Assessing Climate Impact: Reusable Systems vs. Single-use Takeaway Packaging

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Report for

Technical Review

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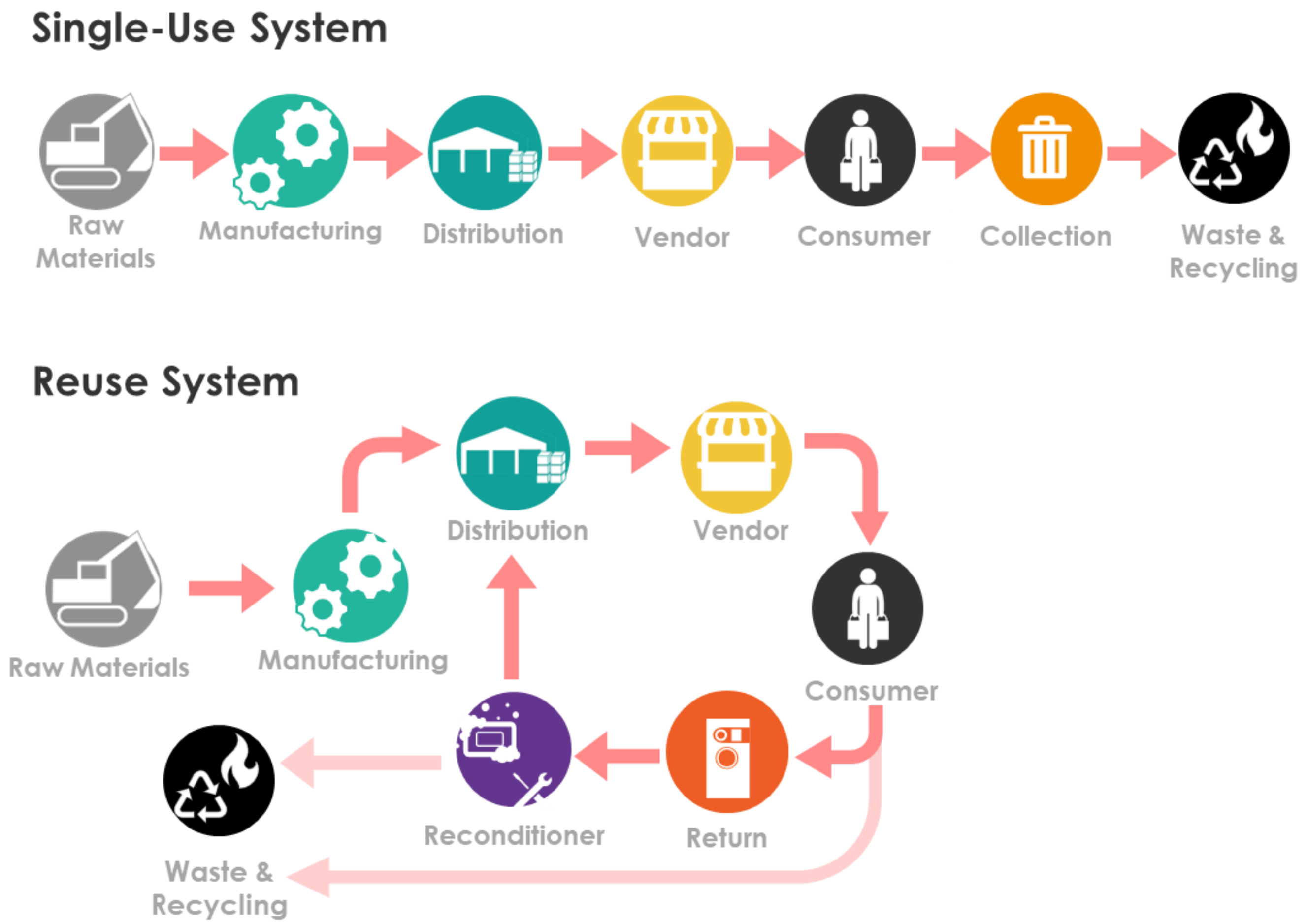
Executive Summary

This study involved modelling to measure the greenhouse gas (GHG) emissions from reusable takeaway packaging compared to single-use equivalents. The results indicate that, for most types of takeaway packaging used in Europe, reuse through a safe, efficient system for collection, washing, inspection, and redistribution has potential to yield greater environmental benefits than recycling or discarding single-use containers. The study also highlights key aspects to optimise in designing and operating reuse systems.

The research simulated a reuse system that employs logistical networks to manage the efficient reuse of takeaway containers. The figure below depicts the lifecycle stages of containers in both a single-use and a reusable system.



When a consumer buys a takeaway coffee (for example), some GHGs have already been emitted to extract raw materials, transform them into the cup via manufacturing, and distribute it. More GHG will be emitted as the cup is managed as waste at the end of life. A cup that is used only once embodies all the emissions from its manufacture, distribution, and end-of-life management. It may be recycled, although single-use takeaway containers are often thrown away, with some ending up as litter due to inadequate waste management.

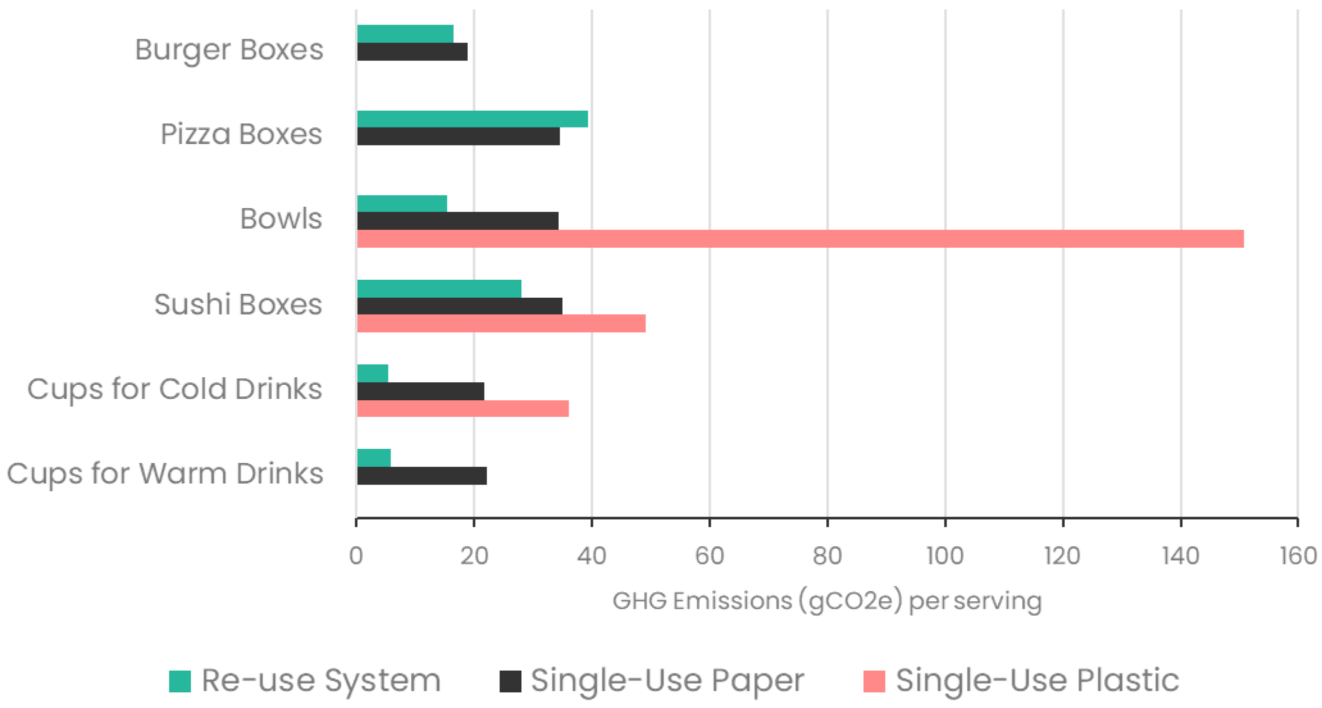
In a reusable system, each container is used for multiple servings of food or drink (multiple consumption events). Fewer raw materials are used to enable each consumption event, and fewer containers need to be manufactured and then eventually managed as waste. This means that each container's embodied emissions are spread over numerous consumption events rather than just one.

