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

Addendum Report

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Report For

Zero Waste Europe (ZWE) is the European network of communities, local leaders, experts, and change agents working towards a better use of resources and the elimination of waste in our society. We advocate for sustainable systems; for the redesign of our relationship with resources; and for a global shift towards environmental justice, accelerating a just transition towards zero waste for the benefit of people and the planet.

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1.0 Introduction

In a collaboration between the Municipality of Aarhus and TOMRA, Aarhus became the first Danish city to trial a return system for reusable takeaway packaging. The three-year pilot initially focuses on creating a reuse system for takeaway cups, with the plan to expand the system to cover all types of takeaway packaging. The TOMRA system is designed as an open system, which means packaging from different packaging providers can be returned 24/7 to a shared infrastructure of automated collection points throughout a city. Consumers pay a deposit when purchasing the takeaway food or drink item, which is then reimbursed to the consumer in full when the packaging is returned to a collection point.

The trial is the first of its kind and inspired Zero Waste Europe (ZWE) to explore the potential of adopting such a concept across European Cities.

This report is an Addendum to the main report, titled 'Assessing Climate Impact: Reusable Systems vs. Single-use Takeaway Packaging' (hereafter referred to as the 'main report'). The main report demonstrated the potential greenhouse gas (GHG) savings from implementing a reuse system for takeaway items compared to single-use alternatives.[1] The aim of this Addendum is to build on the main report and apply the 'per serving' climate impact within the context of reuse schemes in two European cities: Aarhus (Denmark) and Berlin (Germany).

The report is structured as follows:

- Section 2.0: Methodology (Additions and Updates to the Main Report)
- Section 3.0: Results
- Section 4.0: Drivers and Sensitivities

2.0 Methodology (Additions and Updates to the Main Report)

The GHG impact assessment conducted as part of this Addendum is based on the methodology and assumptions used in the main report. Both assessments compare single-use packaging to a reusable packaging system in which takeaway food vendors use a shared pool of reusable packaging that is managed by a system operator. Food and drink are served in reusable packaging, which is deposited, after use, into reverse-vending machines (RVMs). The packaging is then collected by dedicated vehicles, washed at a centralised facility or facilities, and redistributed for reuse back to takeaway food vendors.

Building on the methodology and assumptions in the main report, a number of additions and updates were applied for this assessment:

- **Scale and composition:** For both Aarhus and Berlin, the total number of units of single-use packaging placed on the market (POM); the composition of packaging formats; and the material composition of each format is shown in Figure 1 and Figure 2. Berlin is roughly ten times larger than Aarhus in terms

[1] Available at: https://zerowasteeurope.eu/library/assessing-climate-impact-reusable-systems-vs-single-use-takeaway-packaging

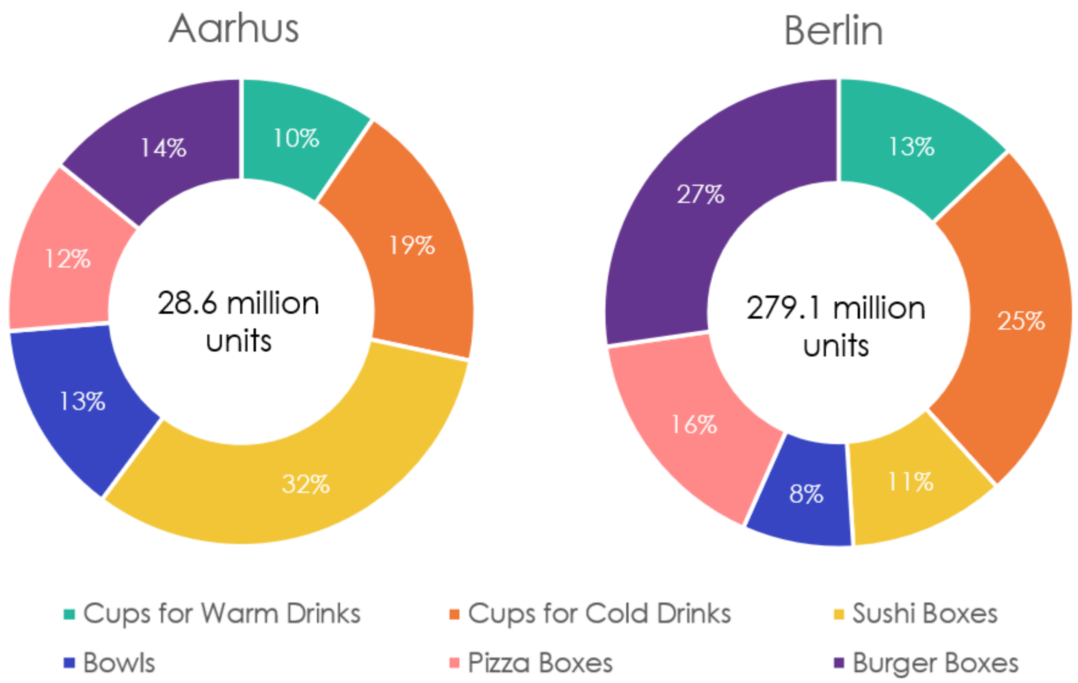
of units of packaging POM. The data summarised in these figures are derived from data provided by Future Market Insights (FMI) – a research and business intelligence provider.[2]

