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Research article

Many Happy Returns: Combining insights from the environmental and behavioural sciences to understand what is required to make reusable packaging mainstream

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ABSTRACT

The introduction of reusable packaging systems (both refill and return) has the potential to significantly reduce waste from single-use plastic packaging. However, for these schemes to be successful, both the environmental impact and the willingness of consumers to engage with such systems need to be carefully considered. This paper combines and discusses two complementary studies: (i) a life cycle assessment comparing the environmental impacts of single-use, refillable, and returnable containers for a takeaway meal, and (ii) a large online survey of UK adults exploring what types of product and packaging consumers are willing to reuse, how, and why. The findings of the life cycle assessment indicate that reusable containers outperform single-use plastic containers on most measures of environmental impact. The survey found that given the choice of disposal, reuse or recycling, that recycling is the preferred method of dealing with packaging once empty in the UK, and that people's decisions with regards to what types of packaging they are willing to reuse are largely driven by the aspects of the packaging itself (e.g., material and type) rather than the nature of the product inside of the packaging (e.g., state of matter of the contents). The survey also showed that people were more willing to engage in reuse systems with which they were already familiar. Additionally the language used to describe these schemes and the term 'reuse' needs to be considered. Combined, these factors can be used to determine the best packaging reuse system for a given product and situation.

Introduction

An estimated 1.53 million tonnes of primary packaging for consumer goods was placed on the UK market alone in 2017, with just 30% of this being recycled (Thomson et al., 2018). Mismanagement of plastic waste worldwide has contributed to significant pollution and is expected to continue to rise unless action is taken. If current trends continue, 12 billion tonnes of plastic waste is likely to be in landfills or the natural environment by 2050 (Geyer et al., 2017). Through its lifetime, packaging transitions from a position of use, with value and worth, to a position of waste without any of these (Langley et al., 2011); identifying routes to maintain the use, value and worth is key to reducing plastic packaging waste. One potential way to achieve this is by the implementation of reusable packaging systems. It has also been estimated that replacing 20 per cent by weight of single-use plastic packaging with returnable or refillable systems presents a business opportunity of $10bn globally (EMF, 2019). However, for reusable packaging systems to bring about such benefits, it is important to ensure that other, unintended, negative impacts do not result. It is also vital that consumers are willing to engage with and use such reuse systems.

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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. It is therefore critical when considering reuse systems to take an interdisciplinary approach considering both environmental impacts and willingness to engage. Wever and Vogtländer (2013) combined eco-costs (damage based) with value (product price) into an eco-costs/value ratio (EVR) in an attempt to simultaneously consider eco-burden and economic value creation. Whilst this doesn't measure willingness to engage in reuse behaviour, the product price does demonstrate a customer's willingness to invest.

The work presented here combines insights from the environmental and behavioural sciences to start to understand what is required to make reusable packaging mainstream. For any given reuse system, it is important to identify a suitable material, type of packaging, and reuse model. Life Cycle Assessment (LCA) is used here to consider the environmental impact of a range of possible reusable packaging options for takeaway containers. On-the-go food packaging is seen as a problem area for packaging waste due to a lack of recycling infrastructure. Over 7.5 billion single-use expanded polystyrene (EPS) containers are used annually in the USA and over 1.8 billion single-use aluminium containers in the UK, giving a combined total emissions of more than 450 Mt CO_2e (Gallego-Schmid et al., 2019). Whilst the life cycle of refillable (customer owned) takeaway containers has been compared to single-use plastic in the past (e.g., Gallego-Schmid et al, (2019)), the comparison with returnable (company owned) and bagasse single-use containers is novel. Although the technology and materials to produce durable alternatives to single-use packaging exist, little research has explored which types of packaging consumers are willing to reuse, and no research has considered which methods of reuse consumers prefer for different products and packaging. Here we present a large, online consumer survey to understand what types of packaging people are willing to reuse (and how) and explore factors that influence people's decisions with respect to packaging that they are willing to reuse. The balance between the potential environmental impact of various packaging systems (as identified by LCA) and users' willingness to engage with those systems is then discussed.

Literature Review

Reusable packaging systems have been part of EU packaging legislation since 1994, when the European Union stipulated that packaging should be recyclable, reusable or recoverable (European Union, 2004). However, unlike recycling, there are no quotas set by the EU for member states to comply with and no legislative drivers at an EU level. As a consequence, to date, reuse has been limited to business-to-business packaging (such as returnable plastic crates used for fresh produce), beverages, a few consumer refill packs (e.g., instant coffee and cleaning products) and bring-your-own container options in (to date, niche) 'zero waste' stores. However, there is increased interest in reuse models and numerous brands have signed up to voluntary schemes like the New Plastics Economy Global Commitment (EMF, 2018) and national Plastics Pacts (USPP, 2020; Wrap, 2020), which include targets to investigate and implement reusable packaging systems by the end of 2025.

Formats of (re)use

There are many different kinds of reusable packaging systems (Coelho et al., 2020; Lofthouse et al., 2009), which can be broadly divided into two main categories - (i) return, where the container is owned and cleaned by a business (or group of businesses) and (ii) refill, 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) (EMF, 2019; Greenwood et al., 2020). Fig. 1 illustrates the different forms of product delivery, ranked in decreasing order of anticipated packaging waste from left to right. Note that the EU definition of reusable packaging is packaging that "has been conceived and designed to accomplish within its life cycle a minimum number of trips or rotations in a system for reuse" (BSI, 2004).

Single-use and Repurpose

Single-use refers to packaging which is intended to be used once and is then recycled or disposed of; it is also referred to as 'one way' in the context of reusable packaging systems (Golding, 1999). Repurpose is when packaging is used for a secondary purpose (e.g. a biscuit tin used to keep wood screws in). Research has indicated that consumers often find secondary uses for nominally single-use packaging (Haws et al 2014; Price & Ridgway, 1983), and how it is executed is largely unpredictable (Shipton, 2007) meaning that there is not a clear line between single-use and repurpose.

Refill models

Refill systems are gaining in popularity (Fuentes et al., 2019) especially since the advent of 'zero-waste shopping' and could be more appropriate and easier to implement for some products than a return system.

Refill at home (EMF, 2019) is possibly the simplest reuse option to implement for a manufacturer. There is still waste from the single-use packaging used to refill the original pack, but less packaging overall and reverse logistics are not required. A disadvantage, however, is that the refill packaging is often made from multilayer film which cannot currently be recycled (Coelho et al., 2020).

Refill on-the-go (EMF, 2019) is where the consumer takes the original packaging, or their own container, to a sales point to be filled or refill themselves. In many cases, there is still the issue of packaging waste at the store level (e.g., bag in box containers for the dispensing of liquids use single-use cardboard boxes with hard to recycle inner bags such as Ecover bulk retail packs (Ecover, 2021)). Reusable coffee cups are a good example of refill on-the-go and although the Covid-19 pandemic in 2020 put a temporary halt to such schemes, 'contactless' serving techniques were quickly developed to enable their use once again (City to Sea, 2020).

Return models

In return systems the packaging is effectively rented by the consumer and then returned. Various return models have been developed for primary packaging, mainly for drinks bottles (e.g., (Golding, 1999)). A review of the environmental impact of returnable packaging systems across the life cycle (WRAP, 2010) identified a number of factors that influence the environmental viability of a return model including the burden of manufacture of the containers, the number of cycles a that container will complete in its lifetime, transportation distances, the size of the container pool (i.e., the number of containers in circulation in the system), vehicle utilisation and recycled content/post-consumer recycling. These factors imply that the most efficient return model will utilise containers that; contain recycled material, are recyclable themselves, are tough enough to have a long life in the system, and are nestable when empty to optimise vehicle utilisation. These containers can also be shared between multiple manufacturers of different products in order to create a collective return model. This type of system has been in operation for a number of years in some European countries, where generic bottles are used

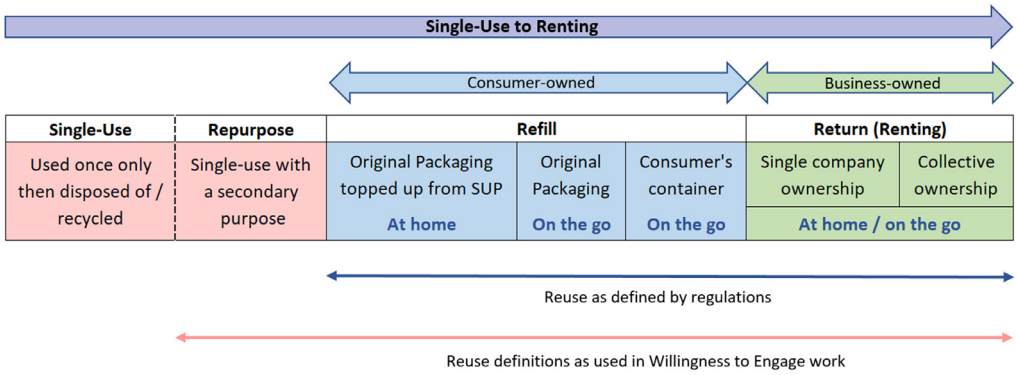

Fig. 1. Single Use to Reuse ordered in decreasing levels of anticipated packaging waste from left to right (based on (Greenwood et al., 2020)).

(Lee et al., 2008), and for transit crates for e.g., factory-made bakery products (Bakers Basco, 2021).

In a collective return model, standard types and sizes of containers are delivered to the product manufacturer, or a co-packer (in returnable transit packaging) who fills and labels the containers and distributes them to the retailers. Once the consumer has finished the product, they return the empty container either via a return station or through doorstep collection. A network of local facilities clean and recondition the containers and deliver to the closest of the co-operative of manufacturers ready for the next duty cycle. The use of standard pool containers minimises the length of the journeys the containers make. Inventory control is simplified and peaks and troughs in demand can be smoothed (WRAP, 2010).

A simple collective model has been applied to foodservice (Caulibox, 2020; Ecobox, 2020); Consumers buy a freshly prepared meal in a returnable container, which they take back to a participating outlet or collection point once finished. The container is then washed, either by the outlet themselves or at a central facility, and then used again by one of the collective businesses. For fast moving consumer goods, however, it is unlikely that brands will be willing to engage with collectively-owned consumer packaging as bespoke packaging is considered important for brand equity. A system that uses a brand's own packaging ('Loop') is currently under trial in locations worldwide (Smithers, 2020). Whilst the packaging is owned by the individual brands, the operator is responsible for logistics and washing of multiple brands' containers.