Results

The study modelled the climate change impacts associated with providing a single serving of takeaway food or drink across all six packaging formats used in Europe: bowls; boxes for pizza, burgers, and sushi; and cups for warm and cold drinks. All results were normalised to individual servings of takeaway items; For instance, reusable packaging impacts are allocated per serving based on the packaging's total lifetime servings.

The scope of the study envisions a scenario in 2030, reflecting a near-future setting. By then, it is possible that reusable packaging systems will have reached steady-state and electrified transport and decarbonised electricity grids will be more prevalent, aligning with international targets. This time frame was chosen to emphasise the relevance of understanding future impacts rather than current ones.

The study found that, for all formats except pizza boxes, switching from single-use (both plastic and paper) containers to reusable ones in an efficient system has good potential to reduce GHG emissions – see the figure below. The extent of possible reduction varies between container types, with cups showing the largest reductions. Some types, such as pizza boxes, are likely to need further design improvements to fully realise the benefits of reuse.



Assumptions and Sensitivities

Climate impact assessments of reusable vs single-use packaging often rely heavily on assumptions that significantly affect results. Certain assumptions help model aspects of consumer behaviour for which data is sparse, such as return rates, home washing, and dedicated return journeys. The lack of good data in these areas does create some uncertainty. To address this, the study tested the sensitivity of some key assumptions used in the modelling to identify break-even points – the point at which the assumption changes the outcome.

The key sensitivities explored were changes to the energy grid, the proportion of dedicated car journeys, the throughput of the professional washing process, and reuse return rates/rotations. These sensitivities give system designers a good benchmark to aim for to ensure that reuse is the optimum solution. Table E-1 shows how many rotations are necessary for each reusable item to outperform single use; this should be the *minimum* design-life specified.

To demonstrate how design can influence the outcome, the weight of a reusable pizza box was also varied – its large and bulky mass makes it the most challenging item to reuse. The results show that decreasing the weight of the reusable pizza box by 20% (85g) could reduce the GHG impacts from a reusable system below those from a single-use system.

Table E- 1: Breakeven analysis on the reuse return rates for different reusable packaging formats

Product	Breakeven # Rotations	Breakeven Return Rate
Burger Boxes	30	97%
Pizza	63	98%
Bowls	13	92%
Sushi Boxes	35	97%
Cups for Cold Drinks	6	83%
Cups for Warm Drinks	6	83%

Conclusions

The results of this study show there is definite potential for a reusable system to outperform a single-use system in the takeaway sector. However, such a system must be designed and implemented well. Some of the key assumptions are driven by aspects of behaviour that require a mindset change, one that must be ingrained into societal norms. While the study demonstrates the art of the possible, this cannot happen without thinking beyond simply swapping one packaging type for another.

The results can be used to help guide those implementing reusable systems by indicating the potential for reducing GHG emissions and highlighting the important system design considerations that are required to facilitate success. There now appears to be enough evidence to move the conversation move from a discussion of reuse vs single-use towards: *How can we implement re-use in the most effective way?*

Real-world trials, such as the Aarhus project in Denmark, are needed to further evaluate the findings, refine the system, and measure the benefits, although small trials and pockets of activity are unlikely to show the long-term benefits this study demonstrates are possible. The evidence presented here and gathered through trials should be used to inform the development of standards for effective reusable systems. This will be where the true gains are likely to be realised.

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1.0 Introduction

The study has been commissioned by TOMRA with the goal of understanding:

- The relative climate change impact of single-use and reusable takeaway food packaging when reusable packaging is implemented at scale, and
- What are the key conditions that need to be met and how sensitive are the results if those conditions are not met.

This study has considered the climate change impacts of common takeaway packaging containers (see Figure 1 for examples). A model has been developed to show the comparative impacts of equivalent single-use and reusable packaging formats, highlight the sensitivities involved in modelling these impacts, and clarify the necessary components of an effective reuse system. Both paper and plastic based single-use packaging have been chosen as a comparison to a reusable system.

Figure 1: Examples of single-use and reusable packaging

The study considers only the relative impacts of takeaway packaging in relation to climate change. This has been chosen as it is a relatively well-understood type of impact, which provides a reasonable proxy for other life-cycle impacts (such as those related to resource efficiency and air pollution). However, it is worth noting that the environmental impacts of packaging are not limited to climate change, and there may be other trade-offs between the two systems.

Although it is essential to conduct life cycle assessments (LCAs) using real-world comparative trials, reuse systems are at an early stage of development; therefore, comparing what exists today directly with highly optimised single-use systems cannot be considered a robust approach.[1] As centralised reuse systems for takeaway packaging do not so far exist at scale and at a steady state, there are uncertainties about how they will perform, particularly with regard to the behaviour aspects of consumer interactions. This study has considered the key assumptions that impact which system will perform better (e.g. return rates, washing cycles) and varied these to provide an indication of the key performance indicators necessary to show benefits over single use. Certainty over these key assumptions will only come from operating reuse systems over a prolonged period to achieve steady-state and, if necessary, further optimising the systems to reduce their GHG emission impact.

[1] Zero Waste Europe 2023 2023-SB-ZWE-The-economics-of-reuse-systems.pdf (zerowasteeurope.eu)

2.0 Scope of the Study

The functional unit of the study applies to all six packaging formats: bowls; boxes for pizza, burgers, and sushi; and cups for warm and cold drinks. It can be defined as:

Providing a consumer with one serving of takeaway food or drink.

All results are therefore normalised to individual servings of takeaway food or drink. For example, for reusable packaging the impacts of producing the physical packaging itself allocated to an individual serving according to the number of servings the packaging delivers over its lifetime.

Regarding the temporal scope of the study, a time horizon of 2030 has been selected. The design and impacts of the system represent a plausible scenario in 2030. This year has been chosen as representative of a 'near-future' scenario, in which reusable packaging system will have had sufficient time to optimize performance, key technologies such as electrified freight vehicles will be more widespread, and the electricity grid would be decarbonised in line with international targets. A 2030 time horizon has been chosen in recognition that, if consumption patterns are to shift towards relying more on reusable and less on single-use packaging, then understanding the impacts going forward are more relevant than understanding the impacts today.

