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FEFCO Corrugated Packaging

Case study analyses

Assessing impacts in the supply chain of substituting corrugated cardboard packaging with reusable alternatives

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Executive Summary

Deloitte has been appointed by the European Federation of Corrugated Board Manufacturers (FEFCO) to conduct an impact assessment on single use corrugated cardboard packaging and reusable alternatives made from other materials. This study was conducted as a basis for internal discussions within FEFCO as well as with policy makers in the context of the on-going legal development of the regulations for packaging and packaging waste. The study leverages information from interviews, industry knowledge and literature to gather quantitative and qualitative insights on economic, environmental, and logistics impacts. In order to assess the impacts, the report models, in a stylised way, the production and logistics flows for two product cases: Grouped packaging for biscuits and Packaging for heavy furniture kits. The objective of the analysis is to improve the understanding about reuse impacts in order to inform the public debate and contribute to better policy making.

The proposal of the European Commission for a Regulation on Packaging and Packaging Waste (PPWR) aims to make packaging more circular and reduce the greenhouse gas emissions (GHG) from the production, use and end-of-life of packaging. The proposed regulation contains reuse targets that would have far-reaching effects on packaging design and selected materials. More specifically, corrugated cardboard packaging, a commonly used packaging solution, is almost exclusively single use and would be affected strongly in case reuse targets are applied everywhere without taking into account the economic, logistics and environmental benefits of the material in a wide range of packaging applications.

Although reusable packaging reduces materials consumption, its suitability depends on the specific application and can lead to unintended negative externalities due to three main effects:

- Reuse requires recirculation of used packaging which increases the energy consumption for transportation, sorting and cleaning
- Reuse requires standardisation of packaging dimensions while products remain highly diverse in size and shape which may lead to empty space and inefficiencies in transportation
- Reuse may lead to a shift in materials used. For example, if corrugated cardboard is replaced by plastic packaging, recycling rates and related circularity advantages would go down.

This report looks at the potential impact of replacing corrugated cardboard with reusable packaging. The study focuses on logistics aspects including transport and storage, as well as environmental impacts. The analysis builds on two case studies related to grouped packaging for biscuits and packaging for heavy furniture kits. An analytical model compiles insights from industry interviews and literature data to provide, quantitative, as well as qualitative insights. The report aims to feed the public debate with insights in relevant sustainability aspects and foster better policies.

Corrugated cardboard packaging is widely used for transport and protects over 75% of the goods shipped in Europe. This leading position is based on appealing environmental and logistics characteristics of corrugated cardboard packaging. Indeed, corrugated cardboard packaging is circular and renewable with 88% of the feedstock coming from recycled fibres and the remaining virgin fibres coming from sustainably managed forests. It is also a lightweight and low-carbon material with a carbon footprint of only 0.49 tonne CO_2e per tonne corrugated cardboard packaging. Most importantly, the potential customization to the dimensions of the packaged good prevents empty space (headspace) inside the packaging, thereby optimizing storage space and logistics once the product has been packed. Finally, the material allows for tailor-made branding, logo printing and printed instructions to operators which allows combining the functions of transport packaging and sales packaging, thereby preventing packaging waste along the way.

To assess the impacts of substituting corrugated cardboard packaging with a reusable alternative, an analytical circular network design model has been developed. The model is based on a stylised version of the packaging supply chain that includes material producers, packaging produces, brand owners, retailers and reuse or recycling activities to compare the 'current situation' with the 'counterfactual', i.e., the hypothetical situation where corrugated cardboard packaging would be forced out of specific markets and replaced by reusable plastic crates due to regulatory decisions. The model builds on literature data, insights from interviews and industry knowledge. The assessment simplifies industrial reality significantly and relies on strong assumptions for key economic, logistics and environmental parameters. Consequently, all results must be interpreted cautiously.

The first case study focuses on grouped packaging[1] for biscuits and similar confectionary. It focuses on the annual demand for biscuit packaging in Europe. Total demand for corrugated cardboard packaging is estimated at 28 million tonnes with around 5% or 1.4 million tonnes of corrugated cardboard being used for biscuits packaging. Assuming an average weight of 0.65 kg per box, this relates to 2.2 billion shipments per year.

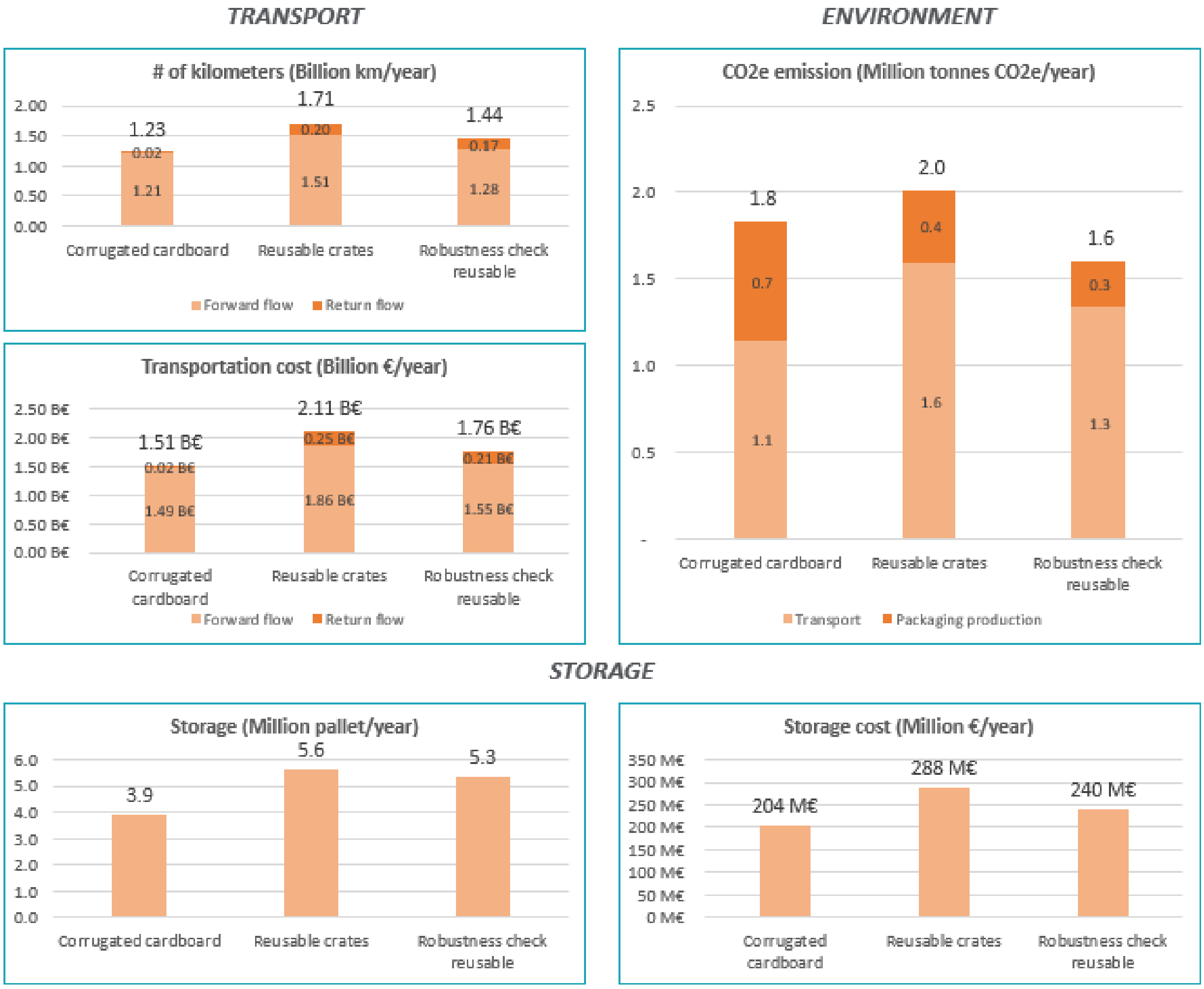
The three most impactful transport and storage parameters are: additional empty space due to the need to standardise the size of reusable crates (20% empty space added for reusable packaging), thickness of folded packaging (6 mm for corrugated cardboard vs 7 cm for folded reusable plastic crates) and additional transport in the return flow (20 km extra for reusable packaging from unpacking to reuse as packaging). For production, the three most impactful parameters are the amount of cycles that the crates can be reused (25 cycles), the weight of the reusable crates (0.65 kg for the specified corrugated cardboard box vs 1.66 for a reusable and foldable plastic crate) and the CO2 footprint of the different applications (0.49 tonne CO2 per tonne corrugated cardboard packaging vs 2.79 tonne CO2 per tonne of reusable plastic crates).

Figure 1 assesses the impact on transport, environment, and storage by comparing three different scenarios:

- All boxes are made of corrugated cardboard (current situation – Corrugated cardboard)
- A counterfactual scenario where in a hypothetical way the corrugated cardboard is replaced in this packaging application by reusable and foldable plastic crates (counterfactual – Reusable crates)
- The packaging is replaced by reusable and foldable plastic crates, but the three most impactful transport parameters and the three most impactful production parameters are modified with 20% in favour of the reuse counterfactual to get an insight in the sensitivity of the results and check whether the results hold with modified assumptions (Robustness check reusable)

[1] Grouped packaging is conceived so as to constitute a grouping of a certain number of sales units at the point of sale whether the latter is sold as such to the end user, or it serves only as a means to replenish the shelves at the point of sale or create a stock-keeping or distribution unit, and which can be removed from the product without affecting its characteristics

Figure 1: Comparison of transport, environment, and storage impacts from three stylised scenarios for grouped packaging of biscuits



The model highlights some important impacts in case corrugated cardboard for grouped packaging of biscuits would be substituted by reusable plastic crates:

- Transport costs increase substantially, due to less efficient logistics resulting in additional shipments and more kilometers spanned along the supply chain. The main driver is the additional empty space shipped around due to the low potential to customize the size of the reusable crates to the product size.
- Given the assumptions, there is a small increase in GHG emissions when reusable crates substitute corrugated cardboard boxes. Indeed, the decrease of emissions owing to a lower need for materials in a reuse scenario, is smaller than the additional transport emissions needed for reuse. However, the sensitivity analysis and 'robustness check' scenario show that different assumptions can also lead to a small decrease of GHG emissions in case reusable packaging is introduced. These ambiguous results highlight that both single use and reuse options for grouped packaging of biscuits are almost equivalent in terms of GHG emissions.
- The need for storage and associated storage costs are substantially higher in a reusable system, due to the average increase in crate size to be able to deal with different product sizes, the extra thickness of folded crates and the need to store additional crates to cover for seasonality and other fluctuations all along the supply chain.