Life Cycle Assessment of Reusable Packaging

It is essential when considering new products and processes to assess their environmental impacts to avoid unintended consequences. Life cycle assessment (LCA) considers the environmental impacts associated with all stages of a product's life cycle. In the context of reusable plastic packaging containers, the environmental impact of raw materials used to make the product, the energy used in processing, transport throughout all stages of the cycle, number of reuses and eventual end of life of the product are all important.

The environmental impacts of reusable packaging have been considered by a number of authors, e.g., for milk. Stefani et al., (2020) considered a centralised milk supply chain, finding that reusable glass milk bottles had significantly higher environmental impacts than their lighter weight reusable PET counterparts due to the much higher transport emissions from moving the heavier packaging between consumer and refilling location. Meyhoff Fry et al. (2010) considered doorstep delivery of a local milk supply chain, finding the impacts due to packaging production (raw materials and processing) were the most significant. Accorsi et al., (2014) evaluated the life cycle impacts of secondary packaging (i.e., crates and boxes), finding that reusable containers had lower environmental impacts, however higher economic cost than single-use alternatives. The environmental impacts of takeaway containers have been considered previously, but only for single-use and refill options and not return. Gallego-Schmid et al., (2019) evaluated the environmental impact of single use aluminium, polypropylene and expanded polystyrene (EPS) containers and compared them to reusable polypropylene. The polystyrene containers were found to have the lowest impact across impact categories, due to the lower volume of raw materials required for a container and the lower energy required for processing. However, the recycling rates of EPS are negligible due to its low density and therefore poor cost effectiveness, and the problems posed by its low degradability and impact as marine litter are significant, though it should be noted that marine litter is not included as a specific impact category in Life Cycle Assessment. To date there has not been any analysis published comparing the life cycle impacts of refill and return options with single-use takeaway packaging. The return loop for takeaway containers is simpler than that for some other returnable packaging, such as Loop (Smithers, 2020), but the case study presented here serves as a starting point for the understanding of larger systems.

Consumer Willingness to Engage with Reuse Models

Technical solutions, infrastructure, and opportunities interact with individuals' and organisations' beliefs, skills, and motivation to determine their behaviour that, in turn, shape outcomes like a reduction in plastic waste (Khan et al., 2020). By way of an analogy, imagine a Local Authority spending £2 million on new cycle lanes and expecting to observe an increase in the number of people cycling to work. The infrastructure may well help, but its success also depends on people's attitudes toward cycling (and other modes of transport), normative beliefs (that is what people think i) others do or ii) what others think they should do), motivation, perceptions of risk and so on that dictate whether or not the cycle lanes are actually used. A successful reuse packaging system requires people to be willing to engage with that system, which depends on attitudes toward reuse, normative beliefs, motivation, perceptions of contamination and so on.

Consumer research has indicated that 85% of people want to buy products in packaging that they can reuse; however, less than one in five people actually engage with reuse systems (Poole, 2019). These findings suggest that, although people have positive attitudes towards reuse and are motivated to reuse, they often struggle to translate these intentions into behaviour. Considerable research has studied what has been termed 'the intention-behaviour gap' in other domains (e.g., with respect to health be-

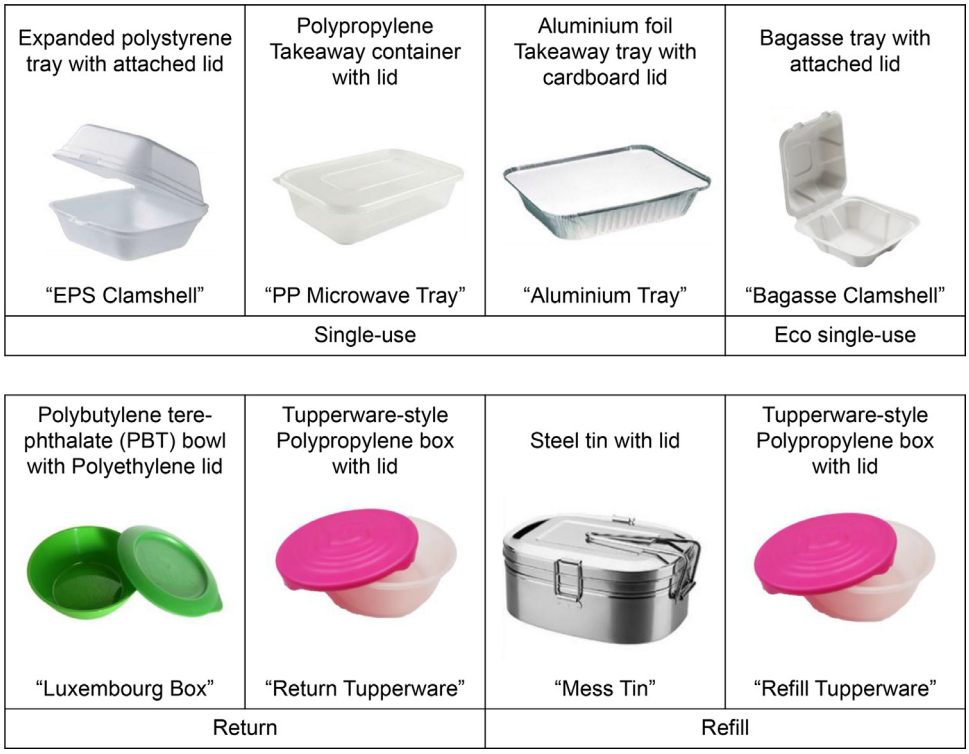

Fig. 2. Packaging options considered in the LCA.

haviours, for a review, see Sheeran and Webb, (2016) and identified a multitude of reasons why people struggle to translate intentions into action. However, one factor that might be important to consider is whether people actually have the opportunity to engage in a reuse system. Given that reuse models are currently far from the norm, even the best intentions may be thwarted by a lack of opportunity (e.g., a supermarket does not allow a consumer to use their own container for products from the deli counter because of hygiene concerns). Therefore, this research focuses on understanding what people might be willing to do, rather than their current intentions, as intentions are likely constrained by the current (lack of) availability of reuse systems. Behavioural willingness refers to how willing a person would be to perform a behaviour if given the opportunity to do so (Gibbons et al., 1998). Although willingness is a cognitive construct, research has indicated that willingness to engage in a behaviour is a key predictor of that behaviour in the future (e.g., (Hukkelberg and Dykstra, 2009)). Research has also shown that as people's experiences of engaging in a behaviour increases (e.g., experience of using an in-store refill station), then people's intentions replace willingness as the key predictor of that behaviour (Pomery et al., 2009). Exploring what people might be willing to reuse can also provide useful directions for where a new model of reuse might prove successful.

Despite the important role of consumers in the success of reuse models, very little research has considered the factors that might influence whether consumers' use reusable packaging or engage with reuse systems. One exception is a study conducted by Ertz et al (2017) who found that contextual factors, such as legislation and pricing, and psychological factors, such as attitudes and subjective norms, predicted consumers' intentions to use reusable packaging. However, to our knowledge, no research to date has explored how aspects of the product or packaging could influence a consumer's willingness to engage in reuse of the packaging.

Methods

Life Cycle Assessment (LCA) Methodology

The LCA was carried out in accordance with the Product Environmental Footprint (PEF) method (2012) as well as ISO14040 and ISO14044 guidelines, and is composed of four main steps: goal and scope definition, inventory analysis, impact assessment and results interpretation. The LCA was carried out using SimaPro9.0 software. The outcomes will be of interest to packaging manufacturers and those involved in the packaging supply chain, policy makers, packaging wholesalers and consumers.

Goal and Scope

The goal of the study is to evaluate and compare the cradle-to-grave environmental impacts of 8 different takeaway containers used within the UK to assess the "best" container on an environmental basis. The 8 cases (see Fig. 2) represent various options for single-use, refill, and return. In each category, the most commonly used packaging was selected and in some categories multiple types of packaging were analysed to represent a range of material options. The same Tupperware-style box has been included in both the return and refill cases in order to allow a comparison of these cases independent of the container.

The functional unit is the reference unit on which the data is normalised. Here the functional unit is "the production and use of an item of packaging that can hold 300 g of takeaway food, used to take away food from a restaurant to a nearby home in Sheffield, UK". To compare reuse and single-use cases, the life cycle impacts were first calculated for all cases for 200 takeaways (uses), then the average of those uses calculated to give the functional unit. 300g is a typical size of a food-to-go portion; for some meals of the day more than one portion is sometimes purchased. A location is chosen to enable accurate transport calculations; the impact of transport (and therefore exact location) is discussed in