The geographical scope of the project is Europe. Aspects such as the GHG intensity of electricity generation, average waste treatment methods, and average transport modes and distances have therefore been chosen to represent an average for Europe. It is important to recognise that countries within Europe vary considerably and thus the findings will not necessarily apply to all European countries. Given this, reusable systems are likely to perform better in terms of climate impacts in some countries than in others. Table 1 summarises the packaging formats analysed; these were chosen to represent the types of takeaway packaging currently placed on the market.

Table 1: Details of Packaging Evaluated in the Analysis

Packaging Format	Type	Volume (ml)	Mass (g)	Primary Material	Secondary Material
Cups for Cold Drinks	Single-use (Paper) [a]	426	12.1	Bleached sulphite pulp	PLA Lining
	Single-use (Plastic) [a]	501	14.1	PET	N/A
	Reuse [a]	470	57.3	PP	N/A
Cups for Warm Drinks	Single-use (Paper) [a]	395	18	Bleached sulphite pulp	PLA Lining
	Reuse [c]	300	61	PP	N/A
Bowls	Single-use (Paper) [a]	909	20.8	Kraft	PLA Lining
	Single-use (Plastic) [b]	750	42	PP	N/A
	Reuse [c]	1,250	182.6	PP	N/A
Sushi Boxes	Single-use (Paper) [b]	1,118	26	Kraft	PLA
	Single-use (Plastic) [b]	850	13	PLA	N/A
	Reuse [c]	1,343	158	Stainless Steel	Tritan Plastic (Lid)
Pizza Boxes	Single-use (Paper) [b]	4,500	40	Cardboard	N/A
	Reuse [d]	~3500	425	PP	N/A
Burger Boxes	Single-use (Paper) [b]	1,044	18	Paperboard	N/A
	Reuse [c]	1,103	119	PP	N/A

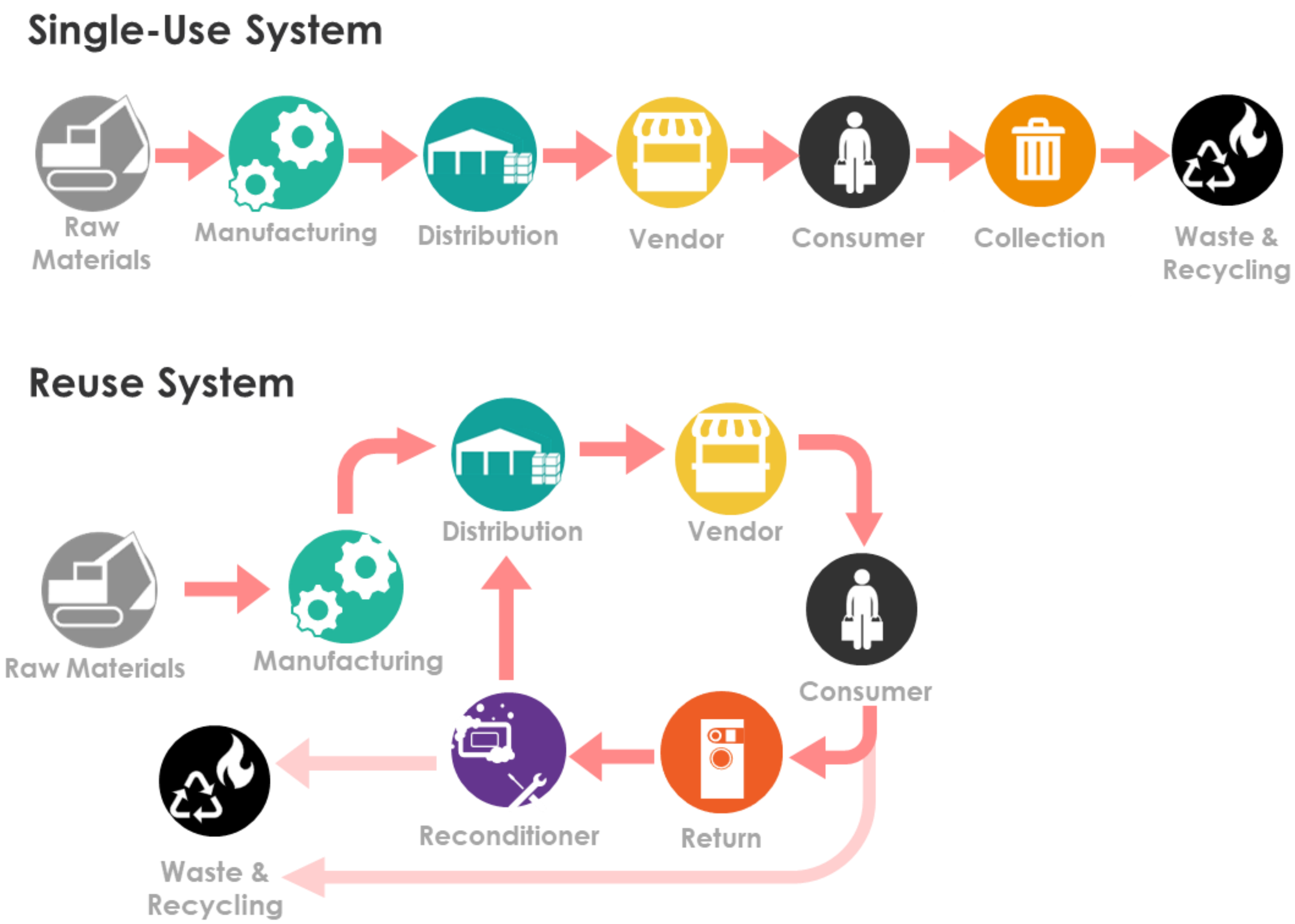
a) UpScoreCard: A project analysing the impacts of reusable vs single-use takeaway packaging
b) Data taken from single-use takeaway packaging wholesalers
c) Vytal: A German reuse scheme that uses high quality reusable takeaway containers
d) Koziol: A German company that designs many types of products, including sustainable plastic packaging

What is a Reusable System?

The study modelled a reuse system that involves using logistical networks to manage the centralised collection, washing (reconditioning), and distribution of takeaway packaging. For single-use takeaway packaging, the raw materials are typically converted into a package through a manufacturing step and sent to vendors, who sell the packages to a consumer. The consumer then typically disposes of the package into waste or recycling systems, and some items are lost to the environment through poor waste management or as litter. By contrast, a reusable system enables the collection, washing, and distribution of the packaging for reuse, thus reducing the number of containers used and the amount of raw material required for each serving (e.g. drinking one cup of coffee).

Figure 2 describes the lifecycle stages of both the single-use and reusable systems. A description of each stage can be found in Table 2.

Figure 2: Lifecycle of Single-use and reusable packaging systems



Key Assumptions

Climate impact assessments of reusable vs single-use packaging are, often, heavily reliant on a few key assumptions which have significant impact on results. Assumptions are often required to model behavioural aspects such as return rates, home washing and dedicated return journeys, for which there is a lack of data resulting in uncertainty. It is therefore crucial that studies are transparent about the assumptions that have been made and to test those assumption through sensitivity assessments.

The key assumptions for this study have been outlined in Table 2 The Sensitivity section explains these in more detail and why these were chosen for the base case, followed by testing what happens to the results if the assumptions change.