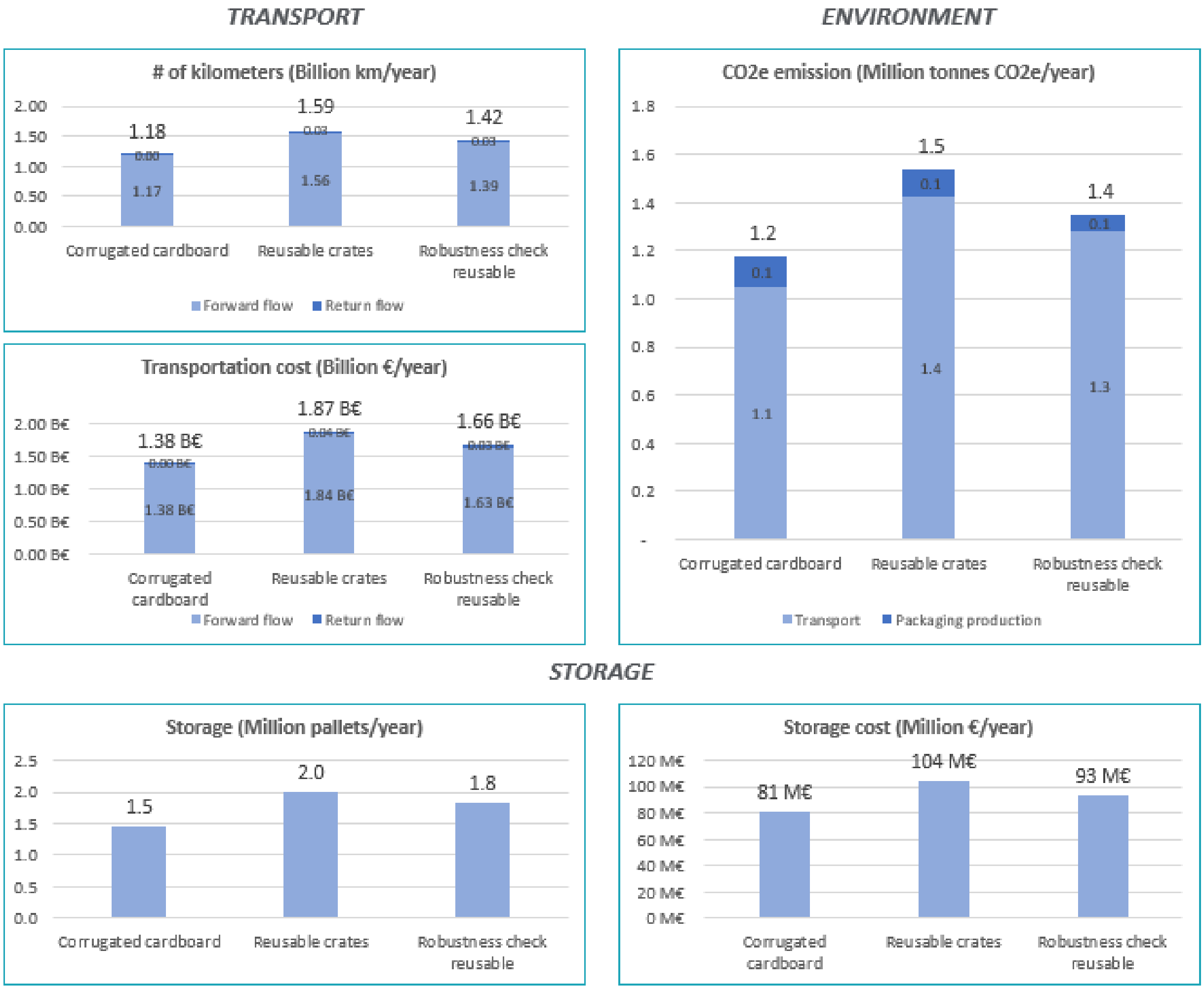
The second case study focuses on packaging for heavy furniture kits, e.g., for a mid-size closet or an office chair that needs some assembly at home. The model builds on a stylised supply chain that is similar as for packaging, but now also includes transport to and from end-consumers. Figure 2 assesses the impact on transport, environment and storage of different packaging solutions for the annual demand of furniture kit shipments. Total demand for corrugated cardboard packaging is estimated at 28 million tonnes with furniture packaging representing around 0.9% or 252 thousand tonnes of single use corrugated cardboard. Assuming an average weight of a box of 3.1 kg per box, this relates to 81 million shipments.

The key drivers of the furniture case are similar to the biscuits case. However, there are some specificities in the furniture case as the packaging needs to provide more strength in this application: increased packaging thickness (1 cm for corrugated cardboard vs 7 cm for reusable plastic crates) and increased packaging weight (3.1 kg for the specified corrugated cardboard box vs 11.64 kg for a reusable and foldable plastic crate). The high weight of the reusable plastic crate takes into account the over-dimensioning of strength and size to be able to deal with various products in different cycles.

The results of the case study on furniture kits point to the same direction for transport and storage as the case study on biscuits. The costs of transport and storage increase substantially when reuse is introduced due to more kilometres driven, larger average sizes of packaging crates and an increased thickness of the folded packaging. However, this case study does not show the same ambiguity on GHG emissions. In the analytical model, single use corrugated cardboard packaging generates less GHG emissions than the reuse alternative. The main drivers being the increased weight of the crates due to the required high strength, the empty space due to the limited customization potential of the size of the reusable packaging and the additional transport in the reverse flow. The sensitivity analysis shows the robustness of the increase in GHG for this case, even if assumptions are modified.

Additionally, a shift from single use packaging with well-established collection and recycling facilities to reusable alternatives with collection systems for reuse that probably require more effort and temporary storage, particularly affects end consumers. This effect is difficult to monetize, but the burden for end-consumers might be significant. Altogether, corrugated cardboard packaging comes out this analysis as a preferred packaging solution for heavy furniture kits both from an economic as environmental aspect.

Figure 2: Comparison of transport, environment, and storage impacts from three stylised scenarios for the packaging of furniture kits



Overall, the analysis of these case studies highlights the importance of taking into account the impacts of potential reuse obligations on the 'forward flow' and the related storage and logistics costs. Also, more empty space and more kilometres driven in the forward or reverse flow will counteract the political ambitions for efficient and low-carbon packaging solutions. The analysis, therefore, highlights the need for a granular analysis per application on the effects of reuse to avoid unintended negative externalities and optimize the overall economic and environmental footprint of the packaging sector.

Disclaimer

1 Introduction

Packaging waste in the EU increased between 2009 and 2020 by more than 20% and amounted to almost 80 million tonnes in 2020[2]. The increasing amount of waste combined with an average recycling rate of 64%[3] highlights that packaging materials loops are yet to reach the climate and circularity targets established by the European Green Deal[4] and the EU's New Circular Economy Action Plan (CEAP, adopted in March 2020)[5].

To this effect, the EU has adopted and is discussing several regulations that relate to packaging, raw materials[6] and green claims[7], with the recent draft regulation for Packaging and Packaging Waste (**PPWR**)[8] spearheading the policy package. The PPWR aspires to prevent 18 million tonnes of waste and 23 million tonnes of greenhouse gas (GHG) emissions by 2030, as compared to a projected baseline in a "business-as-usual" scenario[9]. More specifically, the draft PPWR aims at an absolute reduction of packaging waste by 5% by 2030 compared to 2018, equivalent to a reduction of 19% compared to a "business as usual" scenario; and by 15% by 2040.

In order to meet the objective for reduction of packaging waste, the PPWR puts forward '**reuse**' as an important lever. Reuse is defined as "any operation by which reusable packaging is used again for the same purpose for which it was conceived".

Although reuse seems appealing at first sight, there are a few caveats. The Commission's PPWR Impact Assessment highlights the challenge to quantify impacts and trade-offs between recycling and reuse for various materials[10]. More specifically, economic, environmental, and logistics impacts of replacing single use with reusable packaging are heavily reliant on the **application** and can include **unintended negative externalities**[11]. Three effects are critical:

- Reuse **requires recirculation** of used packaging which increases the energy consumption for transportation[12], sorting and cleaning purposes
- Reuse requires standardisation of packaging dimensions while products remain highly diverse in size and shape which leads to **empty space** and inefficiencies in transportation
- Reuse may lead to a **shift in materials** used. For example, if corrugated cardboard (recycling rate of 88%) is replaced by plastic packaging (recycling rate of 38%[13]), recycling rates and related circularity advantages would go down.

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[2] Eurostat, Packaging waste statistics. URL: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging_waste_statistics
[3] Ibid.
[4] European Commission, Green Deal. URL: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[5] European Commission, A new circular economy action plan, 2020. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN
[6] European Commission, Critical raw material resilience, 2020. URL : EUR-Lex - 52020DC0474 - EN - EUR-Lex (europa.eu)
[7] European Commission, Green claims directive, 2023. URL: Proposal for a Directive on green claims (europa.eu)
[8] European Commission, PPWR, 2022. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022PC0677
[9] European Commission, Executive Summary of PPWR Impact Assessment, 2022. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2022%3A385%3AFIN&qid=1669893874042
[10] European Commission, Executive Summary of PPWR Impact Assessment, 2022. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2022%3A385%3AFIN&qid=1669893874042
[11] Zink, T., Geyer, R., 2017. Circular economy rebound. J. Ind. Ecol. 21 (3), 593–602
[12] Castro, C.G., Trevisan, A.H., Pigosso, D.A., Mascarenhas, J., 2022. The rebound effect of circular economy: definitions, mechanisms and a research agenda. J. Clean. Prod., 131136.
[13] Eurostat, Packaging waste statistics, 20023. URL: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging_waste_statistics#Recycling_and_recovery_targets_and_rates

The PPWR proposal already acknowledges that reuse is not a one-size-fits-all solution for packaging applications. The PPWR (Article 3) therefore defines three types of packaging (transport packaging, grouped packaging and sales packaging[14]) and foresees exemptions on the reuse obligations dependant on the material and the type of packaging to avoid negative externalities.

For the producers of corrugated cardboard packaging the regulations about reuse are highly impactful. Corrugated cardboard packaging is almost exclusively single use, so without appropriate exemptions, reuse obligations would disrupt the market and the activities of the producers of corrugated cardboard packaging. This would not only have direct negative economic effects on the associated firms but would also complicate the logistics of many supply chains.