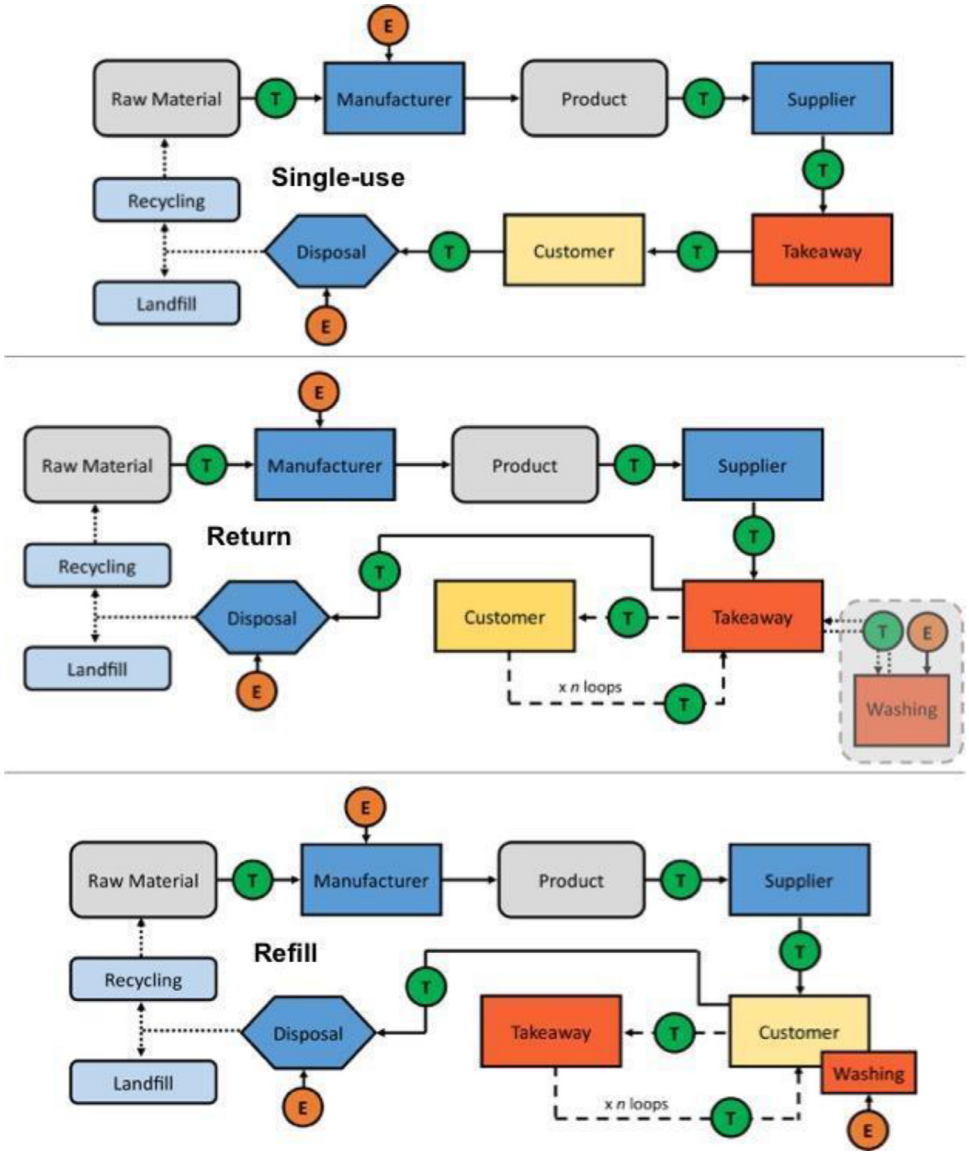

Fig. 3. Flowchart for the single-use (top), return (middle) and refill (bottom) cases. Products, processes and locations are shown, with major transport ("T") and energy ("E") inputs highlighted.

the results section. The focus of this study is the packaging, and as such the impact of the food contained within the packaging is excluded from the study. The food is likely to have a very significant impact on the total environmental impacts of the takeaway meal, but due to the wide variation between food types and the fact that packaging impact is independent of the food, the food is not included in the analysis. Transport between the takeaway and the consumer location is assumed to be on foot, and to have no energy consumption or environmental impacts attached to it. This is a reasonable assumption if the takeaway and home are close to each other. When takeaway food is ordered, it is very common for additional packaging, e.g., plastic or paper bags, to be used. This additional packaging is not included in this study, since it is assumed that such packaging would be required regardless of the takeaway container used.

Fig. 3 shows the flowcharts for the three cases considered. Across all cases, the processes of manufacturing and distributing each container are fundamentally the same: Raw materials are transported, processed and manufactured into the container, which is then transported to a supplier. Additional packaging which may be used for the bulk transport of containers is not considered in this study.

In the return case, the container is purchased from a supplier by the takeaway food -outlet, and first transported to, then stored at, the takeaway. It then enters a loop, where it is filled then transported to the customer's home, then back to the takeaway, where it is washed and stored ready for reuse. It is assumed that the returnable takeaway containers are reused by a single takeaway, rather than being used at multiple takeaways as part of a larger scheme. However, assuming that each takeaway was a similar distance from the customer's home and there were no significant differences in the washing process between takeaways, the results of this study would hold true for a larger scheme. If the collective return model (see page 3) is employed, whereby the container is transported to a third party for washing then returned to the takeaway, an additional transport process is required. If the container is washed on site, there is not a transport contribution at the washing stage.

In the refill case, the container is owned by the customer, so is purchased from the supplier and stored by the customer. The loop

Table 1
Life cycle inventory.

Product	Raw materials	Processing	Production Location and Transport to port	Port to Supplier	Supplier to Takeaway	Lifetime uses
EPS Clamshell 14 g	14 g product requires 14.799 g raw material: Expandable polystyrene (EPS), white and grey - Plastics Europe; manufactured by suspension polymerisation process.	Thermoforming of plastic sheets {RoW} | processing | APOS,U	Raw materials and Production - Shanghai, China 48km to Shanghai international shipping container port (7.5-16 tonne EURO5 lorry)	19360 km Shanghai port to Felixstowe (transoceanic container vessel (10 knots)) 400km Felixstowe to Bristol (7.5-16 tonne EURO6 lorry)	280 km to Sheffield (3.5-7.5 tonne EURO6 lorry)	1
PP Microwave container 34.4 g	34.4 g product requires 36.36 g raw material: (Container and lid) Polypropylene, granulate - Ecoinvent	Thermoforming, with calendering {RoW}| production | APOS, U, container and lid	Raw materials and Production - Shanghai, China 48km to Shanghai international shipping container port (7.5-16 tonne EURO5 lorry)	19360 km Shanghai port to Felixstowe (transoceanic container vessel (10 knots)) 400km Felixstowe to Bristol (7.5-16 tonne EURO6 lorry)	280 km to Sheffield (3.5-7.5 tonne EURO6 lorry)	1
Aluminium tray 6.2 g	6.2 g product requires 6.5 g raw material: Aluminium, primary, ingot - Ecoinvent	Sheet rolling, aluminium {GLO} market for | APOS, U. Impact extrusion of aluminium, 1 stroke {GLO}| market for | APOS, U.	Raw material produced in Hebei province, China. Ingots transported 915km to Jiangsu province (7.5-16 tonne EURO5 lorry) for tray manufacture, then 139km to Shanghai international shipping container port (7.5-16 tonne EURO5 lorry.	19360 km Shanghai port to Felixstowe (transoceanic container vessel (10 knots)) 400km Felixstowe to Bristol (7.5-16 tonne EURO6 lorry)	280 km to Sheffield (3.5-7.5 tonne EURO6 lorry)	1
Board lid for Aluminium tray 5.7 g	5.7 g product requires 5.985 g raw material: Liquid packing board container - Ecoinvent	Carton board box production {GLO}| market for | APOS, U	Raw materials and Production - Shanghai, China 48km to Shanghai international shipping container port (7.5-16 tonne EURO5 lorry)	19360 km Shanghai port to Felixstowe (transoceanic container vessel (10 knots)) 400km Felixstowe to Bristol (7.5-16 tonne EURO6 lorry)	280 km to Sheffield (3.5-7.5 tonne EURO6 lorry)	1
Bagasse Clamshell 22 g	22 g product requires 23.1 g raw material: Bagasse, from sugarcane (Brazil) ethanol by-product - Ecoinvent and Fangmongkol (2020)	Thermoforming, with calendering {RER}| production | APOS, U (electricity modified to Electricity, medium voltage {US}| market group for | APOS, U)	Raw material produced in Brazil. Transported 400km to Santos (7.5-16 tonne, EURO5 lorry), shipped 13674km (transoceanic container vessel) to Long Beach, then 604km (7.5-16 tonne, EURO5 lorry) to Fremont, CA, USA for clamshell manufacture, then 604km back to Long Beach (7.5-16 tonne, EURO5 lorry)	14228km Long Beach to Felixstowe, (transoceanic container vessel (10 knots)) 400km Felixstowe to Bristol (7.5-16 tonne EURO6	280 km to Sheffield (3.5-7.5 tonne EURO6 lorry)	1
Luxembourg Box 25.6 g	25.6 g requires 25.75 g raw material: Polybutylene terephthalate (PBT), granulate, bottle grade - Ecoinvent	Injection moulding {RER}| processing | APOS, U	Raw materials and Production - Minden, Germany. 587km to Calais ferry port (7.5-16 EURO6 lorry)	40.7km to Dover (transoceanic container vessel (10 knots)) 324km Dover to Bristol (7.5-16 tonne EURO6	280 km to Sheffield (3.5-7.5 tonne EURO6 lorry)	50
Luxembourg Box Lid 15.7 g	15.7 g requires 16.06 g raw material: Polyethylene (PE), granulate - Ecoinvent	Thermoforming, with calendering {RER}| production | APOS, U	Raw materials and Production - Minden, Germany. 587km to Calais ferry port (7.5-16 EURO6 lorry)	40.7km to Dover (transoceanic container vessel (10 knots)) 324km Dover to Bristol (7.5-16 tonne EURO6	280 km to Sheffield (3.5-7.5 tonne EURO6 lorry)	50
Steel Mess Tin 183.15 g	183.15 g Steel, chromium steel 18/8	Impact extrusion of steel, hot, 3 strokes inc. tempering {GLO}| market for | APOS, U	Raw materials and Production - Shanghai, China 48km to Shanghai international shipping container port (7.5-16 tonne EURO5 lorry)	19360 km Shanghai port to Felixstowe (transoceanic container vessel (10 knots)) 400km Felixstowe to Bristol (7.5-16 tonne EURO6 lorry)	280 km to Sheffield (3.5-7.5 tonne EURO6 lorry)	100 or 200 (see results)
Tupperware Box and Lid 40 g	40 g requires 41.3 g raw material: Polypropylene granulate - Ecoinvent	Thermoforming, with calendering {RoW}| production | APOS, U	Raw materials and Production - Shanghai, China 48km to Shanghai international shipping container port (7.5-16 tonne EURO5 lorry)	19360 km Shanghai port to Felixstowe (transoceanic container vessel (10 knots)) 400km Felixstowe to Bristol (7.5-16 tonne EURO6 lorry)	280 km to Sheffield (3.5-7.5 tonne EURO6 lorry)	50
Tupperware Seal 1.3 g	1.3 g Synthetic Rubber - Ecoinvent	Extrusion, co-extrusion {GLO}| market for | APOS, U	Raw materials and Production - Shanghai, China 48km to Shanghai international shipping container port (7.5-16 tonne EURO5 lorry)	19360 km Shanghai port to Felixstowe (transoceanic container vessel (10 knots)) 400km Felixstowe to Bristol (7.5-16 tonne EURO6 lorry)	280 km to Sheffield (3.5-7.5 tonne EURO6 lorry)	50

Table 2
Inventory for washing sensitivity analysis.

	Return Commercial Dishwasher	Refill Domestic dishwasher	Handwashing
Water use per wash (litres)	4	20	9
Energy use per wash (kWh)	0.5	1	0.264
Takeaway tray allocation of total (%)	4	1.6	10
Water use per takeaway container (litres)	0.16	0.32	0.9
Energy use per takeaway container (kWh)	0.02	0.016	0.0264

is similar to the return case, but with washing taking place at the customer's home before storage ready for reuse.