Table 2: Summary of the Key Assumptions (see Sensitivities section for full explanation)

Assumptions	Values
System Return Rate	98%
% Packaging Taken Home/Business	25%-75%
Preliminary Washing	90% compliance with advice to cold rinse or dishwash for bowls and burger
Professional Washing Efficiency	Modern flight type washing
% Dedicated Car Journeys	3% returned 2km
System Collection Method	Electric van
Collection Rate for Non-Returned Reusables	75% collection rate

3.0 Results and Sensitivities

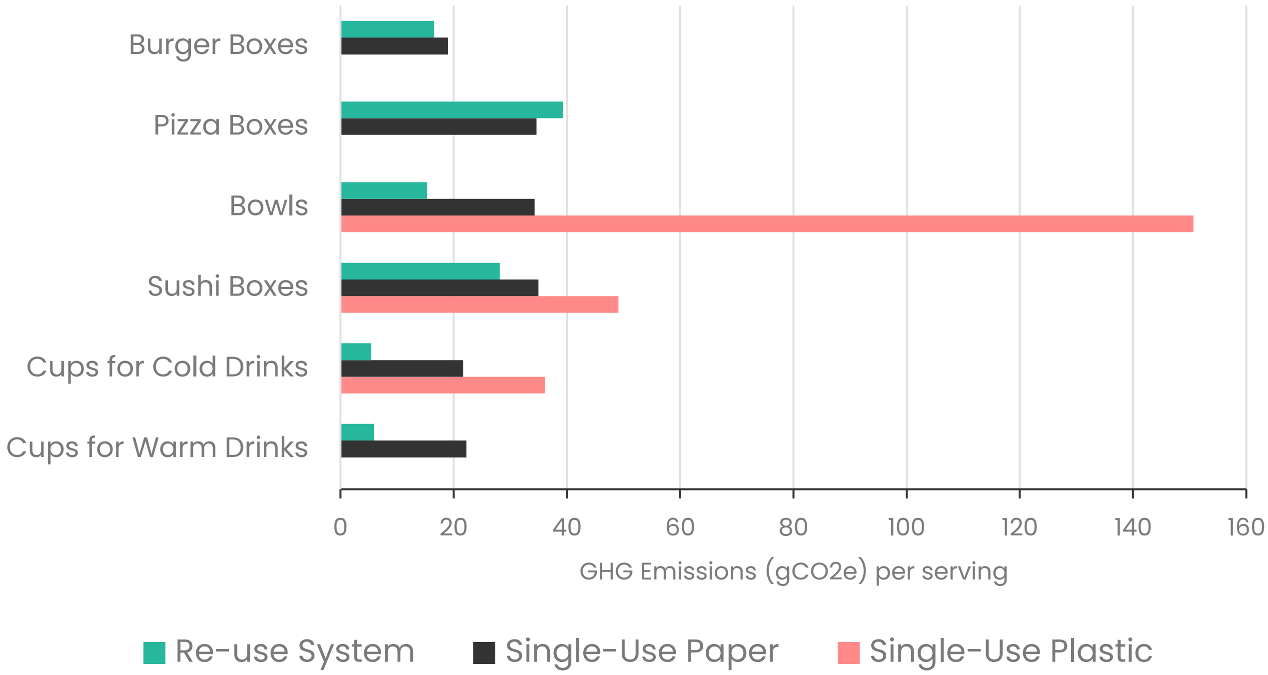
The analysis shows that the climate change impacts vary depending on the material and packaging format. The modelled emissions vary for different types of containers, and for single-use paper[2] and plastic versions where both options exist. Figure 3 shows a comparison per consumption event between each single-use and reusable item.

Generally, reusables outperform single-use paper and plastics. Note that the comparison does not include *plastic* single-use burger boxes, pizza boxes, or cups for warm drinks, as data shows that negligible quantities of these formats are placed on the market – they are mostly packaging in paper/card.

For single-use cups (for both warm and cold drinks) the reduction in GHG emissions is at least 70% and therefore are likely to be the most suitable items for reuse without much system optimisation. Reusable bowls show a 55% reduction compared with paper and 90% compared with plastic – an item that also requires little additional improvement or optimisation. For sushi containers and burger boxes, reusable versions still produce lower GHG emissions in comparison to single-use options, but the difference is reduced to 20% and 13% respectively – these items could therefore benefit from improved design to increase that gap. System optimisation will be more important for these items. The single-use pizza boxes are the only item to show lower GHG emissions compared to reusable one. Further work is therefore required to improve the system and the packaging design to make reuse a viable option here.

These discussed results are based on a set of assumptions chosen to simulate a full-scale steady-state system. As such a system does not yet exist, the assumptions are based on published literature and the performance of other, similar systems such as beverage DRS. The Sensitivities section therefore explores theses key assumptions to evaluate the system modelled and stress-test their importance.

Figure 3: Comparison of Single-use and Reusable Packaging per serving



[2] The term paper here has been used throughout this report to various paper-based materials, including cardboard, boxboard, and solid bleached sulphate (as can be seen in the Study Scope section of this report).

Contributional Analysis

The relative contributions of each life-cycle stage are shown in Figure 4. Typically, raw material and manufacturing have the largest contribution to the results particularly for single use packaging. For reusable packaging this stage is less pronounced and replaced in part by the professional washing stage.

These aspects are further discussed in Table 3.

Figure 4: The relative contribution to each stage of the lifecycle for each packaging format