- **Market penetration rate:** A rate of 85% market penetration has been used, meaning that for the packaging formats considered, 85% of servings previously fulfilled by single-use packaging would be replaced by reusable packaging.

- **Residual waste treatment**: It has been assumed that 100% of residual waste containing single-use take away packaging in Aarhus and Berlin is sent to energy-from-waste (EfW) based on current practices and trends. This is an increase from 90% in the main report, where the remaining was 10% sent for landfill, based on EU-wide 2030 landfill targets.

- **Electricity emissions factor:** Country-specific 2030 emissions factors have been calculated by combining current electricity grid fuel mixes[3] with 2030 renewable electricity generation targets[4]. As a result, 0.13kgCO_2e per kWh and 0.02 kgCO_2e per kWh are used for Berlin and Aarhus respectively. Further detail regarding the impact that the grid fuel mixes have on the results can be found in Section 4.0.

Figure 1: Number of units of single-use packaging POM per year in each city, split by packaging format

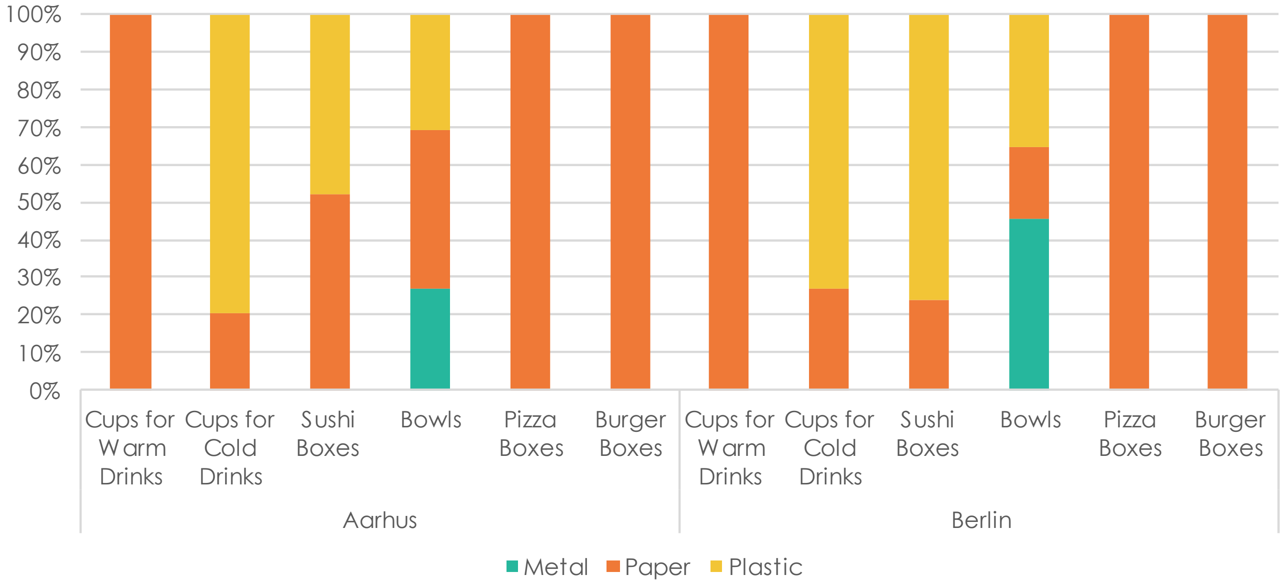


[2] Future Market Insight (n.d). Homepage. Available at: https://www.futuremarketinsights.com/

[3] Production fuel mix GHG emissions factors were taken from the Association of Issuing Bodies' *European Residual Mixes 2022* report. Available at: https://www.aib-net.org/sites/default/files/assets/facts/residual-mix/2022/AIB_2022_Residual_Mix_Results_inclAnnex.pdf

[4] Based on current targets it was assumed that Germany and Denmark's electricity grids are powered by renewable energy sources for 80% and 95% of energy demand, respectively.

