June 2011.
Woods, L., Bakshi, B.R., 2014. Reusable vs. disposable cups revisited: guidance in life cycle comparisons addressing scenario, model, and parameter uncertainties for the US consumer. Int. J. Life Cycle Assess 19, 931–940 (2014).
Worrell, E., Allwood, J., Gutowski, T., 2016. The role of material efficiency in environmental stewardship. Annu. Rev. Energy Resour. 41, 575–598 (2016).
WRAP, 2007. In: Reusable 'Carrierpac' packaging for kitchen worktops at B&Q (Final Report). Waste and Resource Action Programme (WRAP), Banbury, UK.