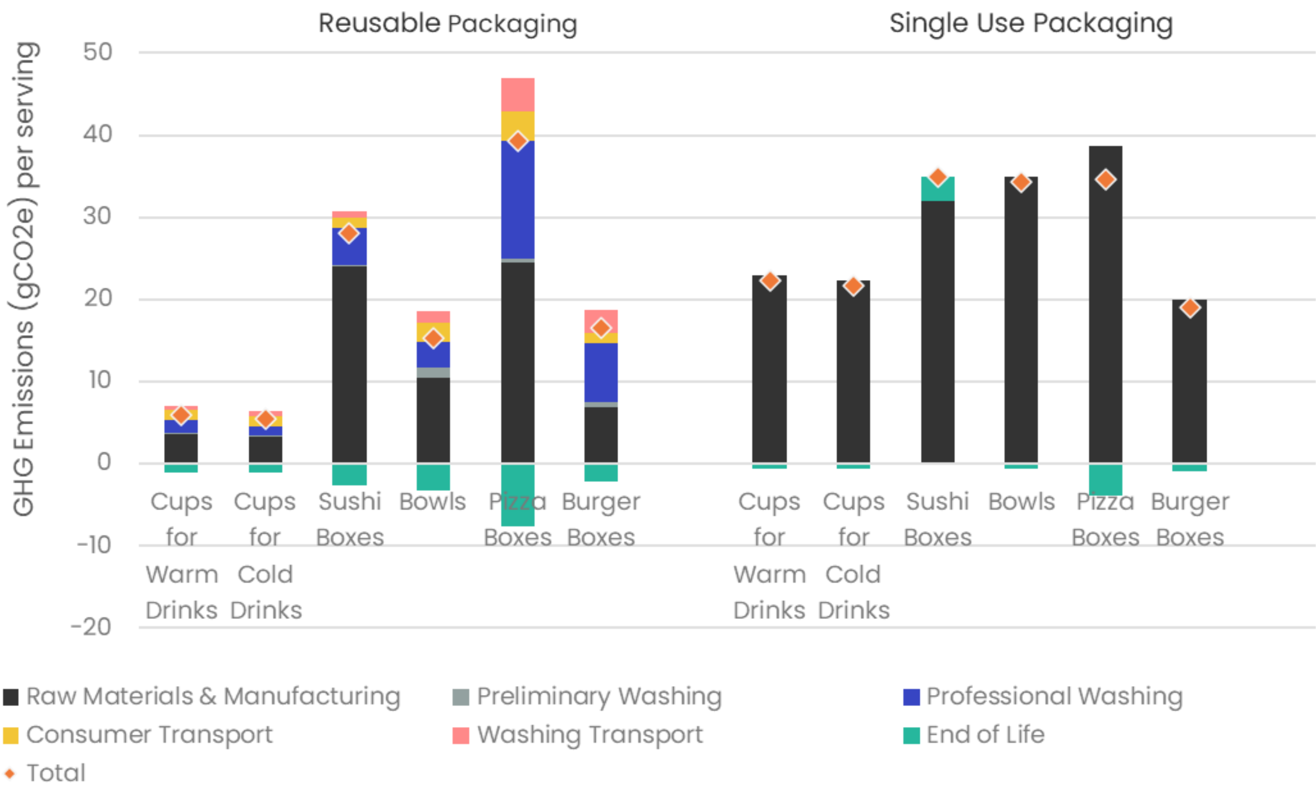


Table 3: Description and summary of the relative GHG impact of each stage in the product life cycle

Life-cycle stage	Description	Summary of impact
Raw Material & Manufacturing	The impacts associated with both the extraction of the raw materials required to manufacture a unit of packaging (aluminium, PP), as well as the manufacturing process itself (extrusion, injection moulding, etc.)	• The impact of this stage is almost always the most significant when compared to other parts of the life cycle and is mostly proportional to the weight of a given container. • The results differ between each packaging format due to variation in the weights of each single-use unit when compared to its reusable equivalent. • Reusable packaging is significantly heavier than single-use, requiring more raw materials to produce; plastic/metal containers are also more GHG emissions intensive to manufacture when compared to paper equivalents. • When comparing one reusable container with one single-use equivalent, the impacts from this stage of the lifecycle are significantly greater for the reusable container. This can be overcome by a scheme that achieves a high number of

Life-cycle stage	Description	Summary of impact
		rotations, so that one unit of reusable packaging will displace many single-use units.
Preliminary Washing	The impact of a consumer washing a unit of reusable packaging with either a dishwasher or cold tap water, prior to returning it to a collection point. This only applies to the proportion of units that are taken home to be consumed after being purchased (more detail on this in the next section).	• This stage typically has the lowest GHG impact compared to the overall lifecycle, as cold washing is considered sufficient for most packaging formats and assuming that each container is air-dried and only a small proportion are taken home before consumption; cold water use also has a relatively low GHG emissions impact.
Professional Washing	The impacts from cleaning each unit of reusable packaging with an industrial washing machine at a reconditioning facility, prior to the units being redistributed to vendors.	• This stage contributes significantly to the overall impacts, and combined with the raw materials and manufacturing stage makes up most of the emissions generated over a container's life cycle. This is more impactful for larger items such as pizza and burger boxes, which are relatively inefficient to stack in an industrial washing machine (more detail in the next section). The impacts are primarily due to the high energy usage (as well as detergent) required for washing such a large volume of containers.
Consumer Transport	The impact from a very small percentage of consumers making a dedicated car journey to return a unit of packaging to a collection point, before it is sent to a reconditioning facility.	• This part of the life cycle has the potential to contribute significantly to the overall impacts, even assuming that just 3% of packages taken home are returned via a dedicated return journey, as an entire journey is being used to return one or two containers. However, its impact was shown to be fairly insignificant after modelling the electrification of personal cars and the decarbonization of the electricity grid.
Washing Transport	The impacts of each container arise through: a) retrieval from a collection point, b) transportation from a collection point to a reconditioning facility, and c) collection from the reconditioning facility and redistribution to a vendor – all using an electric van.	• Washing transport contributes a reasonable amount to the overall impacts, but is still insignificant compared to other stages. The impacts are greater for larger and more awkwardly shaped items such as pizza and burger boxes, as these formats are relatively inefficient to stack in return vehicles and fewer can be sent to a washing facility in each journey.
End of Life	The impact of a unit of packaging being recycled, incinerated, or landfilled at the end of its life.	• The impacts at this stage of the lifecycle are more favourable for reusable formats, as relatively more units are assumed to be recycled compared to single-use equivalents. The GHG emissions associated with recycling reusable contains are also relatively lower per item, due to the greater mass of material being recycled per container when compared to single-use formats (though this is also dependent on the material). Thus heavier reusable formats like pizza boxes have a more beneficial climate change impact at the end of their life compared to other formats.

Sensitivities – Varying the Key Assumptions

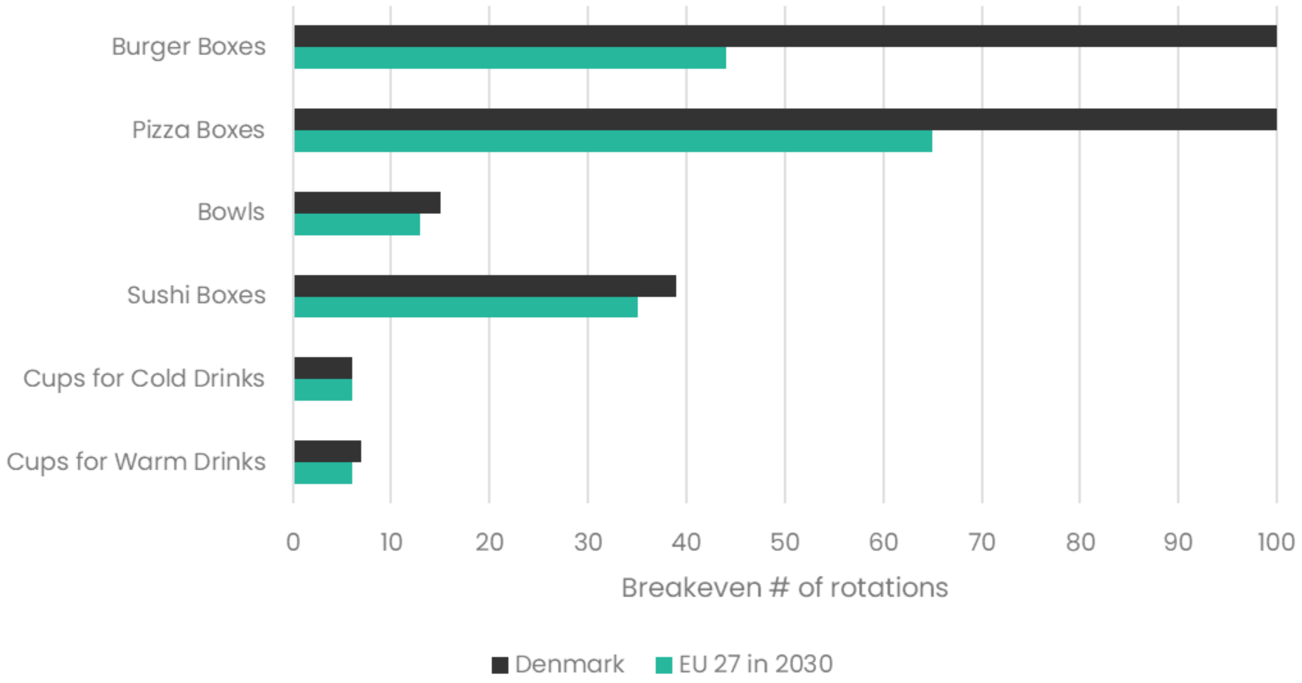
The analysis explored several assumptions and sensitivities, including return rates for the reusable items, decarbonisation of the energy grid, and professional washing assumptions. The following section looks at the impact on the results of varying these assumptions.