Inventory Analysis

The life cycle inventory, including transport details, is given in Table 1. Inventory data was taken from a range of sources. Although some general manufacturing process information was available, no specific data was available directly from container manufacturers, so previous literature on the subject was consulted. Existing studies highlighted the most likely manufacturing locations and methods for some containers (Fangmongkol and Gheewala, 2020; Gallego-Schmid et al., 2019; Lightart and Ansems, 2007); but did not provide sufficient data to conduct LCA, so additional data was taken from the Ecoinvent 3.5 (Weidema and Wesnæs, 1996) database, with further supplementary material data from Plastics Europe via the Industry Data 2.0 database. For each container, the main manufacturing processes used (as identified in the literature or industry information) were applied using representative processes from the Ecoinvent 3.5 database in SimaPro. These processes were modified if necessary to represent the correct country of manufacture, as shown in Table 1. Raw material data was collected through direct measurement (by weighing containers with a digital weighing scale), and the most appropriate material was selected from the Ecoinvent 3.5 database or data supplied by PlasticsEurope, as described in Table 1.

In all cases, manufacturing methods are based on common actual production facilities, and the most common manufacturing location and method, supply route, and transport method have been applied. The EPS Clamshell, PP Microwave Tray and Aluminium Tray are assumed to be manufactured in China (see Table 1), then transported by lorry to Shanghai port, where they are shipped by sea to Felixstowe port, then transported to a large catering supplies company, assumed to be in Bristol. From here they are assumed to be transported to the takeaway in Sheffield. In the EPS and PP cases, manufacture of polymer and moulding of boxes are assumed to take place at the same facility. In the aluminium case, aluminium ingots are assumed to be produced in Hebei province, then transported by lorry to Jiangsu province for foil manufacture. The bagasse raw material is a waste product from the sugarcane refining process. This process primarily produces sugar, with co-products including ethanol and bagasse produced simultaneously. Production data was taken from the Ecoinvent database and is based on a large sample of production volume and time period. The allocation methods suggested in this dataset were applied. For impacts other than CO_2 emissions, the allocation of impacts of the sugarcane refining process between these co-products was based on economic allocation, meaning that the impacts are divided between each co-product based on their economic value. For CO_2 emissions, allocation was based on carbon balance, meaning that the CO_2 emissions attributable to the sugarcane refining process were divided between co-products based on their relative embodied CO_2. Information on the production of bagasse products was based on previous work (Fangmongkol, 2020). The bagasse clamshell is assumed to be made in the USA using raw material from Brazil. PBT and PE used in the manufacture of the Luxembourg box are manufactured in Germany, as confirmed by the manufacturer.

Manufacturing process data was taken from Ecoinvent in all cases and was based on the most common method of manufacture for each product. Full manufacturing processes were modelled in each case (see Table 1). Details of end-of-life treatment of each container are given in Table 3. The manufacturing location was selected based on the most common manufacturing location of products offered by the largest UK supplier (Nisbets, 2020). This supplier was also used for the calculation of transport distances. Transport distances were measured using online mapping (Google, 2020) for road transport and the SeaDistances website (Sea Distances, 2020) for marine transport. Road transport emission standards were based on the current standards (International Transport Policy Standards, 2020) in relevant countries (EURO5 equivalent in China, Brazil and USA, EURO6 in Europe).

A reusable container must be washed before being reused: for the refill case this washing takes place at the customers home, whereas for the return case washing takes place at the restaurant. The default case assumes a domestic dishwasher and a commercial dishwasher are used for the refill and return cases respectively, but sensitivity analysis is also performed on the mode of washing for the reuse case as only around half of the households in the UK have a dishwasher so hand washing of dishes is also likely. Handwashing has the potential to increase CO_2 emissions and water use, due to an increase in volume of water used relative to using a dishwasher, but the handwashing process varies widely between consumers, for example in the amount of water used per wash, the water temperature, and (assuming water is used to wash other products as well as the takeaway container) the acceptable level of water contamination before water is replaced. The domestic dishwasher is the default case for the refill model due to the higher confidence in inventory parameters.

The water and energy required for the washing stage are included in the analysis, however the treatment of wastewater produced during the washing is considered to be outside the system boundary. Organic load in the wastewater due to food residue will vary dramatically with both the type of food contained, the amount of food left, and the consumers cleaning habits before washing. As this analysis looks at the packaging and not the food, treatment of the wastewater is not considered, although it should be noted that this will increase the impacts of reuse models slightly and should be explored in future work.

A takeaway container in a domestic dishwasher (in the refill case) takes up approximately 1.6% of the available space, therefore 1.6 % of the energy and water use of a standard dishwasher (20 l of cold tap water and 1 kWh electricity per cycle) are allocated to washing the container. For the return case, a commercial dishwasher (4 l cold water and 0.5 kWh electricity per cycle) is assumed to be used, with the container having a 4% allocation by volume. (Note: a small commercial dishwasher was chosen on the basis that a takeaway would not have a lot of space available. The volume that can be washed in time is larger because the wash cycle for the commercial dishwasher takes about 2 minutes vs. ap-

proximately an hour for the domestic dishwasher). For handwashing, 9 litres of water are assumed to be used per wash, with a water temperature of 50 °C, and an allocation of 10% for the container being washed. The inventory for the washing sensitivity analysis is given in Table 2. Data on dishwasher cycle times were taken from manufacturer data (Hobart, 2019) and dishwasher and handwashing energy and water use were taken from previous studies (Berkholz et al., 2013, 2010; Which?, 2020).

End-of-life treatment was based on the most likely disposal method for each container type in a typical UK city. Specifically:

- Expanded polystyrene is not commonly collected for municipal recycling in the UK, and Polypropylene is not collected by all councils, so it was assumed that these containers were sent to landfill at the end of life. This applies to the single-use Microwave trays and the refill and return Tupperware containers.
- Aluminium foil trays are assumed to be recycled by municipal collection, but their cardboard lids are assumed to be disposed of in landfill, since these are coated and are likely to be contaminated, meaning that they cannot be accepted for recycling.
- Bagasse is assumed to be disposed of in landfill at the end of life. Though other disposal routes are possible (such as industrial composting), there is no data available on the rates of use of these routes, and such routes are unlikely to be available in a UK domestic setting.
- PBT is not collected for recycling in the UK, so at the end-of-life is assumed to be sent to landfill.
- Steel is fully recyclable and is assumed to be collected by municipal collection and recycled.

In the reuse cases, it was assumed that plastic containers (Luxemburg and Tupperware cases) were used 50 times before disposal. Steel containers were studied with both 100 and 200 uses. An additional 2g mass was added to the single-use containers sent to landfill to represent contamination, since it is assumed the customer would not wash this container before disposal.

Full details of the life cycle inventory applied at the end of life for each container type are given in Table 3.

As highlighted in Table 3, electricity consumption in Aluminium and steel recycling processes were modelled by setting the mass of offset virgin material to represent the difference between using recycled and virgin material. This was done using published data on the relative energy use of virgin and recycled materials. In the aluminium case, industry data (Corus 2020) suggests that a unit of recycled aluminium requires 5% of the energy required to manufacture the same mass of virgin material. Consequently it can be said that the recycled material offsets 95% of the energy use of the manufacture of virgin aluminium. The same value was applied across all impact categories to determine the impact of recycling aluminium at the end of life. Although energy use is a key contributor to many impact categories, the application of this value across all impact categories is a potential source of inaccuracy. The sensitivity of the results to these values was tested and it was found that varying the energy use per unit mass of recycled aluminium between 0% and 10% of that of virgin aluminium had no effect on the break-even points described in Table 4. Energy use in steel manufacture was considered in the same way. Here the reported burdens of recycled and virgin steel vary. A study on stainless steel (Johnson et al, 2008) suggests a recycled steel burden of 33% of that of virgin steel. This value was adopted and a sensitivity analysis was again conducted, which found that changing this value between 20% and 50% had no impact on the break-even points described in Table 4. Due to the long lifetime of the product, the impacts derived from the end-of-life treatment of steel are a very small part of the overall steel results (less than 1% of overall impact for most impact categories).

Table 3
Life cycle inventory: End-of-life treatment.

Product	Transport	End-of-life process
EPS Clamshell 16 g (14 g container +2 g contamination)	6km transport distance by municipal waste lorry (0.000096tkm per container). Ecoinvent process: Municipal waste collection service by 21 metric ton lorry {RoW}| market for municipal waste collection service by 21 metric ton lorry | APOS, U	Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, landfill | APOS, U
PP Microwave container 36.4 g (34.4 g container + 2 g contamination)	6km transport distance by municipal waste lorry (0.0002184tkm per container). Process as above	Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, landfill | APOS, U
Aluminium tray 6.2 g	6km transport distance by municipal waste lorry (0.00192 tkm per container). Process as above.	Aluminium (waste treatment) {GLO}| recycling of aluminium | APOS, U Process modified to yield 0.95 kg avoided product per 1 kg recycled product.
Board lid for Aluminium tray 7.7 g (5.7 g container + 2 g contamination)	6km transport distance by municipal waste lorry (0.00231 tkm per container). Process as above.	Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, landfill | APOS, U
Bagasse Clamshell 24 g (22 g container + 2 g contamination)	6km transport distance by municipal waste lorry (0.000144tkm per container). Process as above.	Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, landfill | APOS, U
Luxembourg Box and Lid 43.3 g (container 25.6 g + lid 15.7 g + 2 g contamination)	6km transport distance by municipal waste lorry (0.0002598 tkm per container). Process as above.	Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, landfill | APOS, U
Steel Mess Tin 183.15 g	6km transport distance by municipal waste lorry (0.0010989 tkm per container). Process as above.	Steel and iron (waste treatment) {GLO}| recycling of steel and iron | APOS, U Process modified to yield 0.67 kg of avoided product per 1 kg recycled product.
Tupperware Box, seal and lid 43.4 g (40 g box and lid + 1.3 g seal + 2 g contamination)	6km transport distance by municipal waste lorry (0.0002598 tkm per container). Process as above.	Municipal solid waste (waste scenario) {RoW}| Treatment of municipal solid waste, landfill | APOS, U

Table 4
Number of uses of reusable containers needed to break even with the global warming potential of single-use containers.

	Number of uses required			
	Luxembourg Box	Return Tupperware	Steel Mess Tin	Refill Tupperware
EPS Clamshell	4	3	33	4
PP Microwave Tray	2	2	13	2
Aluminium Tray	3	2	18	2

Impact Assessment

The Impact Assessment Method was ReCiPe 2016 Midpoint (Hierarchical) (Huijbregts et al., 2017). The method contains 13 out of 14 impact categories recommended for the Product Environmental Footprint (Manfredi et al., 2010). The remaining category "Eutrophication – terrestrial" is assumed to be covered by Marine eutrophication, Terrestrial acidification, Freshwater eutrophication and Terrestrial ecotoxicity.