To evaluate the risk of undesirable negative externalities and the need for application-based exemptions on reuse obligations, FEFCO, the European Federation of Corrugated Board Manufacturers, has asked Deloitte, to assess two case studies where cardboard packaging is well established. More specifically, the case studies relate to grouped packaging for biscuits and packaging for heavy furniture kits (e.g., a medium sized closet or office chair that needs to be assembled at home). The aim is to analyse economic, logistics and environmental impacts in case regulatory obligations would force the market to substitute single use corrugated packaging by a reuse solution.

This report builds on extensive interviews with producers as well as users of corrugated cardboard packaging. Moreover, FEFCO and its members have provided studies and operational data points to document the current use and lifecycle of corrugated cardboard packaging. To build the ‘counterfactual’, i.e., the hypothetical situation where an alternative reusable material would substitute corrugate cardboard packaging in the two case studies, Deloitte has combined a literature review with circular and logistics expertise.

The structure of the report is as follows:

- Chapter 2 describes the use and advantages of corrugated cardboard packaging
- Chapter 3 describes the methodology to select and assess the case studies
- Chapter 4 analyses the Product case on “grouped packaging for biscuits”
- Chapter 5 Analyses the product case on “packaging for heavy furniture kits”
- Chapter 6 summarizes the key takeaways of both cases

[14] The definitions of the types of packaging are as follows:

- Sales packaging meaning “packaging conceived so as to constitute a sales unit consisting of products and packaging to the final user or consumer at the point of sale”
- Grouped packaging meaning “packaging conceived so as to constitute a grouping of a certain number of sales units at the point of sale whether the latter is sold as such to the end user, or it serves only as a means to replenish the shelves at the point of sale or create a stock-keeping or distribution unit, and which can be removed from the product without affecting its characteristics”
- Transport packaging meaning “packaging conceived so as to facilitate handling and transport of a number of sales units or grouped packages, including e-commerce packaging but excluding road, rail, ship and air containers, in order to prevent physical handling and transport damage”

2 Use and advantages of corrugated cardboard packaging

In 2021 the corrugated cardboard packaging industry employed about 100,000 people directly, generated a turnover of around 25 billion € and used around 28 million tonnes of corrugated cardboard[15]. Corrugated cardboard packaging is widely used for transport and protects over 75%[16] of the goods shipped in Europe. This leading position is based on the environmental and logistics benefits of corrugated cardboard packaging.

2.1 Environmental benefits

Corrugated cardboard packaging is almost fully circular[17]. Fibres can be recycled at least 25 times[18] in closed loops and the recycling system is mature allowing to produce corrugated cardboard packaging with 88%[19] recycled content. Recycling corrugated cardboard is also highly automated and cost-efficient with short average loops from cradle to cradle of 15 days[20]. This makes paper and board the most recycled packaging materials in Europe[21].

Corrugated cardboard is a renewable material as it is produced in Europe using fibres from sustainably managed forests which are then recycled over and over again. Owing to its natural origin, cardboard is considered biodegradable[22]. Even in the undesirable case where corrugated cardboard ends up in the environment, the average decomposition would be rapid with a rate of 2 months in water[23]. Cardboard producers are also constantly innovating and have succeeded in reducing the average board weight by 10% over the past 25 years[24].

The circular life cycle of corrugated cardboard packaging is characterised by its low carbon footprint. According to the LCA commissioned by FEFCO that is third party verified and that is used by the European Commission for reference data, the total carbon footprint amounts to 0.49 tonne CO_{2e} per tonne of cardboard packaging[25] which is low compared to other materials. Moreover, the emissions during transport are also low thanks to a range of elements: corrugated cardboard is a lightweight material; the high potential to customise the packaging to the dimensions of the product minimises empty space during transport; the supply chains are often local with limited

[15] FEFCO. URL: Fefco | European Corrugated Packaging Association in Brussels
CEPI, Key statistics, 2021. URL: https://www.cepi.org/wp-content/uploads/2022/07/Key-Statistics-2021-Final.pdf
European Commission, European greed deal: putting an end to wasteful packaging, boosting reuse and recycling, 2022. URL: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7155
[16] FEFCO website. URL: https://www.fefco.org/
[17] Deloitte interviews.
[18] Technische Universität Graz," Recyclability of cartonboard and carton", 2021.
[19] FEFCO. URL: https://www.fefco.org/circular-by-nature/easy-to-recycle
[20] Deloitte interviews.
[21] Eurostat, Packaging waste statistics, 20023. URL: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Packaging_waste_statistics#Recycling_and_recovery_targets_and_rates
CEPI, Key statistics, 2021. URL: https://www.cepi.org/wp-content/uploads/2022/07/Key-Statistics-2021-Final.pdf
[22] FEFCO. URL: https://www.fefco.org/about-fefco/industry-statistics?page=1
[23] UK Waterflow. URL: https://ukdnwaterflow.co.uk/advice/plastic-biodegradability-in-the-ocean/#:~:text=Paper%20and%20cardboard%20are%20100,months%20in%20a%20marine%20environment .
[24] FEFCO. URL: https://www.fefco.org/about-fefco/industry-statistics?page=1
[25] FEFCO LCA: https://www.fefco.org/sites/default/files/documents/2022/FEFCO_LCA_2022.pdf

distance from corrugated cardboard packaging producers to packers and from unpackers to recyclers[26]; and the supply chains from brand owners to distribution centres and clients are highly optimised which minimises overall transport kilometres. A recent report published by UNEP[27] highlighted that for a range of packaging applications, the switch from flexible plastic to sustainably sourced paper could decrease GHG emissions by 25% on average[28].

2.2 Logistics advantages

Single use corrugated cardboard packaging is part of well-functioning supply chains. Thanks to relatively short distances from packaging producer to packer (an average of only 80km[29]), the supply of corrugated cardboard packaging works with short loops facilitating timely responses to market needs. The high amount of corrugated cardboard recyclers in Europe also leads to short average distances between unpacker and recycler. With the production as well as the recycling of the material[30] occurring within the EU[31], resilience to macro-economic volatility and supply chain disruptions is high.

Corrugated cardboard limits the need for storage along the supply chain. Corrugated cardboard packaging sheets are relatively thin, thus minimizing space loss in transport and storage. Moreover, the flat sheets can be compactly transported to the packer where the boxes will only be folded just before use. Most importantly, the potential customization to the dimensions of the packaged good prevent empty headspace inside the packaging, thereby optimizing storage space once the product has been packed. After unpacking, cardboard can be easily flattened again and even compacted to make transport to recyclers as efficient as possible. As an overall result, both the amount of truck trips and the amount space needed in warehouses is minimised along the supply chain.

Corrugated cardboard boxes are shock resistant and highly customizable to products coming in different shapes[32]. The material allows for tailor-made branding, logo printing and printed instructions to operators which allows combining the functions of transport packaging and sales packaging, thereby preventing packaging waste along the way. Overall, the polyvalency and reliability of single use corrugated cardboard packaging accommodates efficiently the needs of the different actors in the supply chain.

[26] Deloitte interviews.
[27] UNEP, Turning odd the tap, 2023. URL: Plastic_pollution.pdf (unep.org)
[28] Ibid.
[29] Deloitte interviews.
[30] CEPI. URL: Sustainability & Circularity | www.cepi.org
[31] CEPI, European declaration on paper recycling 2021-2030. URL: https://www.cepi.org/wp-content/uploads/2022/06/EPRC-22-010.pdf
[32] Ibid.

3 Methodology case studies

To illustrate the trade-offs and analyse potential undesirable effects from substituting single use cardboard packaging by reuse alternatives, the report assesses the impacts in two specific product cases: grouped packaging for biscuits and packaging for heavy furniture kits. Figure 3This chapter presents the methodology to select the case studies, the data sources and the Circular Network Design model that assesses the effects (Figure 3).

Figure 3: Methodological approach

Case study selection	Data collection	Modelling
Survey Interviews Desk research Validation	Data request Interviews Literature review Validation workshop	Modelling Validation workshop

3.1 Selection of product cases

Two product cases were selected for investigation. The selection process was conducted using a three-step funnel approach:

- Establishing a long list of potential business cases. In this regard, FEFCO conducted a survey amongst members to gather feedback.
- Narrowing down the collected options. Deloitte together with FEFCO established a short list of potential business cases based on criteria such as market relevance, logistics challenges and data availability. Deloitte conducted a further deep dive onto the pre-selected cases through desk research and interviews to assess whether the short-listed business cases were fit-for-purpose.
- Validating the short list of cases. Deloitte presented the cases to the FEFCO members for input and validation. During the validation workshop the FEFCO members reviewed the analysis and validated the selection of the case studies.

Considering the high added value of cardboard as a renewable, circular, and low-carbon material in packaging, two case studies have been selected to illustrate the arguments put forward by this assessment.

3.2 Data collection

The study combined several methods to collect data:

- Literature review: The study builds on existing literature and policy reports. Literature reviews were conducted during product case-selection, model-building, and the analysis to fill up the data gaps remaining after receiving the responses to the data request.
- Strategic interviews: The study team conducted 17 interviews with industry experts that are positioned along the value chain of the corrugated cardboard packaging industry. The interviews took place in the case study-selection process and in the analysis periods.

- Data request: Deloitte built an excel-based data request compiling relevant information to build the quantitative model. The data request included logistics (volume, flows etc.) and environmental parameters (emissions in production, emissions in transport etc.). The data request was shared with the members of FEFCO in order to collect insights on key operational aspects. It is to be noted that the response rate to the data request was low with regards to operational data and insights on reusable packaging, leaving data gaps to be filled by leveraging on literature and interviews.

The combination of data sources provides insights from various perspectives and ample inputs for the modelling. Nonetheless, substantial data gaps remain such that some strong assumptions were made that have an important impact on the results.

3.3 Modelling

The Circular Design Network model that is used to model the supply chain for the two use cases follows a four-step approach to assess the potential impact of transitioning from single use corrugated cardboard to reusable packaging:

- Determining the counterfactual i.e., the hypothetical situation where corrugated cardboard packaging would be forced out of specific markets and replaced by reusable crates due to regulatory decisions: for the selected case studies, glass packaging is considered too fragile, metal too expensive and wood too heavy. Foldable plastic crates are already present on the market for various reuse applications and would probably be the reusable alternative to single use corrugated cardboard packaging in case regulations make reuse mandatory.
- Representing the related supply chains in a stylised way: The supply chains are illustrated in Figure 5 and Figure 10. These visualizations are based on interviews conducted with multiple industry experts and existing literature, but still simplify daily operations and the diversity in the industry.
- Analysing the nodes: A node refers to a different step in the supply chain, e.g., brand owner, retailer, waste management company. For each node, key parameters such as throughput, transportation requirements, and storage are benchmarked to identify differences between the cycles of single use and reusable packaging.
- Quantifying the impacts: The effects of implementing reusable plastic crates are analysed across the entire supply chain, and the impact is quantified in terms of volume, transport, CO_{2e} emissions (including packaging production and transport) and storage.