Decarbonisation of the energy grid

The modelled reusable system uses energy for the professional washing process and transport of the reusable packaging. In the model, a value of 0.075 kgCO_2e per kWh has been applied to the electricity consumed to wash and transport the; this reflects the intensity that the EU27 countries would need to (on average) attain in order to meet their 2030 Paris climate targets. This figure was taken from a 2020 document[3].

Figure 5 shows how the breakeven number of rotations varies with each packaging format, when the GHG emission intensity of the grid is changed from the baseline EU-27 targeted grid intensity in 2030 to a less decarbonised mix – in this case the current Denmark energy mix (0.143 kgCO_2e per kWh).[4] It depicts the sensitivity between a higher-carbon energy mix country (such as Denmark) and a lower average energy mix EU country. This shows that a decarbonised grid will be particular important for products such as burger and pizza boxes, which are relatively less efficient to wash and transport.

Figure 5: Break-even point variance based on future decarbonisation of power grids



[3] Climate Analytics (2020). *Decarbonisation Pathways for the EU Power Sector.*

[4] Association of Issuing Bodies (AIB) 2021 (Production factor) AIB_2021_Residual_Mix_Results_1_1.pdf (aib-net.org)

Note: It is acknowledged that the study is limited in applying the impacts of decarbonisation to only the electricity consumption associated with washing and washing transport – decarbonisation would also reduce the impacts associated with the production of packaging, as well as the end-of-life stages. This limitation is considered accepted for two reasons:

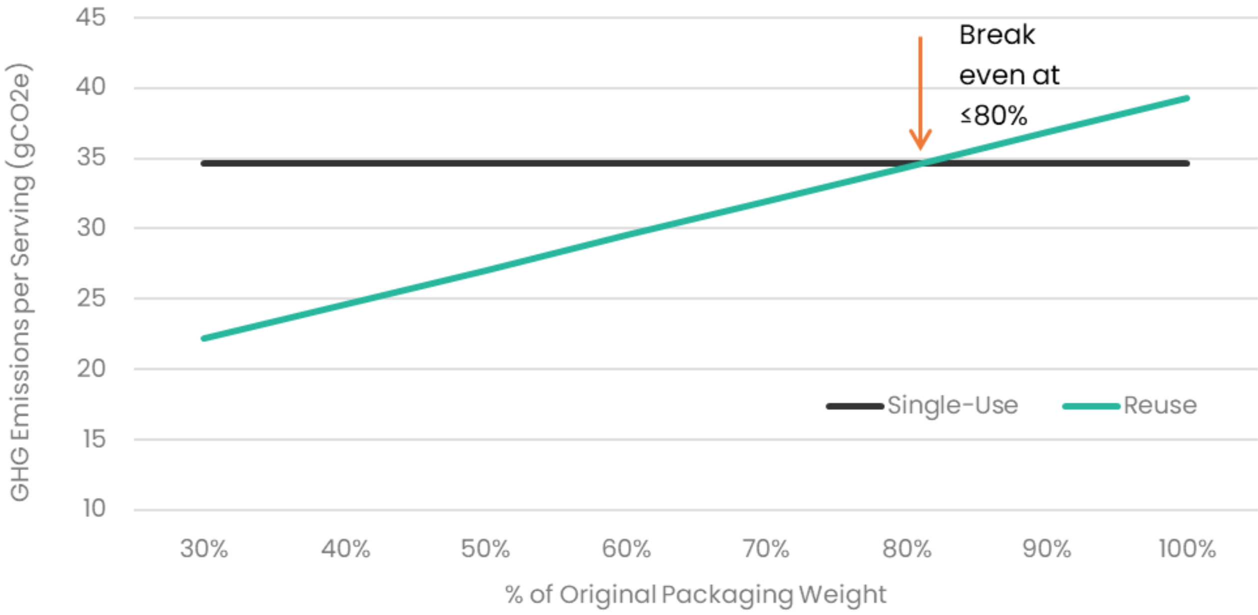
(1) It highlights the impacts of electricity use within the control of the reuse system operator, emphasising the need to power a reusable system with low-carbon electricity, and
(2) Initial research suggested that decarbonisation would have similar affects on both systems, so there was no reason to suggest that including it in all other stages would significantly impact results.

Raw materials and manufacturing

The selection of representative products is a key assumption in this study. The assumptions have been selected based on available information from widely used single-use and reusable packaging (See Table 1). The weight of the packaging item is one of the largest impacts in both the single-use and reusable system, as it is used to calculate the GHG impact of the raw materials and manufacturing. Emissions factors were calculated using EcoInvent data[5], a widely used database of materials and conversion processes. Therefore, packaging weight become a key sensitivity for both the reusable and single-use packaging formats.

In Figure 6, sensitivity analysis shows that decreasing the weight of the reusable pizza packaging the reusable system has lower GHG impact below 80% of the original packaging weight (a decrease in 85g, or 20%). As reusable packaging has not been widely optimised, it is possible that a decrease of 85g is possible and should be considered in designing the reuse system.

Figure 6: Breakeven analysis of the increase in weight of reusable pizza packaging



[5] EcoInvent 3.7.1, APOS, IPCC 2013.

Preliminary washing

Preliminary washing, distinct from professional cleaning, refers to customers cleaning takeaway containers before returning them. This often occurs when consumers enjoy their food at home or in office settings. The study made an assumption that 25% of cups, sushi containers, and burger boxes, 50% of bowls, and 75% of pizza boxes would be consumed at home or in offices. Cold-water rinsing was considered adequate for cups, sushi boxes, and pizza boxes (for liquids and cold/dry food), while warmer water rinsing (dishwasher recommended) was advised for burger boxes and bowls. Cold-water rinsing carries minimal GHG emissions, while dishwashing increases them. An assumption was made that among these recommendations, approximately 90% would be washed according to recommended practices. A sensitivity analysis wasn't conducted for preliminary washing, as dishwashing impacts were relatively minor compared to other lifecycle stages, thus not warranting a sensitivity assessment.