Calculation of Break-even Global Warming Potential

The point at which each reusable option achieves lower global warming potential than the number of single-use items required to do the same number of takeaways was termed the "break-even point", and was calculated for both refill and return cases. The global warming potential (gCO_2e) of a reusable product (i) after n uses ($GWP_{i,n}$)was calculated as shown in equations 1 and 2. When n is greater than the lifetime of one product (e.g., for the Tupperware if n is greater than 50 uses), a second product is assumed to enter service and the emissions associated with the first product are added to its emissions (i.e. a = 2), similarly a third and fourth product as required. $GWP_{i,n}$ is then compared to n times the GWP of the single-use item (j). The break even point is the lowest value for n for which $GWP_{i,n} \leq n\ GWP_j$.

$$GWP_{i,n} = a(M_i + T_i + E_i) + nW_i \quad (1)$$

$$a = \frac{n}{l} \quad (2)$$

where:

- i = reusable packaging being considered
- j = single-use packaging being considered
- M_i = GWP associated with the manufacturing (raw materials and processing) of i
- T_i = GWP associated with transport of i from manufacturing location to customer/business
- E_i = GWP associated with end-of-life of i
- W_i = GWP associated with the washing of i
- n = number of times the reusable packaging is used
- l = number of times the packaging can be used before end of life
- a = number of reusable items required to achieve n uses

Willingness to Engage Methodology

Materials and Procedure

An online survey was conducted, via the survey software, Qualtrics (www.qualtrics.com/). Participants were invited by email and online adverts to participate in a study exploring people's views about different packaging used for products commonly found in UK supermarkets. Those who were interested in taking part, were asked to click on a link to the online survey. First, participants were presented with information about the study, and if they decided to take part, then they were asked to complete a consent form. Participants were then asked to provide demographic information, including their age, gender, ethnicity, and country of origin.

To explore what people are willing to reuse, participants were presented with images of different products commonly found in UK supermarkets and asked to decide whether or not they would be willing to use the packaging again. A total of 90 product images were taken from online shopping websites; 54% of the products were food or drink (e.g., food condiments, raw meat, soft drinks), 24% were homecare products (e.g., cleaning products, washing detergents), and 21% were personal care products (e.g., deodorants, facewash, toothpaste; for a full list of products see Table S1 in the supplementary material, doi:10.1016/j.spc.2021.03.022).

Participants were shown a random selection of 30 products and were asked to make a series of decisions with respect to what they would do with the packaging of that product if they had the option (see Fig. 4 for an overview of the task). Images of the products appeared on the screen one at a time. First, participants were asked whether they would: (i) put the packaging in the bin, (ii) recycle the packaging, or (iii) reuse the packaging. Participants who indicated that they would be willing to reuse the packaging were then asked how they would be willing to reuse the packaging (i.e., would they prefer to refill, return, or repurpose the packaging?), and which model of reuse they would prefer (i.e., refill or return from home vs. refill or return on-the-go). Participants were then asked to specify why they had selected that option for that product in order to understand people's decisions with respect to reuse. Participants were then shown an image of the next product and were asked the same questions in relation to the new product shown (Figure S2 in the supplementary material presents images for each stage of the survey).

To explore what aspects of the product and/or packaging influenced whether or not people were willing to reuse the packaging, a number of different physical characteristics and attributes of the packaged products were coded (e.g., the material used for the packaging, the nature of the contents, shelf life, frequency of purchase). The coding framework was informed by previous research (e.g., (Lindh et al., 2016)), product databases (e.g., Mintel; https://www.mintel.com), and participants' responses. The full coding framework can be found in Table S3 in the supplementary material doi:10.1016/j.spc.2021.03.022.

Sample size and characteristics

The survey was completed by 276 adults currently living in the UK. The majority of participants (90.58%) were recruited via the online recruitment platform, Prolific (https://www.prolific.co), with the remainder (9.42%) recruited via social media. Participants recruited via Prolific were paid £2.50 for completion of the survey, whereas participants recruited via social media had the option to enter a prize draw to win a £20 Amazon voucher. Prolific was chosen as the online recruitment platform as it has been shown to produce higher quality data (i.e., data that is more accurate and reliable) than other recruitment platforms (e.g., (Peer et al., 2017)). Only participants currently living in the UK were eligible to take part as the images depicted products from UK shopping websites. The age of participants ranged from 18 to 75 years old (M = 34.89; SD = 13.18) and the majority of the sample was female (71.70%) and White British (94.60%).

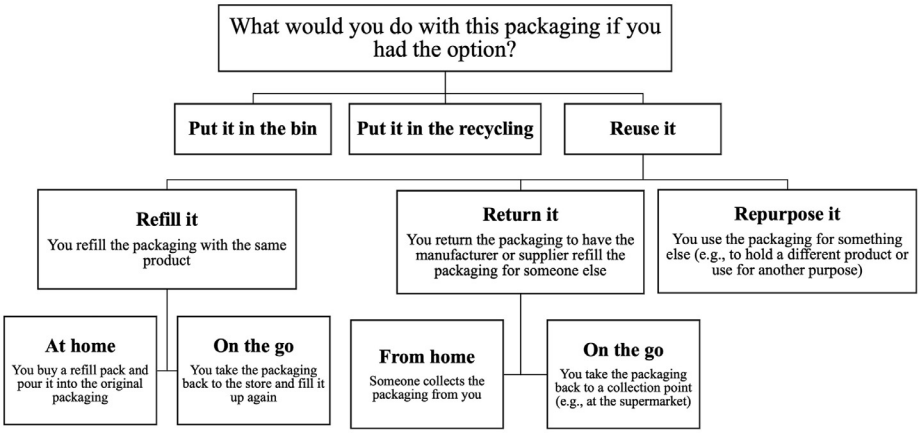

Fig. 4. Flow diagram representing the decisions that participants were asked to make for each of the products shown.

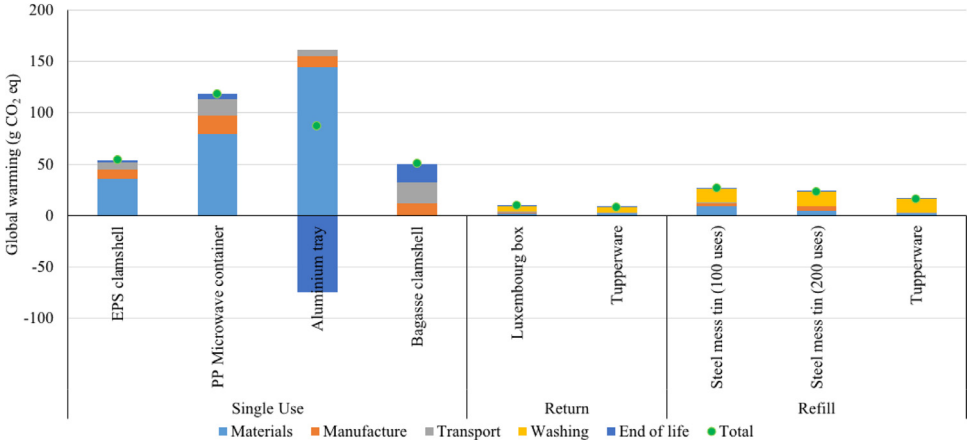

Fig. 5. Global warming potential of one use of each takeaway container (assuming reusable containers are used for the lifetime given in Table 1).

Analysis

To explore what factors influence what people are willing to reuse, the percentage of people willing to reuse packaging was examined as a function of a number of different physical characteristics and attributes of the products using Univariate Analyses of Variance (ANOVA). ANOVA is a statistical technique for comparing an outcome (in this case willingness to reuse) between two or more groups (e.g., packaging made from glass vs. plastic vs. cardboard) in order to determine whether there is a statistically significant difference between the categories (i.e., a difference that is larger than would be expected by chance alone).

Results and Discussion

Life Cycle Assessment

Figs. 5–7, show the global warming impact, land use and water use, respectively, for each type of container considered. All of the impact categories highlighted in the Product Environmental Footprint method are shown in the supplementary material (Figure S4) but are not presented here for simplicity. The global warming potential of the single-use containers show the same trend as found by Gallego-Schmid et al., (2019) with the EPS clamshell having the lowest carbon footprint and the PP microwave container the highest. It is clear from all three figures that the impacts of reuse and refill containers are significantly less than those for single-use containers. Variation between containers used for reuse (either return or refill) is significantly less than the difference between reuse and single-use. This highlights that, in this scenario, as long as a container is reused, it makes very little difference what the container is made of. The more times a container is reused, the lower the impact.

The return options show slightly lower impacts across all three categories presented than the refill options. This is due to the difference between domestic and commercial dishwashers. The small magnitude of the difference between the return and refill options means that both options are good. The choice of which is best will depend on the collection infrastructure for the return model and the extent to which refill is considered an acceptable option for the specific product. Transport accounts for only a small proportion of the impacts, despite the long distances involved, confirming that whilst locations are chosen for the model, the exact location has low impact on the results.

The high land use associated with the PP containers is due to the use of forest products (wood chips) for the incineration of hazardous waste by-products from the PP manufacturing process (Bourgaul, 2011). The high land use for bagasse is due both to the use of forest products for incineration and the land used to grow the sugar cane. The results presented assume PP goes to landfill and is not recycled; when sensitivity analysis is performed to take into account recycling of PP, there is negligible difference in the global warming impact, land use and water use compared to the landfill option.

Sensitivity analysis of the washing process was undertaken for the Tupperware container as this is considered both for return and refill (Fig. 8). Three cases were compared as described in Table 2, namely the domestic dishwasher used in the re-

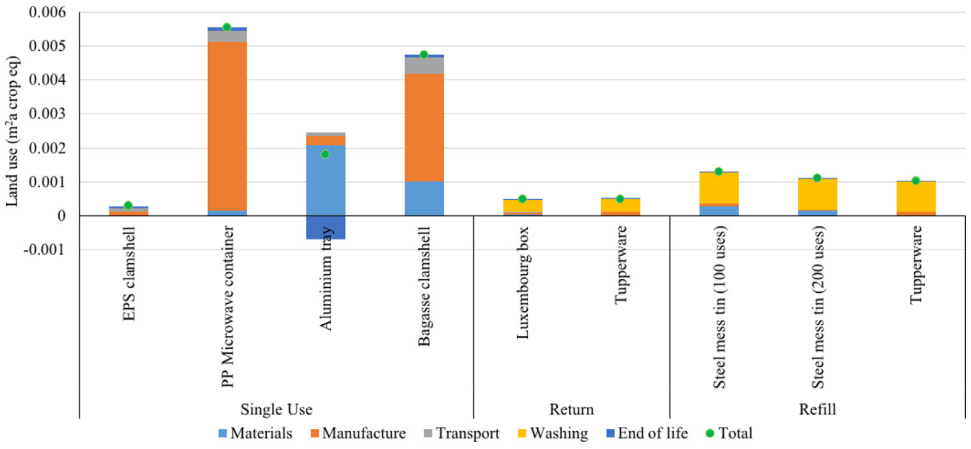

Fig. 6. Land use of one use of each takeaway container (assuming reusable containers are used for the lifetime given in Table 1).