The model focuses on elements related to transport and production of the basic packaging materials. Several other aspects may affect but are not in scope:

- Economic and environmental aspects of tape for corrugated cardboard packaging, washing of reusable plastic crates (in case more than visual inspection and cleaning is needed) and filling materials for empty headspace are not taken into account.
- The walls of reusable crates tend to be thicker than the walls of corrugated cardboard boxes which may lead to a loss of inner space. The loss of available transport volume due to differences in wall thickness has not been modeled.
- Corrugated cardboard has a ‘cushioning’ effect that helps to prevent biscuits from crumbling and furniture to be scratched during transport. Substitution by other packaging materials would need an alternative solution to absorb shocks and prevent damage to the packed goods. The environmental impacts induced by alternative cushioning solutions have not been modelled and are therefore not incorporated in the results.

Table 1 provides further information on the set-up of the model, while the Annex provides a comprehensive list of assumptions and their references. Overall, the data gaps, the stylised set-up and the limitations of the scope have to be taken into account when interpreting the results.

Table 1: Key assumptions and calculations of the analytical model[33]

- To calculate the amount of corrugated cardboard packaging used in the two cases, the model considers the total corrugated cardboard packaging market in weight terms (28 Mt) and multiplies it with the respective market shares for biscuits (5.0%) and furniture (0.9%).
- To calculate the number of boxes required, a corrugated cardboard box with specific outer dimensions and weight has been considered (biscuits: 58 x 39 x 23 cm, 0.65 kg, furniture: 115 x 77 x 66 cm, 3.1 kg).
- Although new reusable plastic crates enter the system and worn-out models are continuously removed, the pool of available crates is relatively constant while demand fluctuates due to seasonality and peak periods, unpredictable return flows and lost or damaged goods. The model therefore incorporates a buffer to project the required amount of reusable plastic crates (20%). In the model, the CO2 impact of production of this extra buffer is spread over a time horizon of 4 years.
- Since reusable plastic crates allow less customization to the size of the packaged good, some efficiency loss, i.e., more headspace is factored in for the plastic crate (20%).
- The combination of another material, a larger box and the need for a design that can be reused, on average, 25 times without loss of quality, results in significantly higher weights of reusable crates (for biscuits: 1.66 kg, for furniture: 11.64 kg).
- During its lifetime, the packaging is moved in different forms:
- *Folded*: Applicable to both corrugated cardboard and plastic packaging. The packaging moves as folded if it doesn't carry any product in it. All reusable crates are considered foldable.
- *Filled*: Applicable to both corrugated cardboard and plastic packaging. From the moment the product is put into the packaging, the packaging moves as filled.
- *Pressed*: Only applicable to corrugated cardboard. During the return flow of corrugated cardboard, the packaging is pressed and transported in a bale.
- The number of pallets needed to transport packaging and/or products is calculated at each node of the cycle. The thickness of a folded plastic crate (7.0 cm) is significantly higher than folded corrugated cardboard packaging (cardboard sheets: 0.6 cm for biscuits and 1.0 cm for furniture), which also effects the total amount of pallets with packaging at each node. After use, corrugated cardboard can be further compressed to optimise transport to a recycler (to 40% of initial thickness).
- The total transport required between each node is calculated, assuming all the transport is done by road using mega trailers (33 Euro pallet footprint, in stackable condition) with an estimated average load efficiency for each node (see details in annex)
- To determine the transport cost and quantity, average figures are used for the distance between each node and the cost per kilometer are considered (see details in annex).
- For the environmental impact from transport, an industry average applies (0.062 kg CO_{2e} per tonne-km).
- For CO_{2e} emissions during the corrugated cardboard production (0.49 tonne CO_{2e} per tonne packaging) and crate packaging production (2.79 tonne CO2e per tonne packaging), literature and LCA figures from sector federations have been taken into account.
- To assess storage costs, the model considers the number of days that packaging remains in stock at each node of the supply chain for both the filled and folded states. The model then applies an average industry cost for storage (5 € per pallet of 1.3 m high per month). The estimation includes expenses associated with warehousing, handling, and other relevant storage-related costs.

4 Case study: Grouped packaging for biscuits

[33] See the tables in Annex for more details on the assumptions and their sources

This chapter analyses the potential impacts of a shift from corrugated cardboard to reusable plastic crates for grouped packaging of biscuits. The analysis focuses on three dimensions: transport, storage, and greenhouse gas (GHG) emissions from transport and production. The sections discuss the set-up of the case study, the impacts, the sensitivity analysis and the key takeaways.

4.1 Set-up

All numbers relate to the approximate annual demand for biscuits including cakes and similar confectionary in Europe. Total demand for corrugated cardboard packaging is estimated at 28 million tonnes with around 5%[34] or 1.4 million tonnes of corrugated cardboard being used for biscuits packaging. Assuming the boxes presented in Table 2 are representative for the market, this relates to 2.2 billion boxes that need to be shipped (see appendix for more assumptions and sources).

Table 2: Product case summary information with outer dimensions and weight

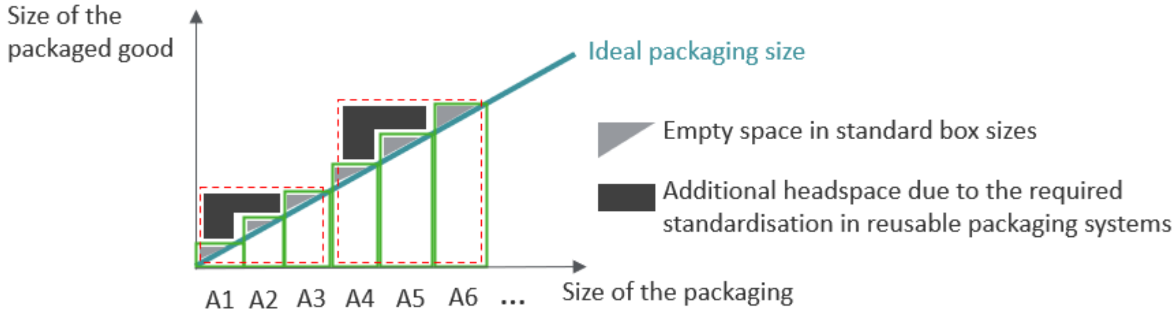
	CORRUGATED CARDBOARD BOX	REUSABLE PLASTIC CRATES
BOX LENGTH	0.58 m	0.58 m
BOX WIDTH	0.39 m	0.39 m
BOX HEIGHT	0.23 m	0.27 m
BOX WEIGHT	0.65 kg	1.66 kg

The study assumes that the single use and reusable boxes have the same length and width (Table 2). However, since reuse boxes will need to be standardised while the dimensions of packaged goods can vary significantly, the reusable crates will contain additional empty space (headspace) represented by the box height that increases by 20%. Figure 4 illustrates how size standardisation in reusable crates leads to empty space and efficiency loss of in transport as well as storage.

Table 2 also shows that the combination of another material, a larger box and the need for a design that can be reused 25 times, results in significantly higher weights of reusable crates.

[34] Rough estimation based on Eurostat categories and finetuning from inputs during interviews. Affects magnitude of effects, but not relative results between scenarios.

Figure 4: Illustration of efficiency loss when packaging has to be highly standardized



The stylised supply chains modelled for both packaging types also have some differences in flows and nodes as presented in Figure 5 and further explained in Table 3.