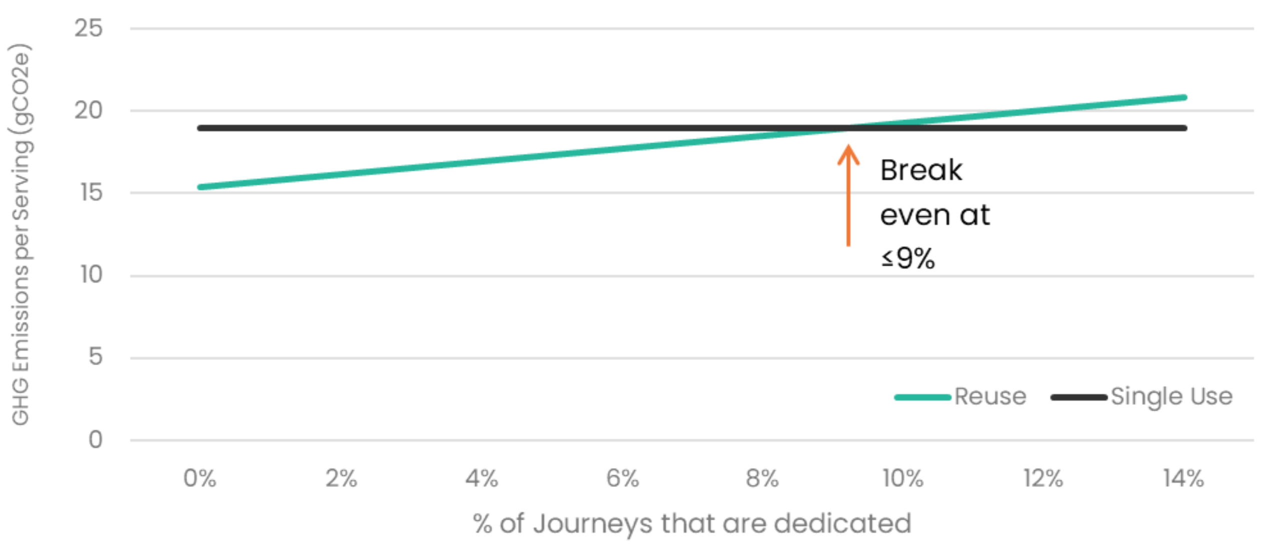
Dedicated car journeys

In a modern, densely populated European city, most consumers are expected to return takeaway containers to a nearby collection point immediately after consumption. In some instances, packaging will be taken home by the consumer (or delivered) instead. While there is a poor evidence base for exactly what kind of behaviour can be expected, experience from deposit refund schemes indicates that a high percentage of dedicated journeys is unlikely. The study has therefore assumed in the base case that, for one in every 33 containers (or 3% of the time), someone will drive 2 km out of their way to return it, using an electric car for 50% of journeys and a car with an internal combustion engine for the other 50% (the average EU car composition predicted for 2030).

In Figure 7, sensitivity analysis shows that for burger boxes, a proportion of dedicated journeys greater than 9% (an increase of 6 percentage points from the baseline scenario) causes single-use packaging to have less of a GHG impact compared to reusable packaging. As there is poor evidence for consumer behaviour here, it is recommended that this be monitored when trialling reusable systems, but it is clear that reducing/limiting dedicated transport should be a priority. With the exception of pizza boxes, all other packaging formats have a breakeven point that is at a higher percentage of dedicated journeys:

- Cold cups: 45%
- Warm cups: 45%
- Bowls: 27%
- Sushi Boxes: 20%
- Pizza Boxes: *No breakeven point, even at 0% dedicated journeys*

Figure 7: Sensitivity of percent of journeys that are dedicated – Burger Boxes



Professional washing

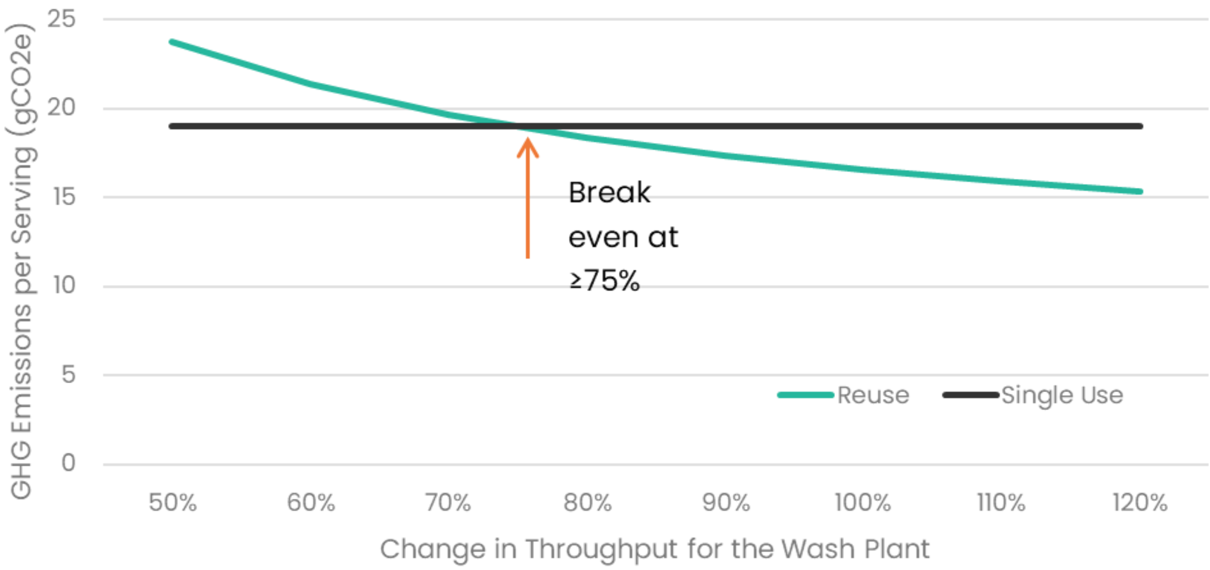
In an efficient reusable system, washing each takeaway package before its next use will have climate change impacts in terms of the water and detergent used to wash it and the energy used to heat the water and dry the container. The washing efficiency has been modelled based on Hobart's FUX5000 model, a large-scale flight-type dishwasher, which is capable of washing large quantities of packaging in accordance with the high food hygiene standards required of reusables. These values have been summarised in Table 4 below, where basis of the information has been provided by the machine manufacturer and adjust to account for potential inefficiency in the system for washing additional items such as lids.

Table 4: Washing Efficiency Data Summary

Product	Throughput per hour	Consumables per hour
Cups for Cold Drinks	4,950	Electricity: 69kWh Water: 250 litres Detergent: 570g Rinsing Agent: 125g
Cups for Warm Drinks	3,300	
Sushi Boxes	1,179	
Bowls	1,800	
Pizza Boxes	375	
Burger Boxes	750	

Another key sensitivity in the system is the rate at which each type of container can be washed. This can vary highly depending upon how optimised the wash system is. The study found that the total number of units of a given container type that can be throughput in a single wash affects the system's GHG emissions. This is dependent on the geometry of the packaging: typically, larger items such as pizza boxes have a lower maximum throughput compared to small items, such as cups. In Figure 8, sensitivity analysis shows that, below ~75% of the maximum throughput of the wash plant, reusable burger boxes have a high GHG impact compared to single-use packaging.

Figure 8: Change in throughput for the wash plant for burger boxes



Note: Material choice is also a consideration, as different materials behave differently throughout the washing cycle; plastic containers require more energy to dry compared to ceramics or metal and therefore result in more GHG emissions during washing. Product design and material choice should be considered in order to minimise the impacts of this stage and other stages (such as transport) of the life cycle.