Figure 2: Material composition of single-use packaging formats in each city



2.1 Methodology in Context

The Joint Research Council (JRC) has recently published a study that produces a series of LCAs comparing reuse with single-use in EU food packaging.[5] Therefore, it is important to highlight here the reasons why the two studies differ in their results and conclusions for some scenarios.

The JRC study follows the Product Environmental Footprint (PEF) method and considers the comparative impacts across 16 impact categories and making good use of primary data. As with nearly all studies on the topic (including the main report to which this is an Addendum), the study *"… identified a significant number of factors (and assumptions) that can influence the performance of single use and multiple use packaging products"*. Examples of these factors include the number of dedicated returns, the number of reuses and the mass and recyclability of materials.

Bound by the PEF method, the JRC study focusses on current circumstances (although, in these instances, other scenarios can be used to show potential future changes). Therefore, the benchmark results presented in the study represent a 'today' scenario for an 'average' EU country, using an average reuse scheme in line with existing practices. However, as recognised within the study itself, *"… predicting the future development of complex systems, such as those in which technologies are integrated, is a well-known challenge in prospective LCA, which can only be addressed through bespoke modelling and analysis"*. As suggested here, the challenge lies with creating likely future scenarios, which can be achieved by adapting certain variables that reflect changes that are most likely. In the study conducted by Eunomia, the decarbonisation of the local energy grid is a key aspect that is used for this purpose. The impact of applying this variable undoubtedly improves the results of reuse when compared with single-use, as the GHG hotspot moves away from raw material production into the local energy used in the reuse system (i.e., washing and transport).

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[5] Joint Research Council (2024). Exploring the environmental performance of alternative food packaging products in the European Union. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC136771

The benchmark results reported by JRC suggest that single-use cups have a lower environmental impact than reusable cups, which contrasts to Eunomia's findings. This is because the two studies have different goals. As described above, the JRC results are calculated based on today's current circumstances and represent an 'average' EU country. In contrast, Eunomia's study represents a 2030 scenario, is tailored to two specific European cities, and incorporates a reuse scheme, based on the pilot in Aarhus, that has been extended in terms of packaging formats and modified to reflect the likely results once the systems have developed and achieved an 85% market penetration.

The impact of the different goals of each study is also evident in the assumptions used and choices made by the authors. The main differences used in Eunomia's study are higher return rates, a lower carbon intensity of electricity generation, and fewer dedicated customer return journeys compared with JRC's central scenario. However, it should be noted that much of JRC's analysis is based upon the extensive sensitivities which also found that multiple-use can outperform single-use in some circumstances. Such nuances are often lost when only the central scenario is shared as the key result, even if it is not the most likely outcome.

Examples of some of the key driving differences between the JRC and Eunomia studies are shown in Table 1. The differences demonstrate a lack of consensus within the industry on many of the key driving assumptions behind a fully operational and optimised reuse system. Although the available evidence suggests that the assumptions used under the central scenario in the JRC report are achievable, the existence of some contrasting views also highlight the importance of developing reuse systems that are capable of delivering the performance that is required to achieve improved environmental outcomes when compared to single-use.

Table 1: Assumptions comparison

Assumption	JRC	Eunomia
Electricity Intensity (kgCO2e/kWh)	~0.2	~0.05*
# Rotations	15	45
Distance between DC and restaurant (km)	172	30

*This figure is used for downstream impacts from washing and transport in the reuse system. A further sensitivity is also presented to demonstrate the difference green grid has on upstream raw materials and manufacturing.

3.0 Results

The results of this GHG assessment support the findings of the main report and demonstrate that there are significant GHG savings to be realised from moving away from single-use take away packaging into reusable packaging.

In summary, the GHG emission savings results show that:

- In Aarhus, implementing reuse could result in savings of **462 tonnes of CO_2e per year**, or a 54% saving compared to a single-use baseline.
- In Berlin, implementing reuse could result in savings **of 2,494 tonnes of CO_2e per year**, or a 34% saving compared to a single-use baseline.

Breakdowns of the GHG emission savings by packaging format, in Aarhus and Berlin, are shown in Figure 3 and Figure 4 respectively.