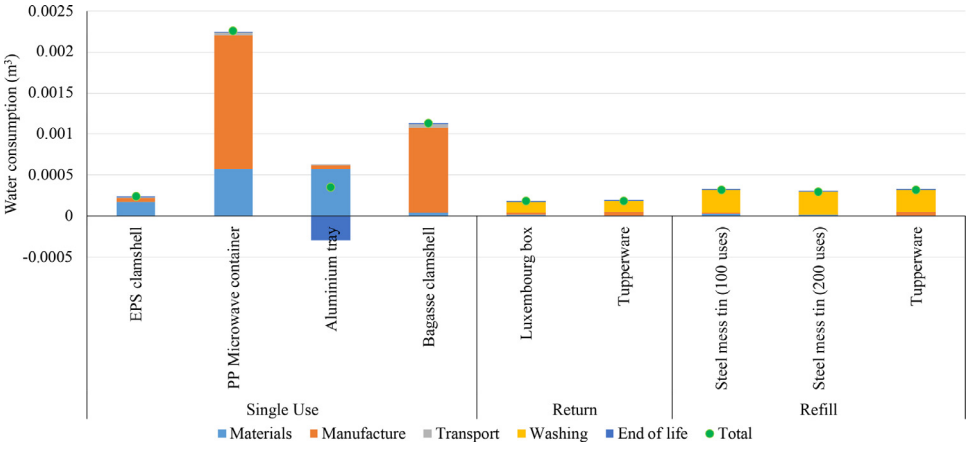

Fig. 7. Water consumption of one use of each takeaway container (assuming reusable containers are used for the lifetime given in Table 1).

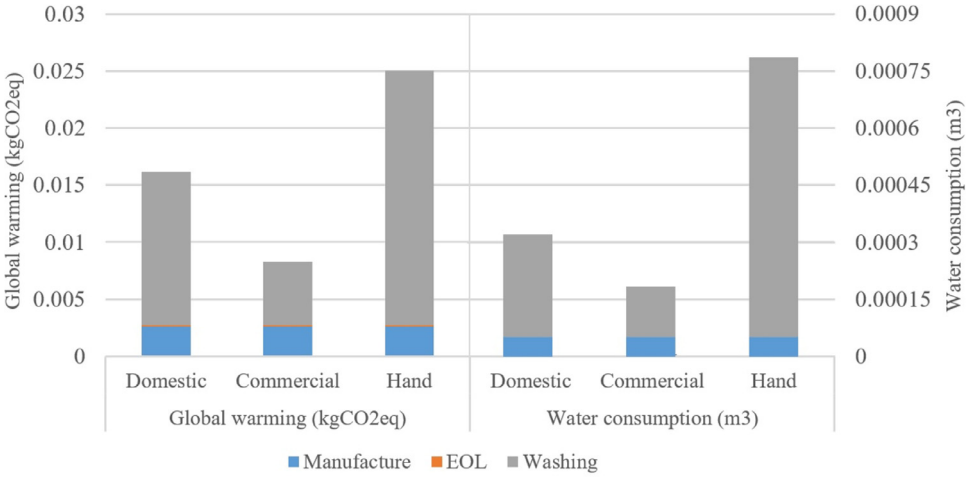

Fig. 8. Changes in global warming potential (left, with left axis) and water consumption (right, with right axis) for a single Tupperware container (average per use values for a box with 50 use lifetimes and landfill disposal) with three washing options: Domestic dishwasher (as in the refill case), Commercial dishwasher (as in the return case), and handwashing. Details as given in Table 2.

fill case, the commercial dishwasher used in the return case, and a domestic handwashing alternative. The domestic and commercial dishwasher results, as in the Return and Refill cases, show that the commercial dishwasher has a lower energy and water use per wash. Handwashing is likely to increase greenhouse gas emissions and water consumption relative to using a dishwasher, though since there is wide variation in the energy and water use of this process this result should be treated as indicative.

Table 4 shows the number of times that a reusable container needs to be used to break even with a single-use plastic container in terms of global warming potential. For all plastic reuse options considered, less than five uses are required for the carbon footprint of reuse to be lower than single-use. In the case of the steel

mess tin it must be used between 13 and 33 times to be better than the single-use containers. If a steel mess tin is replaced after 50 uses, then the carbon footprint becomes greater than that of an EPS clamshell from 50 – 64 uses before once again having a lower footprint. This is due to the high global warming impact of steel manufacture. Gallego-Schmid et al (2019) also compared single-use EPS and aluminium with a refill Tupperware container, finding 11 and 18 uses were required to break-even on global warming potential with aluminium and EPS respectively. The Tupperware considered in that work was 3.5 times heavier than that used here and the end-of-life scenarios and washing also differ. There may also have been differences in the calculation method of break-even which was not published.

Willingness to Engage in Reuse

When people were asked what they would be willing to do with the packaging of various products, recycling was the most commonly selected option (53%), followed by putting the packaging in the bin (34%), and then reusing the packaging (13%). These findings support the idea that recycling has become a deeply entrenched norm (Kunamaneni et al., 2019). When participants were willing to reuse packaging, then refilling and repurposing the packaging were the most commonly selected options (6% each for refilling and repurposing, compared to 1% for returning the packaging). To explore which types of packaging people were willing to reuse, the products were categorised according to what participants indicated they would be willing to do with the packaging of that product. This revealed 13 products that people were willing to reuse the packaging of, including biscuits in a metal tin, milk in a glass bottle, coffee in a glass jar, cleaning sprays and hand wash in plastic bottles. People were most willing to repurpose a biscuit tin, glass jars used for coffee, mayonnaise, and pasta sauce and a metal tin used for petroleum jelly. People were most willing to refill handwash and a tub of dishwasher tablets, and people were willing to return glass bottles used for milk. Table S1 in the ssupplementary material doi:10.1016/j.spc.2021.03.022 shows the percentage of people willing to reuse (refill, return, and repurpose) each of the products included in the study.

What factors influence what people are willing to reuse?

Aspects of the packaging. As can be seen in Table 5, the material, type of packaging, and the closure mechanism all had a significant influence on whether people were willing to reuse the packaging. Specifically, it was found that people were more willing to reuse packaging made from glass (37% of those surveyed) compared to packaging made from films, flexible plastic, or foil (<5% of those surveyed). In terms of the type of packaging and type of closure, people were more willing to reuse jars (36%), bottles (20%), and boxes or cartons (23%), compared to wraps (2%), cans (3%), and aerosols (4%). It was also found that people were most willing to reuse lids and dispensers, and that being able to reseal the packaging was associated with greater willingness to reuse. The dispensing method, whether the packaging was easy to open, and whether the packaging had a window through which the product inside can be seen were not associated with people's decisions with respect to reuse (p's $< .05$).

People were more willing to reuse packaging that was resistant to change over time. For example, we found that the durability of the packaging, whether the appearance of the packaging was likely to change with use, and whether the packaging was easy to clean were all associated with people's decisions with respect to reuse, such that people were more willing to reuse packaging that was durable, resistant to changes in appearance, and easy to clean. The implication of these findings is that materials technology is needed to develop containers that are resistant to frequent

Table 5
Percentage of participants willing to reuse packaging according to aspects of the packaging and product.

Aspect of the packaging/ product	N	Mean	SD	F	p
Nature of the product				0.03	.970
Food/Drink	49	13.00	17.06		
Personal care	19	13.94	11.51		
Home care	22	12.99	11.12		
State of matter of the contents				1.97	.124
Gas	5	3.10	2.29		
Liquid	30	16.95	13.70		
Solid	48	11.31	15.61		
Mixed	7	17.30	11.77		
Packaging material				6.06	<.001
Rigid plastic	37	14.46	10.91		
Film/ flexible plastic	25	4.76	4.21		
Glass	5	37.08	14.27		
Paper/ cardboard	11	15.27	13.39		
Aluminium/tin	11	16.41	25.75		
Foil	1	0	0		
Packaging format				7.02	<.001
Aerosol	6	3.70	2.52		
Pouch/ sachet	8	6.21	4.87		
Jar	4	36.48	4.00		
Bottle	20	19.87	13.19		
Can	2	3.35	3.18		
Tray	5	4.56	7.76		
Tube	5	8.00	7.20		
Bag	11	5.20	4.18		
Carton/ tub/ box	19	22.56	18.84		
Wrap	10	1.75	1.79		
Dispensing method				0.13	.880
Pour/ squeeze	29	14.34	12.17		
Spray/ pump/ roll	11	12.60	15.53		
Remove with hands/utensil	50	12.67	15.88		
Closure type				9.83	<.001
Lid/ cap	38	22.23	16.13		
Clip/ tape/ zip	6	7.20	3.36		
Dispenser (e.g., spray, pump)	11	12.60	15.53		
Ring pull	2	3.35	3.18		
Sealed plastic or foil	32	4.31	5.13		
Packaging has a window/ product can be seen inside				0.78	.381
Yes	38	14.79	14.82		
No	52	12.04	14.47		
Number of portions				6.30	.014
Single portion	15	4.81	6.87		
Multiple portions	75	14.88	15.18		
Shelf-life (if the product is unopened)				1.08	.343
Weeks	18	8.95	13.47		
Months	22	15.58	19.20		
Years	50	13.68	12.52		
Is the product a raw food?				0.37	.693
Yes	4	5.98	11.23		
Not raw, but requires heating	28	13.35	18.65		
No	17	14.08	15.79		
Can the packaging be resealed?				19.84	<.001
Yes	56	17.51	15.29		
No	27	4.02	5.08		
Is the packaging easy to open?				0.30	.558
Yes	81	13.48	14.63		
No	9	10.68	14.93		
Is the packaging durable?				34.96	<.001
Yes	37	21.16	17.12		
No	42	4.82	4.97		
Would the appearance of the packaging change over time?				19.01	<.001
Yes	40	5.95	6.22		
No	13	24.87	25.69		
Is the packaging easy to clean?				14.25	<.001
Yes	48	19.46	16.46		
No	17	4.19	3.71		
Where is the product typically used/ consumed?				1.46	.231
Only at home	66	15.00	15.89		
At home or on-the-go	13	9.45	10.02		

(*continued on next page*)

Table 5 (*continued*)

Aspect of the packaging/ product	N	Mean	SD	F	p
Frequency of Purchase				0.14	.939
Daily	12	13.72	23.70		
Weekly	23	12.14	14.72		
Monthly	34	14.61	12.00		
Yearly	12	12.88	11.36		

Notes: N = number of products in the category; M = Mean percentage; SD = Standard Deviation, F = F-statistic from univariate ANOVAs, indicating the magnitude of the difference between the categories, p = likelihood that the difference occurred by chance alone. In the present study a p value ≤ 0.05 (reflecting a 1 in 20 chance that the difference occurred by chance alone) is considered statistically significant.

reuse and repeated industrial washing for use in a return model. However, where this is not possible/feasible then consumers' beliefs about the implications of changes in appearance (e.g., that it is indicative of contamination) need to be challenged.