Figure 5: Supply chain of grouped packaging for biscuits

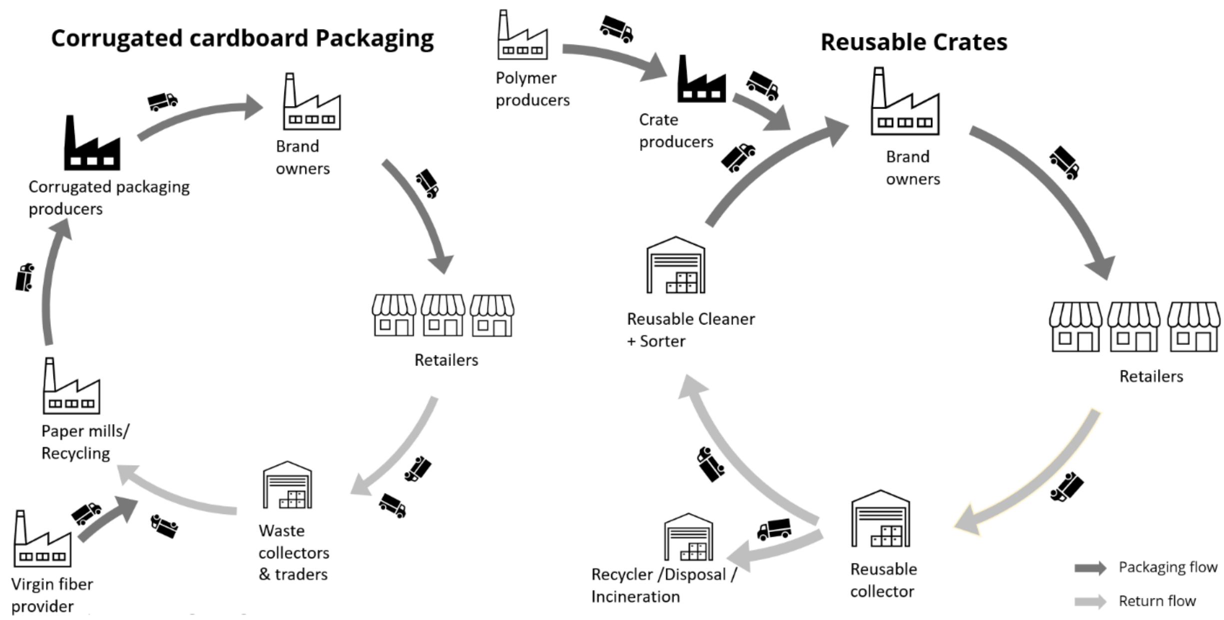


Table 3: Summary information on key flows along the supply chain

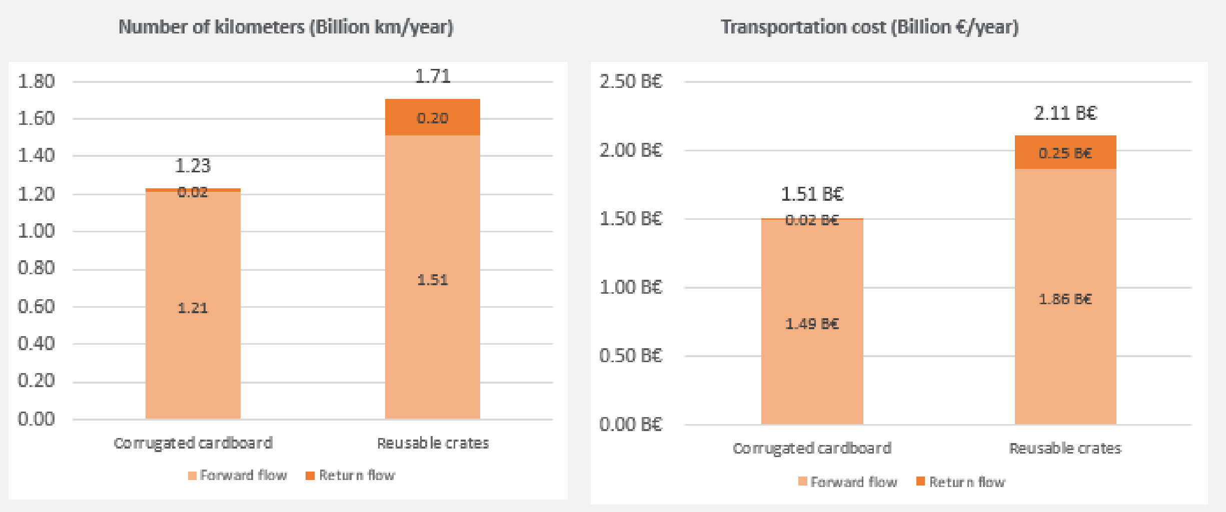
Node	Corrugated cardboard box	Plastic reusable crates
Packaging producers	Corrugated cardboard packaging is produced with materials from paper mills.	Reusable plastic crates are produced with polymers from polymer producers.
Brand owners	Brand owners are the confectionary producers. They receive folded packaging from producers. Brand owners ship packed goods to retailers.	
Retailers	Retailers are businesses directly selling goods to end customers. They centralise and store the packed goods, then dispatch them as per local branch stores' needs.	
Return flow	After usage of corrugated cardboard by retailers. The packaging is pressed and collected by local waste collectors and traders. Packaging is sorted and the recyclable cardboard is shipped to paper mills for recycling.	Used crates are collected by reusable collectors and shipped folded to centralised reusable cleaners and sorters. There, reusable crates are cleaned and sorted before being sent back to brand owners.

4.2 Impact on transport

The model compares transport costs and number of truck journeys required to ship 2.2 billion boxes of biscuits per year (Figure 6). In the case of corrugated cardboard, this operation requires 1.2 billion kilometres per year, for a total cost of 1.5 billion €. Once used, corrugated cardboard packaging is collected from retailers by waste collectors & traders, and recuperated fibres are sent back into the almost fully closed supply chain loop (Figure 5).

In the case of reusable packaging, the same economic activity requires 1.7 billion kilometres driven per year, for a total cost of 2.1 billion €. Reusable packaging is then collected from retailers, cleaned, and sorted before being sent for reuse in the supply chain. Plastic crates can be reused until breakage point, assumed to be 25 times in the model.

Figure 6: kilometres and costs of transport in the selected scenarios for grouped packaging of biscuits



Source: Deloitte internal resources

Figure 6 highlights that the biggest fraction of transport costs and kilometres driven are related to the forward flow (bringing the goods to the consumer). Indeed, in the return flow (collecting the end-of-life packaging for recycling and a new lifecycle), the packaging boxes are transported in folded state which significantly reduces the space needed in trucks. For corrugated cardboard, on top of the foldability, the packaging is transported in compressed bales which gives an additional 40% reduction of volume and related efficiency increase to the return flow.

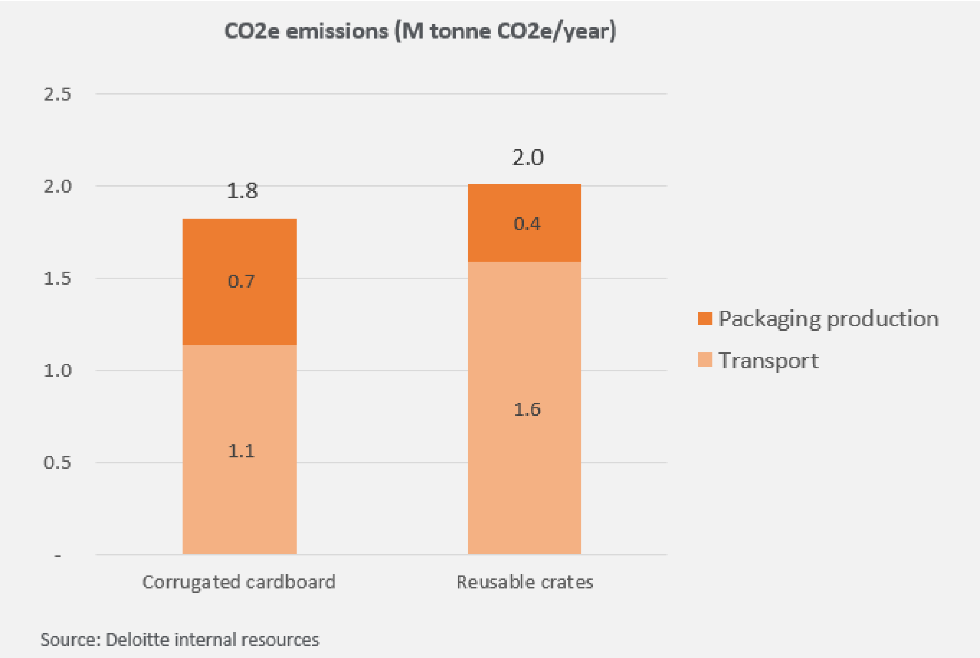
A key element that drives the 0.5 billion kilometres gap, and the 39% cost increase per year, is the larger size of the standardised reusable packaging and the related additional number of truck journeys required to transport the packaged products. There is also a less impactful aspect that affects the forward flow: production of corrugated cardboard boxes is organised in a short, localised loop, in which customers are on average located 80 km away from the production plant. Conversely, reusable crates are needed in lower quantities, but still need to be produced at sufficient scale to be profitable. Hence, they may be produced more centralised, i.e., more distance between packaging producer and packer (200 km or 120 km further than in the corrugated cardboard scenario). Both elements that relate to the forward flow translate into additional truck journeys and explain 62% of the total cost difference in transport.

Compared to corrugated cardboard, the return flow of reusables requires additional steps for sorting and cleaning. The distance between nodes is therefore slightly higher in a reusable system (350 km from retailer that unpacks back to brand owner that packs, compared to 330 km for the equivalent journey in the case of corrugated cardboard packaging). Also, when returned, folded reusable crates are over 11 times thicker than folded corrugated packaging and even more when the end-of-life corrugated packaging is pressed for transport to a recycler. These aspects lead to more trips and costs in the return flow of reusable crates.

4.3 Impact on emissions

The model compares total CO_{2e} emissions generated in the production and transport of 2.2 billion biscuit boxes for corrugated cardboard packaging and reusable crates. The shift from corrugated cardboard to reusable packaging displays an overall 10% increase in CO_{2e} emissions (Figure 7).

Figure 7: Summary graph on CO_{2e} emissions impact for grouped packaging for biscuits



The model shows that CO_{2e} emissions from the production of reusable packaging are 39% lower, mainly driven by the assumption that the crates can be reused up to 25 times. The positive impact of reusability is however diminished owing to the high weight of a reusable crate (2.5 times higher than corrugated cardboard boxes), the additional buffer needed to deal with fluctuations in demand (20% additional crates allocated over a time horizon of 4 years) and the weight-based carbon footprint of a plastic crate (five times higher than for a corrugated cardboard box).

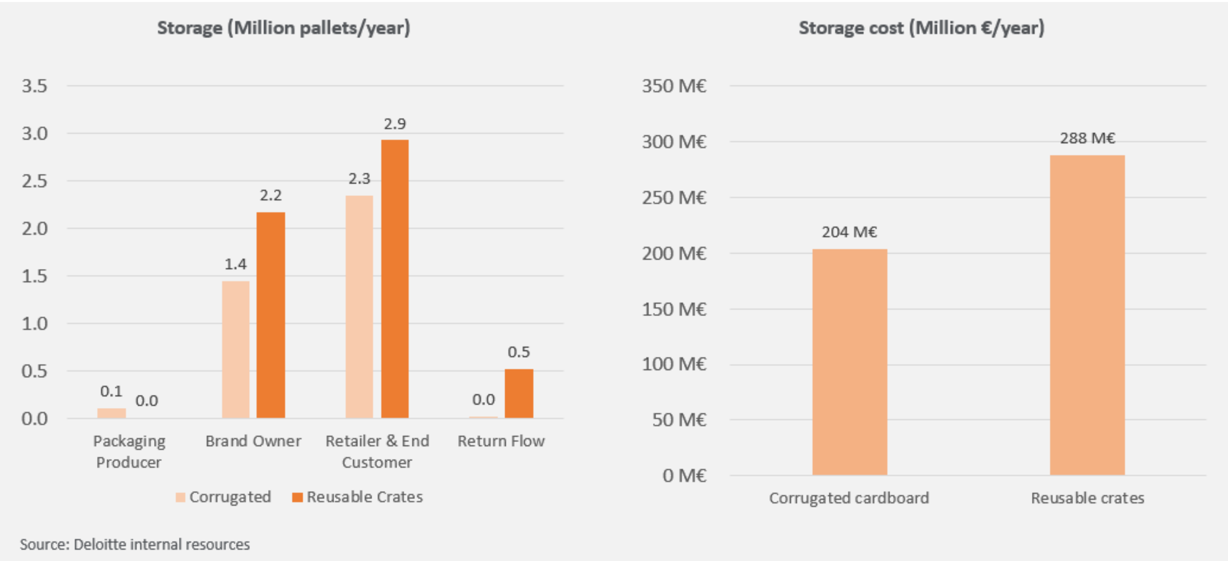
However, the model shows that transport GHG emissions increase 40% when shifting to reusable crates. This is mainly explained by an increase in the number of shipments and kilometres driven as discussed in the previous section. Thus, reuse systems induce additional transport, which translates into additional emissions.

Looking at the overall result of the model, reusable crates for biscuits induce in the given scenario additional GHG emissions because the higher emissions of more transport outweigh the lower emissions of less packaging production.

4.4 Impact on storage

The model investigates storage cost and space needed for the operation of 2.2 billion biscuit boxes a year (Figure 8). The shift from corrugated cardboard to reusable plastic crates leads to a 41% increase in storage space needed and a related increase in storage costs.