Figure 3: Total GHG emissions per packaging format per year: Aarhus

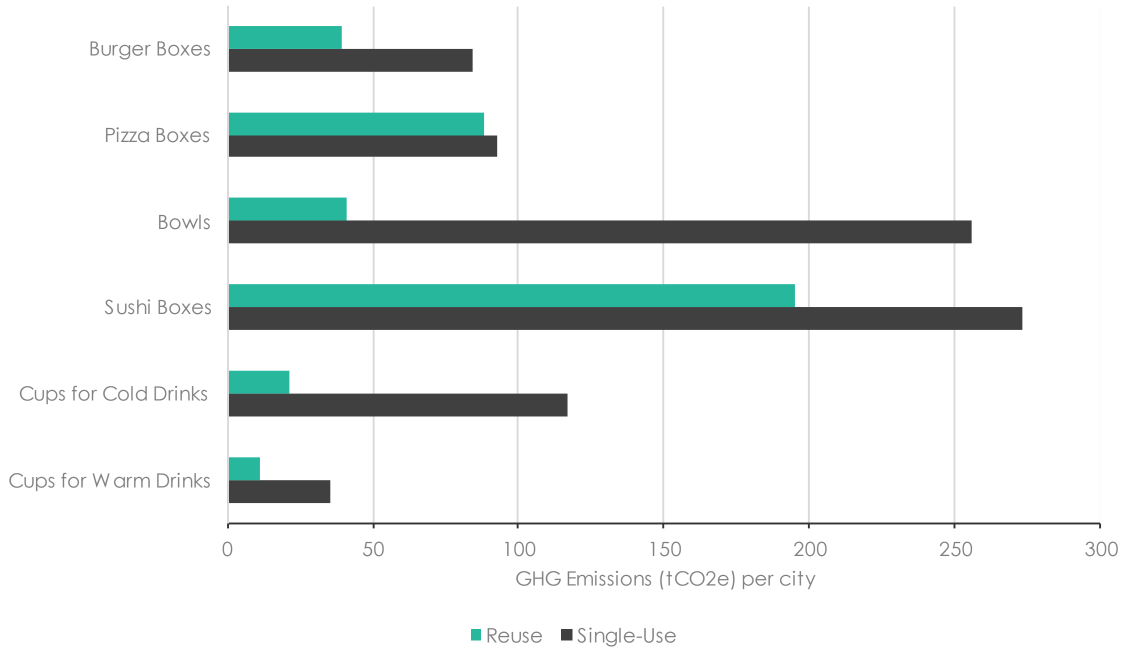
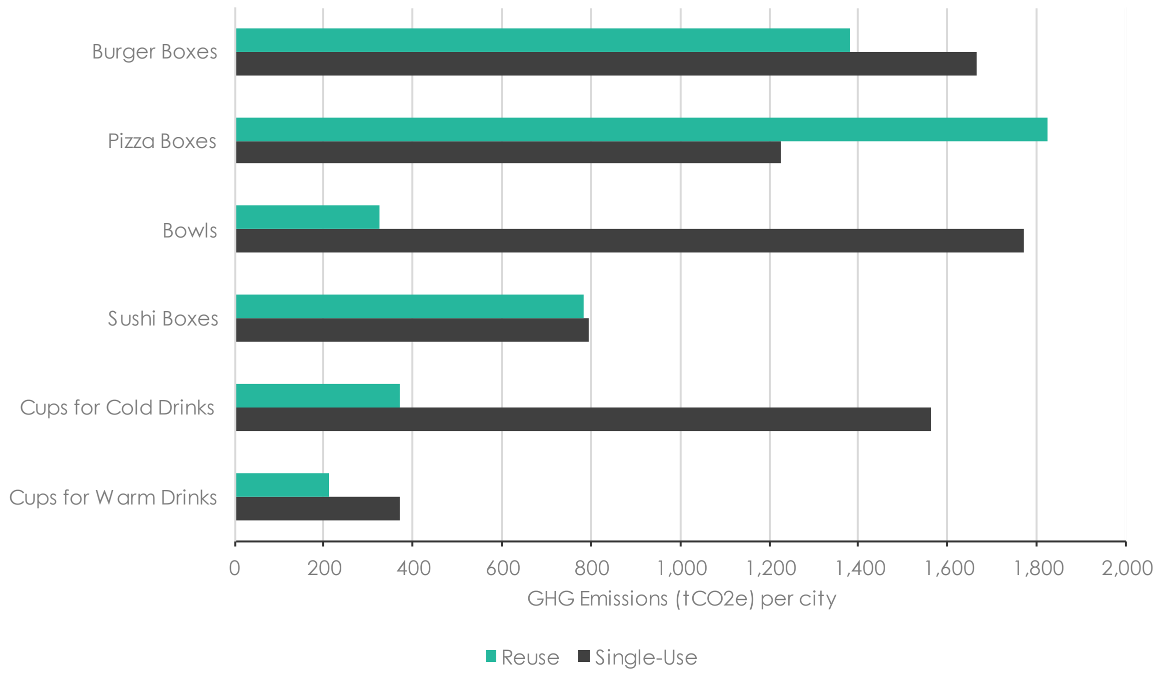