Nature of the product. Table 5 shows that people's decisions with respect to what they would be willing to reuse were not associated with the nature of the product (e.g., food or drink vs. personal or home care), state of matter of the contents (e.g., liquid or solid), shelf-life of the product, where the product is used or consumed, or the frequency with which it is typically purchased (p's $> .05$).

Discussion, Limitations and Future Work

The findings presented provide an exciting agenda for future research. For example, identifying packaging and packaging systems that have the lowest environmental impact allows future work to present consumers with computer-simulated and physical prototypes of reusable containers, along with hypothetical scenarios (e.g., ordering a takeaway), in order to explore what consumers would be willing to do.

Being one part of a multidisciplinary study, the Life Cycle Assessment conducted here does have some limitations. These stem largely from the Life Cycle Inventory data, which includes assumptions around materials, manufacturing processes, and end of life treatment. Sensitivity analyses were conducted to understand the impact of these assumptions wherever possible, and on all aspects of the study which have the potential to significantly influence the results. Manufacturer data on specific material details and primary data on manufacturing processes would enhance the reliability of the results of this study, but the present assessment gives a useful comparison between container types and systems of reuse.

The life cycle assessment demonstrated that both kinds of packaging reuse systems, refill and return, can have a reduced overall environmental impact providing that the containers are used a minimum number of times. Whilst the format of use was much more significant than the material used for the container in this scenario, it is anticipated that where the containers are transported any distance as part of the food delivery cycle, the weight of the containers will become more important and hence durable plastic will become more attractive as a material choice. Steel containers needed to be used many more times than the reusable plastic containers to reach the break-even point when compared to single-use plastic, due to both the raw materials and their heavier nature incurring greater transport emissions. Further work should consider a collective return model with a centralised washing facility and incorporation of a delivery option to compliment the takeaway collection considered here.

Whichever material is chosen for a reusable packaging container, the willingness of consumers to use that container multiple times is crucial. If a container has to be used five times to break even with single-use alternatives, but the appearance is unacceptable to the consumer after three, any scheme will become environmentally unviable, and probably economically unviable too. The number of uses before which the consumer rejects a container on appearance must always be higher than the break-even number of uses for the system to be viable. Changes in appearance of packaging over time (and related factors such as durability and ease of cleaning) were all found to be associated with people's willingness to reuse. Containers that are frequently refilled and reused are likely to become worn and discoloured over time as they are exposed to a range of physical and chemical conditions (Greenwood et al., 2020). Manufacturing durable containers that are designed for reuse requires significantly more energy and resources than packaging intended for single use and, therefore, must be used multiple times in order to extract sufficient value from the raw resources, as shown by the results of the LCA.

It is recognised that there is scant literature available on the properties of different plastics after many washing cycles and this is an area that requires a much larger body of research evidence. Understanding the number of uses before which the consumer rejects a container on appearance also requires more research.

At an even more basic level, the consumer needs to be willing to engage in a scheme to begin with. Findings presented here suggest that recycling is still the norm when people consider what they would do with the packaging of different products given the option. However, people were willing to reuse the packaging of some products (e.g., biscuits in a metal tin, milk in a glass bottle, coffee in a glass jar, cleaning sprays and hand wash in plastic bottles) and the findings suggest that willingness is primarily driven by aspects of the packaging (e.g., packaging material and type of packaging) rather than aspects of the product inside (e.g., nature of the product and state of matter of the contents).

This work sought to explore the factors that influence which method of reuse people prefer for different packaging (i.e., refill at home or on the go, return at home or on the go, or repurpose), however, reuse was rarely selected as an option (perhaps given that reuse is not common-place in the UK) meaning that there was insufficient data to permit meaningful comparisons. As reuse models become more mainstream, it would be valuable to extend the approach used here to identify factors associated with willingness to engage with specific reuse systems. Comparably, international contexts where reuse still plays a large role (particularly in the beverage sector) such as Germany, Denmark and Mexico (WRAP et al., 2008) may produce different results with more people accustomed to and therefore willing to engage in reuse. Alternatively, future research could present novel reuse models in order to explore what people would be willing to do. The need to describe different forms of packaging reuse before asking participants what they would be willing to do highlighted how official definitions (BSI, 2004) and how consumers describe reuse may diverge.

Development of a model, such as the EVR discussed by Wever and Vogtländer (2013) that is able to combine environmental impacts with willingness to engage into a combined factor would be very valuable. The 'value' used by Wever et al., is the product sale price, which inherently includes aspects such as a consumer's attitude to convenience and eco-consumerism, however it would be impossible to unpick willingness to engage with reuse from other behaviour.

The findings showed that consumers are more willing to repurpose and refill packaging than they are to return packaging. Where respondents were willing to return or refill packaging this was for products where reuse systems already exist (e.g., milk in glass bottles). One interpretation is that consumers' behaviour is relatively habitual, such that they are willing to engage in what they – or others like them – have done previously (e.g., reuse of milk bottles), but are less willing to do something new (e.g., reuse microwavable trays). As respondents did not typically envision using return and refill systems which were not already in use (or

had been in use previously), it follows that consumers may need to trial any new reuse system – or see it demonstrated - in order for them to become engaged.

The sample that were asked to complete the survey was obtained via opportunity sampling and as such, may not be representative of the UK population. Although there is no reason to suggest that our findings might differ according to age, gender or ethnicity, future research might seek to recruit a more representative sample. However, recruiting the majority of the sample from Prolific was advantageous in some ways because these participants were paid for their participation. As such they have not necessarily chosen to take part in this study because they are more environmentally conscious consumers (i.e., self-selection bias).

Constructing a vision which prioritises the reuse of plastic packaging must be underpinned by an understanding of public perceptions of plastic and associated actions such as recycling and reuse. Discourses that produce and reproduce worldviews around plastics and reuse are likely to shape people's responses, but are also likely dominated by the current norms of recycling. Linguistic research has shown that terms such as *recycling* and *reuse*, referring to complex processes, or *packaging* and *container*, referring to concrete objects, are first used in narrow, technical contexts, but then tend to undergo semantic change, in the form of semantic broadening and increasing vagueness, as they are used by the public in ever expanding contexts (Kortmann and Nerlich, 1993; Mehl, 2020; Pap and Ullmann, 1959; Sperber, 1938). Semantic broadening can be further complicated by affective associations of each word (Blank, 2013; Mehl, 2020). For example, *recycle* will have developed affective associations and increasingly vague meanings, among many or most English users, as it has moved from strict technical use into broad public use, and become a normative term for a wide range of processes and behaviours. In contrast, *reuse* is at an earlier stage in its semantic development, and may acquire broader meanings among more language users as the process of reuse, and the term *reuse*, become more mainstream. (Madria and Tangsoc, 2019) have shown that visual information on packaging, including language around *recycling* or *reuse*, can influence consumer behaviour. Therefore, further research is required to examine the semantics of these terms across language users, and to connect semantics to behaviour. Ultimately, connecting linguistic and behavioural findings can help to inform communication by manufacturers, policymakers, and campaigners.

Conclusions

Reusable packaging systems can be a viable way to reduce waste and the broader impacts of single-use packaging. The research presented here shows that both refill and return systems that use plastic containers for take-away food in the scenario investigated have a lower global warming potential than single use plastic containers after just 2 to 4 uses. The lightweight nature of durable plastics makes them good potential materials for reusable packaging containers, providing that the materials are sufficiently durable and that people are willing to use a container after multiple use cycles.

Reusable steel containers must be used considerably more times to break-even with single-use packaging on global warming potential, they are however, likely to be more durable and, if the consumer is willing to engage with their reuse, steel containers could also represent a viable option for reusable packaging systems.

The survey shows that consumers are more willing to recycle than to reuse packaging and that people are more willing to engage with systems with which they are already familiar, indicating that future study should involve consumers trialling a system or have it demonstrated to them. Consideration of the factors that influence consumers' willingness to engage with reuse (e.g., durability and ease of cleaning) points to potential ways that reuse might be promoted. Furthermore, clear understanding of what the term 'reuse' means is also important.

Together, the life cycle assessment and behavioural work presented here illustrate the need for a multi-disciplinary approach in order to determine where and how to implement reusable packaging systems with the aim of making their adoption mainstream.

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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.

There are no conflicting interests to declare.

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Supplementary Material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.spc.2021.03.022.

References

Accorsi, R., Cascini, 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. Prod. Econ. 152, 88–101. doi:10.1016/j.ijpe.2013.12.014.

Basco, Bakers, 2021. Bakers Basco Company History [WWW Document] URL https://www.bakersbasco.com/company-history/ .

Berkholz, P., Kobersky, V., Stamminger, R., 2013. Comparative analysis of global consumer behaviour in the context of different manual dishwashing methods. Int. J. Consum. Stud. 37, 46–58. doi:10.1111/j.1470-6431.2011.01051.x.

Berkholz, P., Stamminger, R., Wnuk, G., Owens, J., Bernarde, S., 2010. Manual dishwashing habits: An empirical analysis of UK consumers. Int. J. Consum. Stud. 34, 235–242. doi:10.1111/j.1470-6431.2009.00840.x.

Blank, A., 2013. Why do new meanings occur? A cognitive typology of the motivations for lexical semantic change. In: Blank, A., Koch, P. (Eds.), Historical Semantics and Cognition. Mouton de Gruyter, Berlin, pp. 61–89. doi:10.1515/9783110804195.61.

Bourgaul, G., 2011. Polypropylene, granulate, GLO [WWW Document] ecoinvent.org. URL ecoinvent.org.