End of life management

Destinations: Residual waste – anything not recycled or reused – is either incinerated or sent to landfill. The model assumes 90% of residual takeaway packaging waste will be incinerated and 10% will go to landfill, in line with EU 2035 landfill targets.

Recycling rates for single-use containers: While many cities will have separate collection systems for paper and card by 2030, these may not capture takeaway packaging, which often carries residues of its contents. These residues make recycling challenging and contamination of other material likely. The Confederation of European Paper Industries (CEPI) provides guidance indicating that stains and trace amounts of food are acceptable in recycled paper, but full saturation of paper with grease is considered unacceptable.[6]

Paper with 'high wet strength', like that used for cups, is commonly extracted from municipal waste and incinerated, due to the low yields in the recycling process. It is not clear to what extend recycling of high wet strength paper happens—or could happen—in practice. Further evidence from those who process these materials is required to fully assess how these products could be recycled and if this achievable by a 2030 time horizon. In addition, there is also no agreed approach on how to measure biogenic carbon[7] for paper products and therefore there are several different approaches which could be taken to measure the benefits.

This study has therefore assumed that only 10% of paper takeaway packaging will be recycled by 2030 and that 75% of single-use plastic containers will be recycled – the latter assumption also optimistically presumes that the challenges around recycling of food contaminated plastics is overcome in the future. From a GHG perspective, increasing the recycling collection rate of paper takeaway packaging would not significantly impact the results, as there is already a GHG benefit associated with sending it to energy-from-waste as the main alternative to recycling (even in decarbonised energy grid where the energy credits generated would be relatively less carbon-intensive). The benefits of recycling highly contaminated single-use packaging are therefore likely to be minimal.

Reuse return rate

For a reuse system to deliver a reduction in GHG emissions, consumers must return a high proportion of their takeaway containers. It was assumed that, for every 100 takeaway containers bought, 98 of them will be returned for reuse. This aligns with demonstrated return rates for takeaway packaging in well-established deposit return schemes[8], including one operated by Kooky2Go as well as other schemes for which sources are confidential. Kooky2Go offers a 1 CHF (approximately 1 euro) deposit for cups, which customers return to collection boxes throughout cities in Switzerland[9].

To test the boundaries of this assumption, the number of uses and return rates for different container types was adjusted and the GHG emissions modelled accordingly. This revealed break-even points – the minimum thresholds for uses and return rates required to yield a reduction in GHG emissions. Table 5 shows the differences in these break-even points for each packaging format.

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[6] CEPI (2023), Design for Recyclability Guidelines 3rd Edition https://thecpi.org.uk/library/PDF/Public/Publications/Guidance%20Documents/CPI_guidelines_2022-WEB.pdf

[7] Biogenic carbons refer to all those which are stored in, sequestered by and emitted through organic matter. The most common biogenic feedstocks include trees, plants and soil, which absorb carbon as a natural part of their life cycle.

[8] 2023-SB-ZWE-The-economics-of-reuse-systems.pdf (zerowasteeurope.eu)

[9] https://www.kooky2go.com/en/support

The beneficial climate change impacts are clear in the case of burger boxes, bowls, and cups:

- **Burger boxes**: If 97% of burger boxes are returned for reuse and each one is reused 30 times, the emissions will be lower than those from a single-use box.
- **Bowls**: If 92% of bowls are returned for reuse and each bowl is reused just 13 times, the emissions will be lower than those from a single-use paper bowl.
- **Cups for cold and warm drinks**: If 83% of cups are returned for reuse and each one is reused just 6 times, the emissions will still be lower than those from a single-use paper cup.

The case is weaker for reusable pizza and sushi boxes, which must have higher return rates and be reused more to break even in terms of emissions compared to single-use versions:

- **Pizza boxes**: If 98% of pizza boxes are returned for reuse and each one is reused 63 times, the emissions will be lower than those from a single-use box.
- **Sushi boxes**: If 97% of sushi boxes are returned for reuse and each one is reused 35 times, the emissions will be lower than those from a single-use paper bowl.

Table 5: Breakeven analysis on the reuse return rates for different reusable packaging formats

Product	Breakeven # Rotations	Breakeven Return Rate
Burger Boxes	30	97%
Pizza	63	98%
Bowls	13	92%
Sushi Boxes	35	97%
Cups for Cold Drinks	6	83%
Cups for Warm Drinks	6	83%

Note: In designing a reuse system, the system architects should aim to reduce the number of dedicated journeys whilst maintaining a high return rate. This has been demonstrated in modern DRS systems which have high return rates with a low number of dedicated journeys.

4.0 Conclusions

The aim of this study is to evaluate the climate change impacts of reusable packaging as part of a reuse system in comparison with single use packaging in the takeaway sector. It highlights the key aspects of reuse system design that are important to optimise when implementing such a system. It is by no means definitive, but clearly indicates that, despite being a challenging sector to implement reuse, it is possible that climate change benefits can be realised by doing so.

The study examined the GHG emissions associated with various types of takeaway packaging, including cups, burger boxes, bowls, pizza boxes, and sushi containers, comparing single-use versions to reusable packaging in a reuse system. It found that for all formats except pizza boxes, switching from single-use (both plastics and paper) containers to reusable containers in a reuse system has potential to reduce GHG emissions. The extent of possible reductions varies between container types, with cups showing the largest reductions. More challenging formats such as pizza boxes are likely to need further design improvements, such as light-weighting, to fully realise the benefits of reuse. It should be noted that whilst single-use packaging has had many decades to optimise, reusable packaging has not received the same level of design attention and innovation. If this were to happen, all the packaging in this study could improve and reusable pizza boxes may become the better option.

Climate impact assessments of reusable vs single-use packaging often rely heavily on assumptions that significantly affect results. Certain assumptions help model aspects of consumer behaviour for which data is sparse, such as return rates, home washing, and dedicated return journeys. The lack of good data in these areas does create some uncertainty. To address this, the study tested the sensitivity of some of the key assumptions used in the modelling to identify break-even points – the point in which the assumption changes the conclusion. The key sensitivities explored are changes to the energy grid, the proportion of dedicated car journeys, the throughput of the professional washing process and the reuse return rates/rotations. These sensitive give system designers a good benchmark to aim for to ensure that reuse is the optimum solution.

The findings of this study show that there is definite potential for a reusable system to outperform a single use system in the takeaway sector. However, it is important to recognise that such a system must be designed and implemented well. Some of the key assumptions mentioned above are driven by aspects of behaviour that require a mindset change that needs to be ingrained into societal norms. This study demonstrates the art of the possible, but this cannot happen without thinking beyond simply swapping one packaging type for another.

The results can be used to help guide those implementing reusable systems by indicating the potential for reducing GHG emissions and highlighting the important system design considerations that are required to facilitate success. There now appears enough evidence that the conversation can move from a discussion of reuse vs single-use, towards, *"how can we implement re-use in the most effective way?."* Real-world trials, such as the Aarhus project in Denmark, are needed to further evaluate the findings, refine the system, and measure the benefits. However, small pockets of activity or reuse trials are unlikely to show the long term benefits demonstrated in this study. The evidence presented here and gathered through trials should be used to inform the development of standards for effective reusable systems. This will be where the true gains are likely to be realised.