Figure 4: Total GHG emissions per packaging format per year: Berlin

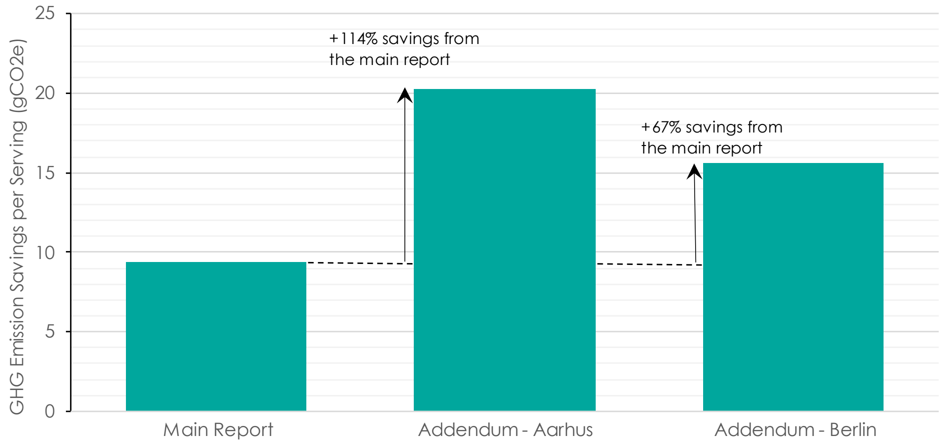


For both Aarhus and Berlin, ‘bowls’ and ‘cups for cold drinks’ are the packaging formats that exhibit the greatest reduction in total GHG emissions when comparing single-use and reuse. It should be noted that the relative performance of packaging formats ‘per unit’ are not comparable to each other as the amount of GHG emissions is determined by the number of units of each format as well as the impacts per unit.

These findings largely reflect those presented in the main report. In both cities, all packaging formats, except 'pizza boxes', show similar or greater GHG savings for each reusable packaging format when compared with its single-use equivalent in line with the main report. In the case of 'pizza boxes', while the results for Berlin align with those presented in the main report (where reuse does not result in GHG savings when compared to single-use), the results for Aarhus contrast those presented in the main report where reuse does result in a GHG saving compared with single-use. Furthermore, for Berlin, the relative performance of reusable 'sushi boxes' and 'cups for warm drinks' is lower than the results presented in the main report. The reasons behind these changes are explained in Section 4.0.

A comparison of the average GHG emissions saved (per serving) across all packaging formats presented in the main report (phase 1) and in each city (phase 2) is shown in Figure 5. The GHG savings per serving are more significant for Aarhus when compared to the Berlin, despite Berlin having greater GHG savings overall. The drivers of these differences are explained in Section 4.0.

Figure 5: Average GHG savings per serving across all formats



3.1 Additional Impacts

While the focus of this report is on the comparison of GHG emissions, there are other environmental impacts that would be reduced as a result of moving from single-use packaging to a reuse packaging system:

- **Material consumption and waste reduction:** The introduction of a reuse packaging system in place of a single-use packaging can lead to a significant overall reduction in the consumption of in scope take away packaging materials. The results of this study indicate a reduction of approximately 450 tonnes and 4,450 tonnes (a reduction of 87% and 85%) for Aarhus and Berlin, respectively. When specifically considering plastic savings, the results of this study indicate a reduction of approximately 65 tonnes and 250 tonnes for Aarhus and Berlin, respectively. **Although, initially, a reuse system will introduce reusable plastic packaging, a well-designed system that achieves high reuse rates will result in less plastic being used per serving over time**. There are two explanations for this. Firstly, of the single-use take-away packaging types modelled in this study, roughly 20% had plastic as the main material. Secondly, of the paper-based single-use packaging modelled, for the majority of formats (cups, bowls and sushi-boxes) these also have a plastic-liner which represents 5% of the mass.[6]

- **Littering:** The on-the-go nature of takeaway food and drink packaging items means they are commonly some of the most littered items.[7] Plastic packaging, including plastic-lined paper-based packaging, is particularly problematic from this perspective given its persistence in the environment. The introduction of a deposit, or another type of return incentive, can reduce the likelihood of consumers disposing of the packaging improperly and can encourage other people to pick up littered items in order to claim the deposit themselves, as has been demonstrated by single-use beverage container deposit return schemes (DRS), whichare common across Europe.