BSI, 2004. BS EN 13429:2004 Packaging Reuse. BSI.

Caulibox, 2020. Caulibox company website [WWW Document]. Caulibox website URL https://www.wearecauli.com/ .

City to Sea, 2020. Contactless Coffee [WWW Document] URL https://conscioucup.ie/resources/contactless.php .

Coelho, P.M., Corona, B., ten Klooster, R., Worrell, E., 2020. Sustainability of reusable packaging–Current situation and trends. Resour. Conserv. Recycl. X. doi:10.1016/j.rcrx.2020.100037.

Corus, 2020. Greenmelt project (LIFE 96 ENV\B\477) Layman's report 7th April 2000.

Ecobox, 2020. Ecobox Website [WWW Document] Ecobox website. URL https://ecobox.lu .

Ecover, 2021. Ecover [WWW Document] URL https://www.ecoverdirect.com/products/non-bio-concentrated-laundry-liquid-15l-refill-up-to-420-washes/econnonbioliq15l.aspx?productid=econnonbioliq15l .

EMF, 2019. Reuse - Rethinking Packaging. Ellen MacArthur Foundation website.

EMF, 2018. New Plastics Economy Global Commitment.

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. doi:10.1016/j.jenvman.2017.01.060.

Union, European, 2004. European Parliament approves directive 196, 191 doi:10.1038/sj.bdj.4811054.

Fangmongkol, K., Gheewala, S., 2020. Life cycle assessment of biodegradable food container from bagasse in Thailand. Journal of Sustainable Energy & Environment 11, 61–69.

Fuentes, C., Enarsson, P., Kristoffersson, L., 2019. Unpacking package free shopping: Alternative retailing and the reinvention of the practice of shopping. J. Retail. Consum. Serv. 50, 258–265. doi:10.1016/j.jretconser.2019.05.016.

Gallego-Schmid, A., Mendoza, J.M.F., Azapagic, A., 2019. Environmental impacts of takeaway food containers. J. Clean. Prod. 211, 417–427. doi:10.1016/j.jclepro.2018.11.220.
Geyer, R., Jambeck, J.R., Law, K.L., 2017. Production, use, and fate of all plastics ever made - Supplementary Information. Sci. Adv. 3, 19–24.
Gibbons, F.X., Gerrard, M., Ouellette, J.A., Burzette, R., 1998. Cognitive antecedents to adolescent health risk: Discriminating between behavioral intention and behavioral willingness. Psychol. Heal. 13, 319–339. doi:10.1080/08870449808406754.
Golding, A., 1999. Reuse of Primary Packaging, Abfallberatung Müllvermeidung & Recycling.
Google, 2020. Google Maps [WWW Document] google.com. URL https://www.google.com/maps .
Greenwood, S., Baird, H., Parsons, R., Walker, S., Neal, T., Slark, A., Webb, T.L., Jackson, P., Evans, D., Rothman, R., Spain, S., Ryan, T., 2020. Buy the product but rent the packaging – making reusable plastic packaging mainstream. In: PRIF Conference: Creative Circular Economy Approaches to Eliminate Plastic Waste. UKCPN, pp. 26–37.
Haws, K.L., Winterich, K.P., Naylor, R.W., 2014. Seeing the world through GREEN-tinted glasses: Green consumption values and responses to environmentally friendly products. J. Consum. Psychol. 24, 336–354. doi:10.1016/j.jcps.2013.11.002.
Hobart, 2019. LXe Series Undercounter Commercial Dishwashers Technical Specification [WWW Document] URL https://www.hobartcorp.com/products/commercial-dishwashers/undercounters/lxe-base-undercounter .
Huijbregts, M.A.J., Steinmann, Z.J.N., Elshout, P.M.F., Stam, G., Verones, F., Vieira, M., Zijp, M., Hollander, A., van Zelm, R., 2017. ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level. Int. J. Life Cycle Assess. 22, 138–147. doi:10.1007/s11367-016-1246-y.
Hukkelberg, S.S., Dykstra, J.L., 2009. Using the Prototype/Willingness model to predict smoking behaviour among Norwegian adolescents. Addict. Behav. 34, 270–276. doi:10.1016/j.addbeh.2008.10.024.
International Transport Policy Standards, 2020. International Transport Policy Standards [WWW Document] URL www.transportpolicy.net .
Johnson, J., Reck, B., Wang, T., Graedel, T., 2008. The energy benefit of stainless steel recycling. Energy Policy 36 (1), 181–192.
Khan, O., Daddi, T., Slabbinck, H., Kleinhans, K., Vazquez-Brust, D., De Meester, S., 2020. Assessing the determinants of intentions and behaviors of organizations towards a circular economy for plastics. Resour. Conserv. Recycl. 163, 105069. doi:10.1016/j.resconrec.2020.105069.
Kortmann, B., Nerlich, B., 1993. Semantic Theories in Europe 1830-1930: From Etymology to Contextuality. Benjamins. ed, Language. Amsterdam. doi:10.2307/416923.
Kunamaneni, Suneel, Jassi, Sukky, Hoang, Dong, 2019. Promoting Reuse Behaviour: Challenges and Strategies for Repeat Purchase, Low-involvement Products.. Sustainable Production and Consumption 20, 253–272.
Langley, J., Turner, N., Yoxall, A., 2011. Attributes of packaging and influences on waste. Packag. Technol. Sci. 24, 161–175. doi:10.1002/pts.924.
Lightart, T., Ansems, A., 2007. Single use Cups or Reusable (coffee) Drinking Systems: An Environmental Comparison TNO Report 2006 -A-R0246(E)/B.
Lindh, H., Olsson, A., Williams, H., 2016. Consumer Perceptions of Food Packaging: Contributing to or Counteracting Environmentally Sustainable Development? Packag. Technol. Sci. doi:10.1002/pts.2184.
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. doi:10.1002/pts.857.
Madria, W., Tangsoc, J., 2019. Factors to Consider in the Design of Plastic Packaging Intended for Reuse of Consumers. In: 2019 IEEE 6th International Conference on Industrial Engineering and Applications, ICIEA 2019, pp. 877–882. doi:10.1109/IEA.2019.8715074.
Mehl, S., 2020. Appropriation, gentrification, colonisation: Newly synonymous?. Lexis.
Meyhoff Fry, J., Hartlin, B., Wallén, E., Aumônier, S., 2010. Life cycle assessment of example packaging systems for milk. Doorstep Distribution System [online] Oxon.
Nisbets, 2020. www.nisbets.co.uk [WWW Document]. URL https://www.nisbets.co.uk/consumables/catering-disposables/disposable-food-packaging/takeaway-food-containers/_/a33-4?cm_sp=NHP Banner Carousel-_-Takeaway Food Containers-_-Takeaway Food Containers (accessed 10.23.20).
Pap, L., Ullmann, S., 1959. The Principles of Semantics. American Speech. Glasgow University Press, Glasgow doi:10.2307/453707.
Peer, E., Brandimarte, L., Samat, S., Acquisti, A., 2017. Beyond the Turk: Alternative platforms for crowdsourcing behavioral research. J. Exp. Soc. Psychol. 70, 153–163. doi:10.1016/j.jesp.2017.01.006.
Pomery, E.A., Gibbons, F.X., Reis-Bergan, M., Gerrard, M., 2009. From willingness to intention: Experience moderates the shift from reactive to reasoned behavior. Personal. Soc. Psychol. Bull. 35, 894–908. doi:10.1177/0146167209335166.
Poole, J., 2019. Refill and reuse: Unilever launches Cif ecorefill, removing 1.5 million plastic spray bottles from shelves [WWW Document]. Packag. Insights. URL https://www.packaginginsights.com/news/refill-and-reuse-unilever-launches-cif-ecorefill-removing-15-million-plastic-spray-bottles-from-shelves.html (accessed 10.2.20).
Price, L.L., Ridgway, N.M., 1983. Development of a Scale To Measure Use Ineovativeness. Adv. Consum. Res. 10, 679–684.
Sea Distances, 2020. sea-distances.org [WWW Document]. URL https://sea-distances.org/ (accessed 10.2.20).
Sheeran, P., Webb, T.L., 2016. The Intention–Behavior Gap. Soc. Personal. Psychol. Compass 10, 503–518. doi:10.1111/spc3.12265.
Shipton, J.M., 2007. Understanding the secondary functions of packaging : UK domestic reuse. PQDT - Glob, Sheffield Hallam.
Smithers, R., 2020. UK launches first online service for groceries in reusable packing. The Gaurdian.
Sperber, H., 1938. The Semantic Development of VerhältnisThe Semantic Development of Verhaltnis. Language (Baltim) 14, 167. doi:10.2307/409442.
Stefanini, R., Borghesi, G., Ronzano, A., Vignali, G., 2020. Plastic or glass: a new environmental assessment with a marine litter indicator for the comparison of pasteurized milk bottles. Int. J. Life Cycle Assess. doi:10.1007/s11367-020-01804-x.
Thomson, H., Illingworth, K., McCoach, H., Jefferson, M., Morgan, S., 2018. PlasticFlow 2025: Plastic Packaging Flow Data Report. Wrap 58.
USPP, 2020. US Plastics Pact [WWW Document] URL https://usplasticspact.org/ .
Weidema, B.P., Wesnæs, M.S., 1996. Data quality management for life cycle inventories-an example of using data quality indicators. J. Clean. Prod. 4, 167–174. doi:10.1016/S0959-6526(96)00043-1.
Wever, R., Vogtländer, J., 2013. Eco-efficient value creation: An alternative perspective on packaging and sustainability. Packag. Technol. Sci. 26, 229–248. doi:10.1002/pts.1978.
Which?, 2020. Which? research reveals how little water dishwashers use compared to hand-washing [WWW Document] URL https://www.which.co.uk/news/2020/09/which-research-reveals-how-little-water-dishwashers-use-compared-to-hand-washing/ .
Wrap, 2020. The UK Plastics Pact | WRAP UK [WWW Document] Wrap. URL https://www.wrap.org.uk/content/the-uk-plastics-pact .
WRAP, 2010. Single Trip or Reusable Packaging - Considering the Right Choice for the Environment. WRAP website.
WRAP, Lee, P., Vaughan, P., Bartlett, C., Bhamra, T., Lofthouse, V.A., Trimingham, R., 2008. Refillable glass beverage container systems in the UK.
EC-JRC. (2012). Product Environmental Footprint (PEF) Guide. European Commision Joint Research Centre, 154. Retrieved from http://ec.europa.eu/environment/eussd/pdf/footprint/PEF methodology final draft.pdf retrieved 07/04/2021.