Figure 8: Summary graph on storage impact for grouped packaging for biscuits



The need for additional storage for reusable packaging is driven by the packaging size and packaging thickness. In the forward flow, the low potential for customisation of reusable packaging to product size results in packaging inefficiency. Hence, plastic crates are on average shipped with 20% more empty space than corrugated cardboard packaging, which increases the amount of reusable packaging material and requires more space for storage at each node. In the return flow, reusable crates are bulkier and more than 11 times thicker than corrugated cardboard packaging when folded. Moreover, corrugated packaging can be pressed in the return flow, making it even more thin, and thus, minimizing storage and transport space needed. There is also a structural need for additional stock of empty crates in order to absorb abnormalities in the supply chain such as unpredictable return flow, stock imbalance, seasonality etc. In the model, it is assumed that 20% extra stock of reusable packaging is kept at brand owners in order to absorb these abnormalities. The impact of this extra buffer is spread over 4 years of period. This significantly affects storage space needed and increases associated costs.

4.5 Sensitivity analysis

Sensitivity analysis gives a perspective on overall uncertainty related to assumptions for the counterfactual (the hypothetical reuse scenario) and provides comparative insights to the baseline scenario. Table 4 helps to understand which assumptions and parameters have the largest effect on the results by increasing/decreasing each of the parameters with 20%. For example, the efficiency loss due to the lack of flexibility to customize packaging dimensions, is estimated to be 20%. In the sensitivity analysis the impact on the results will be measured when the assumption becomes 24% or 16%. Similarly, the impact of the results will be measured when the number of lifecycles of reusable crates is 30 or 20.

Table 4: Sensitivity analysis on parameters with a high level of uncertainty

Parameter in model	Baseline value	Sensitivity applied	impact on transport (M km)	impact on storage (K pallet)	impact on CO2 emission (Mtonne CO2)	impact on transport & storage cost (M€)
Transport & storage parameters						
Efficiency Loss	20%	+20% -20%	154 -217	137 -137	0.14 -0.20	197 -274
Transport emissions	0.062 kg CO2/km	+20% -20%	- -	- -	0.29 -0.29	- -
Thickness folded packaging	0.07 m	+20% -20%	37 -40	202 -202	0.03 -0.04	56 -60
Additional km return flow	100 km extra	+20% -20%	10 -10	- -	0.01 -0.01	13 -13
Seasonality buffer	20%	+20% -20%	0 0	16 -16	0.01 -0.01	1 -1
Distance producer to packer	120 km extra	+20% -20%	1 -1	- -	0.00 0.00	1 -1
Production parameters						
Number of cycles	25 cycles	+20% -20%	-1 1	- -	-0.07 0.11	-1 1
Weight of reusable crate	1.66 kg	+20% -20%	- -	- -	0.09 -0.09	- -
CO2 footprint of reusable crate	2.79 ton CO2/ton	+20% -20%	- -	- -	0.09 -0.09	- -

Table 4 highlights that the four most impactful transport & storage parameters are: efficiency loss, CO2 footprint of transport, thickness of folded packaging and additional transport in the return flow. The seasonality buffer and distance between packaging producer and packer have minor effects. For production, the three most impactful parameters are the number of cycles that the crates can be reused, the weight of the reusable crates and the CO2 footprint of the material.

The high sensitivity of CO_2 emissions in function of transport emissions per km driven suggests that the expected decarbonization of the transport fleet may reduce the environmental impact of reuse solutions significantly. This effect would, however, also reduce the emissions of single use solutions. Moreover, reducing CO_2 emissions of a fleet will probably be more expensive and challenging than reducing the environmental emissions of single-point industrial facilities that recycle and produce materials. The effects of future decarbonisation trends on the balance between single use and reusable packaging in terms of transport costs and CO_2 emissions are therefore uncertain and ambiguous. Investigating the effects of future trends is out of scope for this study and would require forward-looking projections and analysis of emerging technologies for transport as well as production.

The analysis in the previous sections showed that reusable alternatives are both more expensive and emit overall more GHG emissions than single use corrugated carbon. To test whether the results hold in a scenario where innovation would structurally improve reuse characteristics, we compare the baseline scenario with an alternative scenario where the three most impactful transport & storage parameters (excluding transport emissions as this would also bring down the emissions in the baseline corrugated cardboard scenario) and the three impactful production parameters are simultaneously 20% more beneficial for reusable crates (Table 5).

Table 5: Summary information for the Robustness check for reusable alternatives

Parameter	Change in assumptions from the baseline for the robustness check
Efficiency loss from reusable packaging	-20%
Thickness folded reusable packaging	-20%
Additional km return flow in reuse system	-20%
Amount of lifecycles of reusable crates	+20%
Weight of a reusable crate	-20%
CO2 footprint of the material for a reusable crate	-20%

Figure 9: Sensitivity check

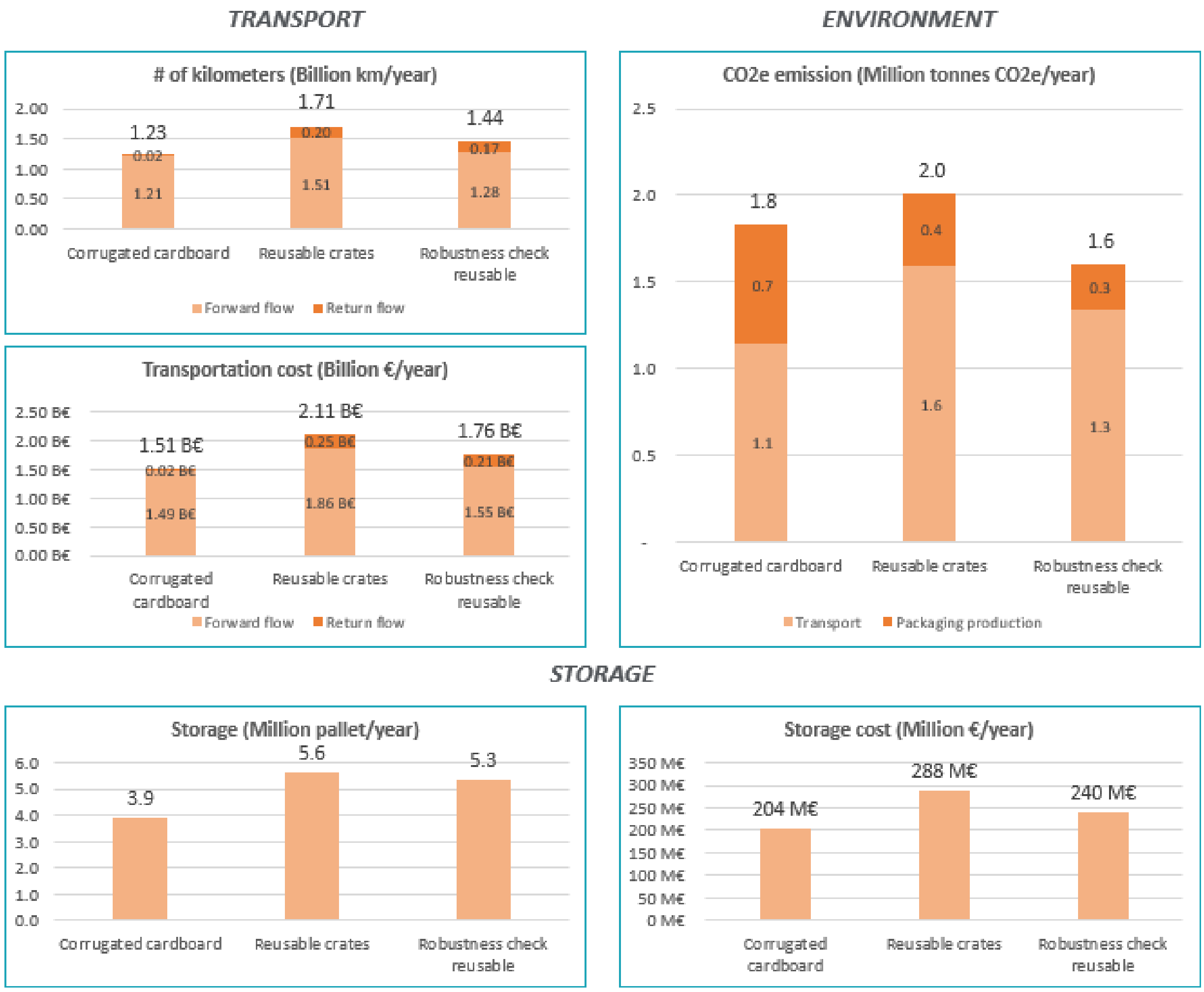


Figure 9 depicts the following elements:

- The increase of transport kilometers and costs induced by reuse is robust even when assumptions for key parameters are modified.
- The higher GHG emissions induced by a shift to reusable are turned around into a GHG benefit for reusable packaging for biscuits. The GHG emissions of both packaging solutions are close to each other which results in ambiguous outcomes depending on assumptions taken. The projections indicate that GHG impacts are equivalent and not sufficiently different to conclude that the emissions of single use or reusable packaging are better.
- The increase in storage space needed and associated costs is robust even assumptions for key parameters are modified.

5 Case study: Packaging for heavy furniture kits

This chapter analyses the potential impacts of a shift from corrugated cardboard to reusable packaging for heavy furniture kits, e.g., a mid-size closet or a heavy office chair that require some assembly at home. The typical weight would range from 15 to 45 kg[35]. The analysis focuses on three dimensions: transport, (GHG) emissions from transport and production, and storage. The sections discuss the set-up of the case study, the impacts and the key takeaways.

5.1 Set-up

Total demand for corrugated cardboard packaging is estimated at 28 million tonnes with around 0.9%[36] or 252 thousand tonnes per year of corrugated cardboard being used for furniture packaging. Assuming the boxes presented in Table 6 are representative for the market, this relates to 81 million furniture kits that need to be shipped (see appendix for more assumptions and sources).