4.0 Drivers and Sensitivities

Average Material Composition of The Market

The material composition of single-use packaging formats has a large impact on the relative climate impact of a reuse packaging system.

The analysis in the main report compared the GHG impacts of a reusable or single-use container that is made from either paper or plastic. The analysis conducted in this report built on this by using market research data, provided by FMI, on the average material composition of each packaging format (by country). The use of a more accurate representation of the composition of a typical/average single-use container allowed the GHG impacts of the reusables to also be compared against single-use counterparts made from other materials, such as metal or bagasse.

The GHG-intensity of different single-use materials also impacts the relative GHG savings observed when compared with a reuse packaging system. The main report focusses on paper-based packaging (including a plastic-lining for some formats), whereas, in this report, a blended average of plastic, metal and paper-based packaging (based on market information) has been modelled. This impacts the GHG results significantly due to the GHG-intensity of different materials. For example, metal containers are typically heavier and more GHG-intensive to produce than paper-based containers, so the GHG impacts for formats which include metal containers in the blended average will increase. The impact of this difference is shown most dramatically in the GHG savings attributed to 'bowls', as this packaging format has the highest share of plastic and metal single-use variants used in each city. For the same reason, single-use packaging formats predominantly made from paper/cardboard (namely 'cups for hot drinks', 'pizza boxes', and 'burger boxes') show the least variation in savings compared to the main report.

This assessment, and the resulting estimated GHG emissions savings, are based on current compositional data. It should be noted that the material composition of the in scope packaging formats may change in the future due to policy and economic drivers, or example, such as single-use plastic packaging bans. While compositional changes of single-use packaging might reduce the GHG emissions savings observed by switching to a reuse system (e.g., by moving from single-use plastic to paper), there are still benefits to be gained from moving towards reuse packaging systems, even in a paper-only scenario.

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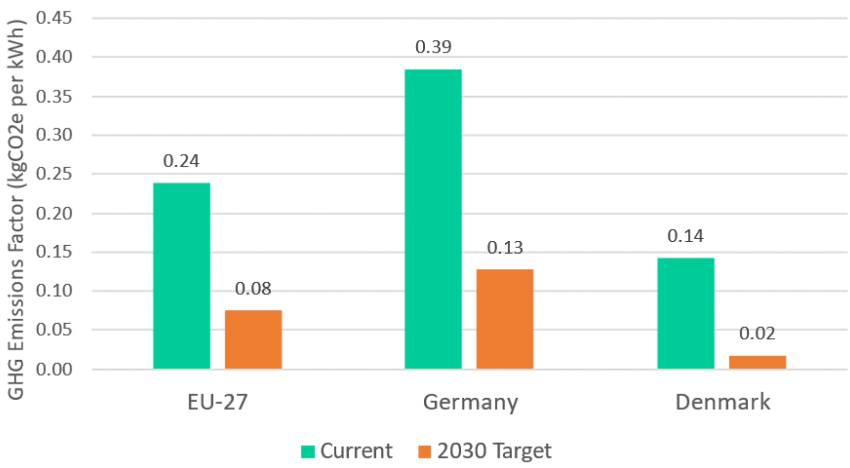
[6] The topic of plastics in paper-based packaging is also covered extensively in Zero Waste Europe's recent report: https://zerowasteeurope.eu/library/functionalisation-of-paper-and-cardboard/#:~:text=Paper%20and%20cardboard%20require%20functionalisation,)%20%2B%20additive(s)

[7] Morales-Caselles, C., Viejo, J., Martí, E., González-Fernández, D., Pragnell-Raasch, H., González-Gordillo, J. I., ... & Cózar, A. (2021). An inshore–offshore sorting system revealed from global classification of ocean litter. Nature Sustainability, 4(6), 484-493. Available at: https://www.nature.com/articles/s41893-021-00720-8

Electricity Grid Intensities

The GHG emission intensity of electricity generation in each country has a significant impact on the results. The grid intensity determines the impact of the washing and collection/redistribution stages of the reusable packaging system, which are the most energy-intensive processes in the system cycle. The 2030 values used in the city assessments vary significantly from the 2030 EU-27 average value used in the main report, as demonstrated in Figure 6. It should be noted that 'current' values (indicated by the green bars) are provided for context only and the orange bars are the figures used in the two reports.

Figure 6: GHG intensity of electricity generation by country, today and projected 2030 value



Denmark currently generates two thirds of its electricity from renewable sources, with a target of 100% in 2030. It therefore has a lower 2030 grid intensity than the 2030 EU-27 average. Germany is much more reliant on fossil fuels for its electricity, and, despite aiming for 80% generated from renewable sources in 2030, the grid intensity in 2030 is assumed to remain higher than the 2030 EU-27 average.

This difference explains why Aarhus (on a per serving basis) performs better than Berlin across all packaging formats. As discussed in Section 3.0, for Aarhus the overall GHG emission savings have improved significantly for 'burger boxes', 'pizza boxes', and 'sushi boxes' compared to the findings from the main report, which found reusable 'pizza boxes' demonstrating higher GHG emissions when compared to their single-use equivalent. The cause for this is that these types of packaging formats, and particularly 'pizza boxes', are the least efficient to wash and transport in comparison to the other packaging formats included in the scope of the study. Since the washing stage is the most electricity intensive stage of the lifecycle, a reduction in the grid intensity has a large impact on the GHG emission savings that can be realised for these packaging formats. As such, in Aarhus reusable 'pizza boxes' outperform their single-use equivalent. For Berlin, the adverse is observed whereby reusable 'pizza boxes' result in significantly higher GHG emissions when compared with their single-use counterpart, and the results for 'burger boxes' and 'sushi boxes' are more closely aligned.

These findings reiterate the importance of decarbonising national electricity grids and/or privately powering reuse systems with renewable electricity to reap greater environmental benefits.

Forward Looking – Decarbonisation of the Upstream Supply Chain

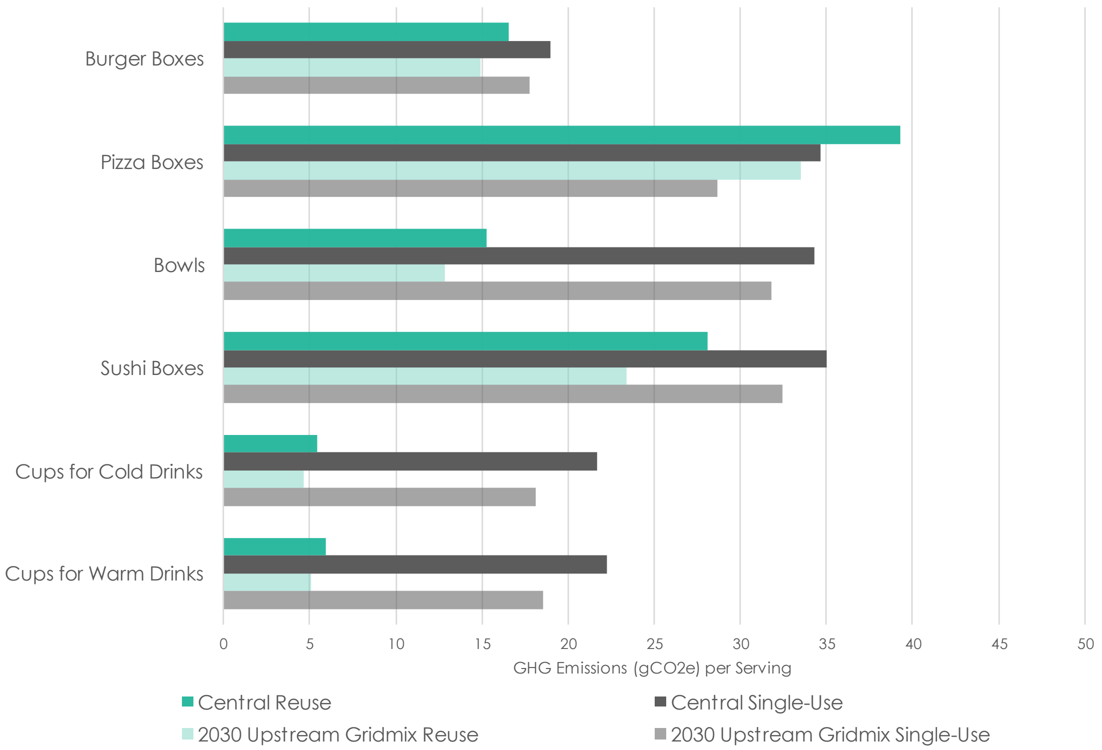
The central scenario in this study applies a 2030 grid mix for the downstream impacts associated with the transport and washing that is required as part of a reuse packaging system. A full future 2030 scenario would be an incredibly complex system to model with many unknowns, particularly if technological changes on the path to Net Zero were included. However, it is important to investigate whether an increase in decarbonised electricity in the upstream value chain (raw materials manufacture and processing) would alter the conclusions of this study significantly.