Table 6: Product case summary information with outer dimensions and weight

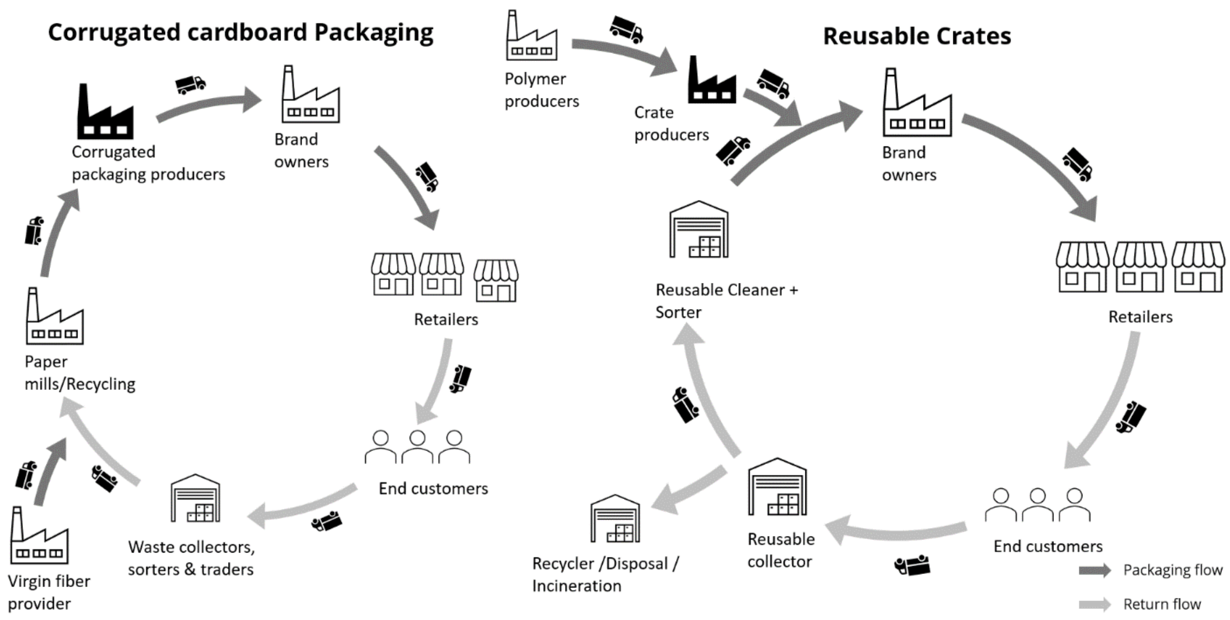
	CORRUGATED CARDBOARD BOX	REUSABLE PLASTIC CRATES
BOX LENGTH	1.15 m	1.15 m
BOX WIDTH	0.77 m	0.77 m
BOX HEIGHT	0.60 m	0.72 m
BOX WEIGHT	3.10 kg	11.64 kg

Table 6 displays the measurements used for the two types of packaging. Since the size of the reuse boxes needs to be standardised while the dimensions of the products shipped will diverge, the reusable crates will contain additional empty space (headspace). The additional empty space, also referred to as “efficiency loss” (Figure 4), is estimated at 20% and leads to a higher height for reusable crates. To carry bulky and heavy products with different shapes, the reusable packaging must be strong. Due to the variety of furniture products, the strength of the reusable packaging will be over-dimensioned for many of the products it will ship in its lifetime, which further drives up the weight of reusable packaging.

35 Deloitte Interviews.

36 Eurostat. https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_TA_TG__custom_6075279/default/table?lang=en

Figure 10: Supply chain of packaging for heavy furniture kits



Single use and reusable packaging for furniture kits follow different flows along their lifecycle as illustrated in Figure 10 that the presents the stylised supply chains used for the analysis. The most important difference with the biscuits case study is that the furniture kit goes beyond the retailer level and reaches the households. Table 7 gives more information on the nodes and flows.

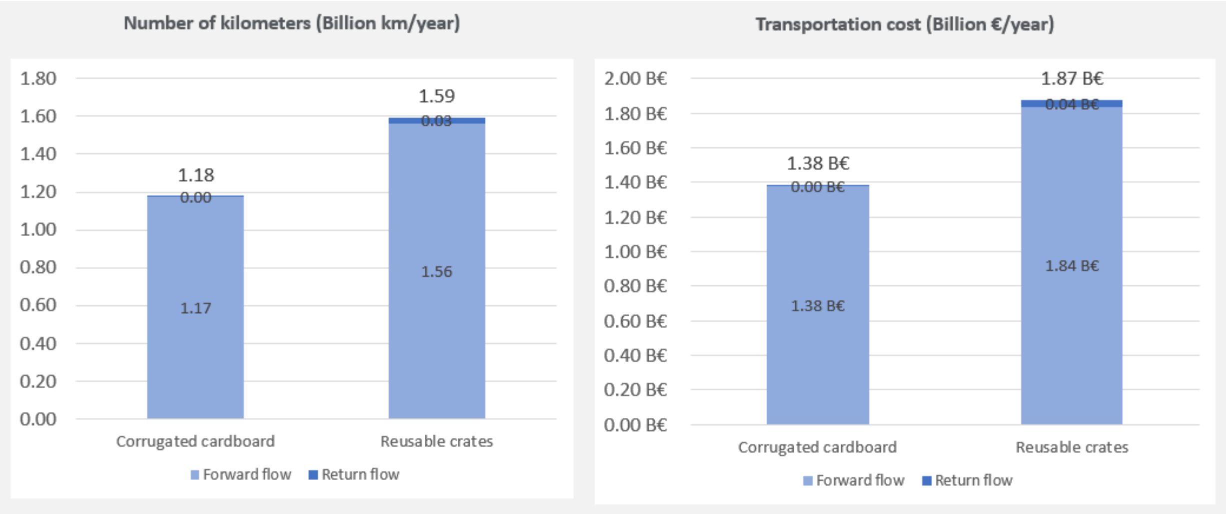
Table 7: Summary information on key flows along the supply chain

Node	Corrugated cardboard box	Plastic reusable crates
Packaging producers	Corrugated cardboard packaging is produced with materials from paper mills.	Plastic reusable crates are produced with polymers from polymer producers.
Brand owners	Brand owners are furniture producers. They receive folded packaging from producers. Brand owners ship packed heavy furniture kits to retailers.	
Retailers	Retailers are businesses directly selling goods to end customers. They centralise and store the packed goods, then dispatch them as per local branch stores' needs.	
End customers	End customers select and buy packed heavy furniture kits from local retailers/stores. The packed furniture is shipped to the premises of end customers.	
Return flow	After usage of corrugated cardboard by end customers. The packaging is collected by local waste collectors and traders. Packaging is sorted and sent to paper mills for recycling.	Used crates are collected from end customers by a reusable collector that ships them to centralised reusable cleaners and sorters. There, reusable crates are cleaned and sorted before being sent back to brand owners.

5.2 Impact on transport

The model compares transport costs and number of truck journeys required to ship 81 million boxes of furniture kits per year. Figure 11 shows a 36% increase in transport kilometres and associated costs in case reusable packaging would be legally imposed. The results are almost fully driven by effects in the forward flow because the bulky reusable crates can be folded to be efficiently transported in the return flow.

Figure 11: Summary graph on transport impact for packaging for heavy furniture kits



Source: Deloitte internal resources

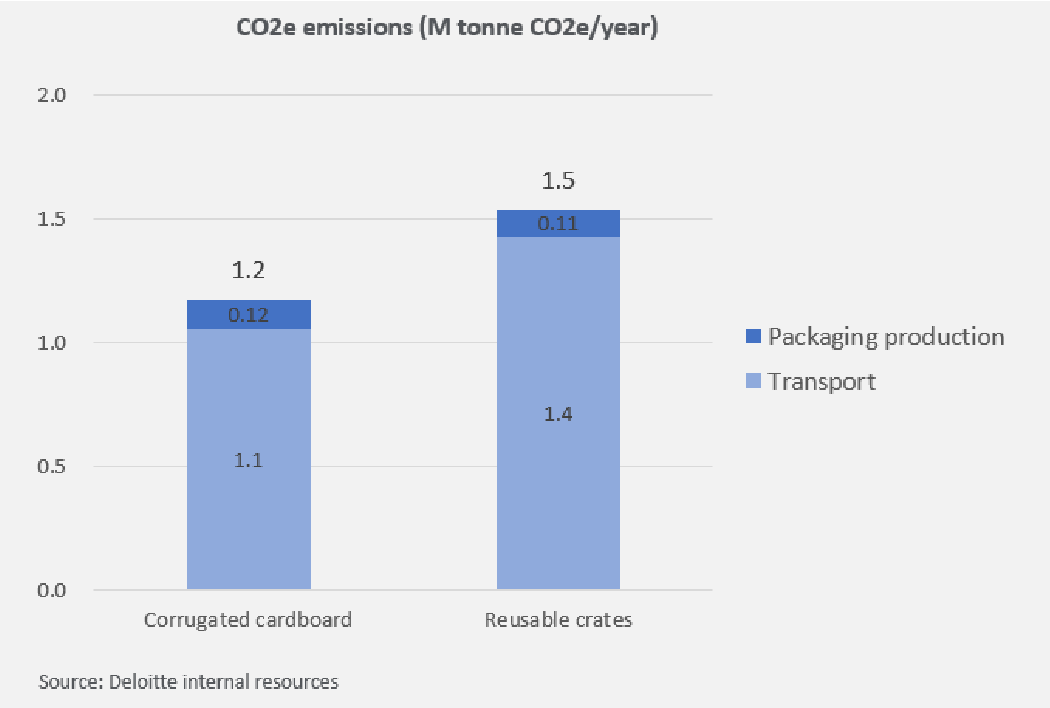
A potential shift to reusable packaging specifically impacts costs for the transport from brand owners to retailers and from retailers' depots to the point of sale that both incur a 33% increase in costs . This is driven by three main elements:

- The additional empty space caused by the lack of customization of the reusable packaging to the dimensions of the product, leads to 0.4 billion additional kilometers because the volume available on pallets and in trucks is an important logistics constraint. This affects transport from brand owners till the point of sale in particular because packaging is shipped filled at these nodes of the supply chain. Therefore, the costs of these actors increase most. The repercussion of crate size on the number of shipments represents 98% of the overall transport cost increase.
- The increase in transportation cost is also a bit affected by distance. In fact, reusable crates production is assumed to be further away from packers for production volume purposes (120 km more between packaging producer and brand owner). Moreover, in the return flow, reusing crates leads to more nodes and slightly more kilometers (20 km more from end-consumer back to brand owner). As a result, reusable crate packaging crosses more kilometers than corrugated cardboard which benefits from presence all over Europe close to the packers.
- Additionally, from a practical point of view, the use of reusable crates for heavy furniture packaging is quite challenging. It creates an extra burden for end customers in charge of transporting and storing packaging before it is picked up for reuse. The impact on the consumer is rather complex to monetise, but effectively affects the business model around heavy furniture kit sales and would require fundamental changes along the supply chain. Therefore, the analysis probably shows an underestimation of the direct and indirect costs of a shift to reusable packaging.

5.3 Impact on emissions

The model compares total GHG emissions generated by the production and transport of corrugated cardboard boxes and reusable plastic crates needed to ship 81 million furniture kits. The shift from corrugated cardboard to reusable packaging displays an overall 31% increase in GHG emissions (Figure 12).