To achieve this, the electricity impacts in the underlying datasets were modified to reflect the 2030 mix as detailed in the previous section. The reality of grid decarbonisation is extremely complex to model with any certainty and this approach should be considered as a hypothetical absolute best case for the value chain grid mix, which is unlikely to exist fully by 2030 given the global nature of value chains. This sensitivity also assumes that there are no other underlying technological changes or improvements in efficiencies.

Figure 7 shows the results of this exercise compared with the central scenario. In this chart the results are not country specific but relate to the EU-average results reported in the main report. The results show that introducing a high proportion of decarbonised electricity into the upstream grid mix (pale turquoise bars) results in higher GHG emissions savings for both single-use and reuse.

Although higher savings are observed within single-use packaging for most packaging formats, the reduction in GHG emissions observed when switching from single-use to reuse is maintained, meaning that the conclusions are transferable for each packaging type. This indicative scenario supports the validity of the results of this report, even in a future scenario where decarbonised electricity is more widely available. However, a more detailed analysis that focuses on decarbonisation trajectories of future scenarios would be needed to provide more than an indicative result.

Figure 7: Upstream grid mix decarbonisation comparison



5.0 Conclusion

In conclusion, this Addendum builds on and supports the conclusions made in the main report and conducts further analysis to look into factors that may influence the magnitude of GHG savings, or potentially change the direction of results.

In line with the conclusions made in the main report, this Addendum, which builds on and applies the same methodology to two European cities, Aarhus and Berlin, finds that GHG emissions savings are realised by moving from single-use packaging to a reuse packaging system for takeaway packaging. **In a near-future (2030) scenario, implementing an optimised reuse packaging system could result in GHG savings of 462 and 2,494 tonnes of CO_2e per year, for Aarhus and Berlin, respectively**. When this is extended to consider a per serving assessment, this study concludes that a reuse packaging system could result in 54% and 34% savings, in Aarhus and Berlin, respectively.

In addition to supporting the results of the main report, **this study further demonstrates that the resulting GHG savings are impacted by the varying material mixes of single-use packaging items**. The GHG savings are increased when the reusable alternative is replacing single-use packaging made from metal and/or plastic (such as 'cups for cold drinks', 'bowls' and 'sushi boxes'), compared with that made of paper, such as 'cups for hot drinks' and 'pizza boxes'. This analysis concludes that the higher the fraction of plastic and metal single-use packaging that is being replaced (relative to paper), the higher the GHG savings potential that can be realised from moving to a reuse packaging system.

However, it should be noted that **GHG savings are still realised even when reusable alternatives are compared with 100% paper single-use counterparts for most packaging formats, as demonstrated in the main report**. If the reusable alternatives are inefficient to collect and wash, then paper single-use packaging can appear more beneficial in terms of GHG emissions. Therefore, for multi-format reusable packaging systems, cities consuming higher proportions of (for example) 'pizza boxes' may, on average, observe fewer GHG emissions savings than cities consuming higher proportions of (for example) 'cups for cold drinks'.

Furthermore, this study demonstrates that the GHG savings potential of switching from single-use to reuse is strongly impacted by location, and the associated GHG intensity of the electricity grid. As discussed in Section 4.0, a lower targeted national grid-intensity in 2030 in Denmark (0.02kgCO_2e/kWh), being five times lower than that of Germany (0.13kgCO_2e/kWh), results in significantly higher GHG savings due to the requirement for additional energy intensive stages involved in a reuse packaging system compared with a single-use packaging. This emphasises the need to decarbonise national electricity grids (or, alternatively, privately procure renewable electricity directly for use in individual reuse packaging systems) in order to deliver GHG savings. This is particularly critical for packaging formats where the difference in GHG emissions is minimal between single-use and reuse, such as 'sushi boxes', which is generally due to the packaging formats being less efficient to wash and collect.

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