Figure 12: Summary graph on CO_{2e} emissions for packaging for packaging for heavy furniture kits



Although reusable crates can transport the same number of products as corrugated cardboard with less than 5% of the boxes, the higher weight of the crates (4 times higher), the need for additional buffer (20%, allocated over a 4-year time horizon) and the weight-based carbon footprint (more than 5 times higher than corrugated cardboard) make that the production emissions in a reuse system for furniture kits are only slightly lower.

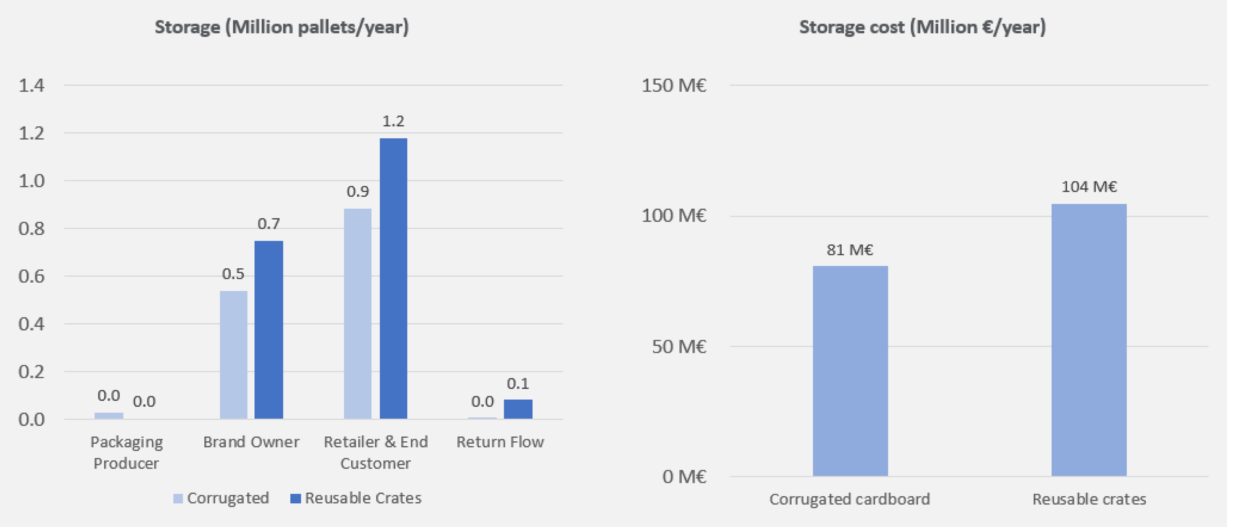
For transport emissions, the model shows an increase of 36% when shifting to reusable crates. This is mainly driven by the higher number of shipments due to efficiency loss and the increase in distance in the return flow.

Overall, the results indicate that total GHG emissions of reusable crates (combining production and transport) are substantially higher than for corrugated cardboard packaging.

5.4 Impact on storage

The model investigates storage cost and space needed for the delivery of 81million furniture kits per year. The transition from corrugated cardboard to reusable crates increases storage costs by 30%.

Figure 13: Summary graph on storage for packaging for packaging for heavy furniture kits



Source: Deloitte internal resources

The increased cost specifically affects brand owners and retailers that require more space to absorb the same volume of goods (Figure 13). The additional space comes from two elements. First, brand owners receive packaged goods, which contain 20% more empty space due to the low potential to customize packaging to product dimensions. Therefore, brand owners, receive bulkier products on stock, requiring a doubling of storage space available. Second, to mitigate the risk for uncertainty and seasonality, a buffer equivalent to an additional 20% stock of empty crates that require additional storage space.

5.5 Sensitivity analysis

The analysis also includes a sensitivity analysis (Table 8) to highlight the level of uncertainty in the results and provide comparative insights to the baseline.

Table 8: Sensitivity analysis on parameters with a high level of uncertainty

Parameter in model	Baseline value	Sensitivity applied	impact on transport (M km)	impact on storage (K pallet)	impact on CO2 emission (Mtonne CO2)	impact on transport & storage cost (M€)
Transport & storage parameters						
Efficiency Loss	20%	+20% -20%	151 -166	67 -67	0.14 -0.14	181 -199
Transport emissions	0.062 kg CO2/km	+20% -20%	- -	- -	0.27 -0.27	- -
Thickness folded plastic crate	0.07 m	+20% -20%	6 -6	47 -47	0.01 -0.01	9 -10
Additional km return flow	100 km extra	+20% -20%	2 -2	- -	<0.01 <0.01	2 -2
Seasonality buffer	20%	+20% -20%	0 0	3 -3	0.01 -0.01	0 0
Distance producer to packer	120 km extra	-20% -20%	0 0	- -	<0.01 <0.01	0 0
Production parameters						
Number of cycles	25 cycles	+20% -20%	0 0	- -	-0.02 0.03	0 0
Weight of reusable crate	11.64 kg	+20% -20%	- -	- -	0.02 -0.02	- -
CO2 footprint of reusable crate	2.79 ton CO2/ton	+20% -20%	- -	- -	0.02 -0.02	- -

Table 8 highlights that the four most impactful transport & storage parameters are: efficiency loss, transport emissions, thickness of folded packaging and additional transport in the return flow. The seasonality buffer and the distance between packaging producer and packer have minor impacts. For production, the three most impactful parameters are the number of cycles that the crates can be reused, the weight of the reusable crates and the CO2 footprint of the reusable material.

The analysis in the previous sections indicated that reusable alternatives for furniture kits are both more expensive and emit more GHG emissions than single use corrugated carbon. To test whether the results hold in a scenario where innovation would structurally improve reuse characteristics, we compare the baseline scenario with an alternative scenario where the key parameters for reusable crates are simultaneously 20% more beneficial (Table 9).

Table 9: Summary information for the Robustness check for reusable alternatives

Parameter	Change in assumptions from the baseline for the robustness check
Efficiency loss from reusable packaging	-20%
Thickness folded reusable packaging	-20%
Additional km return flow in reuse system	-20%
Amount of lifecycles of reusable crates	+20%
Weight of a reusable crate	-20%
CO2 footprint of the material for a reusable crate	-20%

Figure 14: Sensitivity check

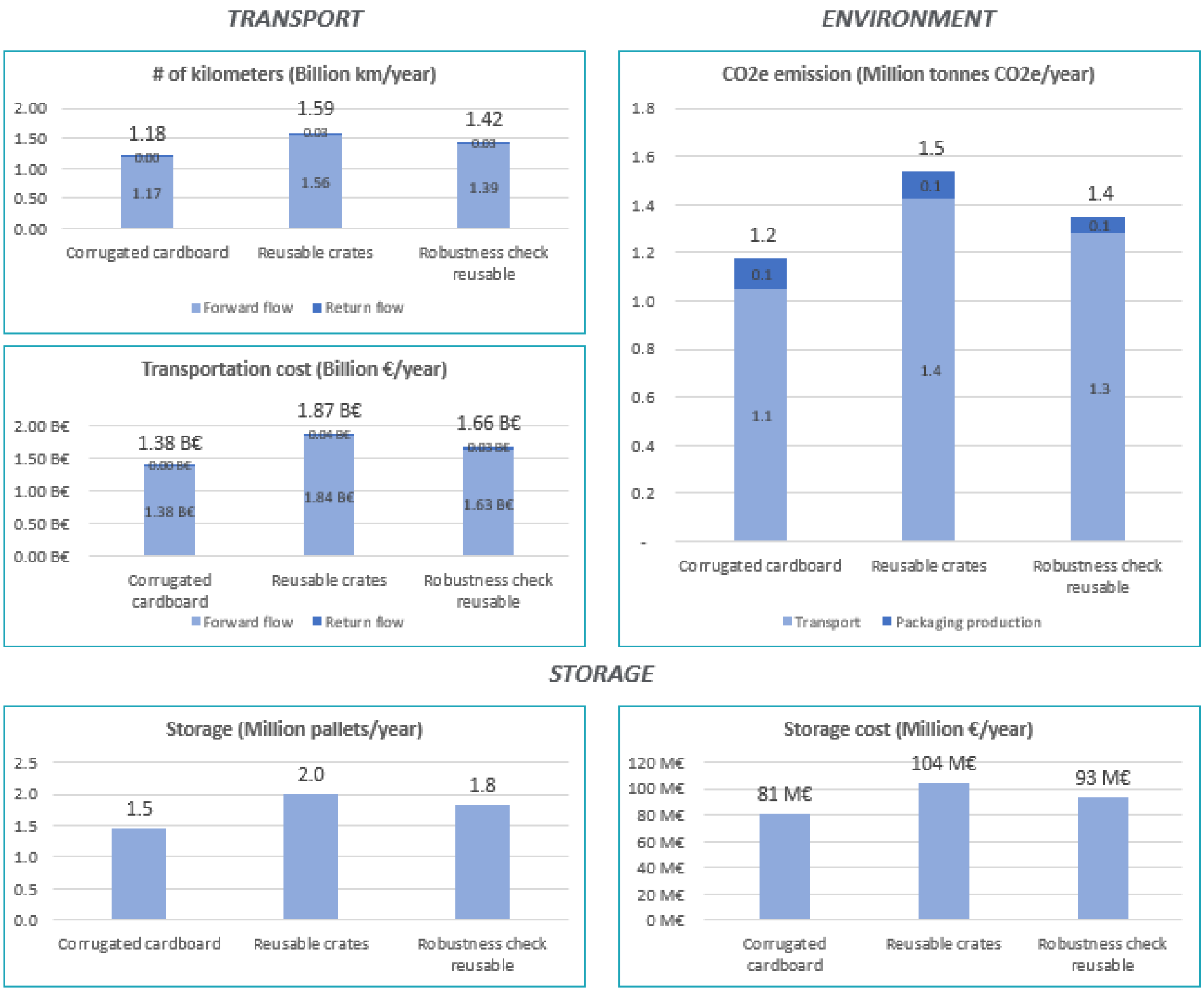


Figure 14 depicts the following elements:

- The increase of transport kilometers and costs induced by reuse is robust even when assumptions for key parameters are modified. The main changes are driven by the forward flow with only minor changes in the return flow.
- The higher GHG emissions resulting from reuse remain robust even when assumptions of the key parameters are modified. In the robustness check, production emissions from reusable plastic crates are

lower than in the corrugated cardboard scenario, but the effect is minor compared to the significantly higher transport emissions.

- The increase in storage space needed and associated costs is robust even if assumptions for key parameters are modified.

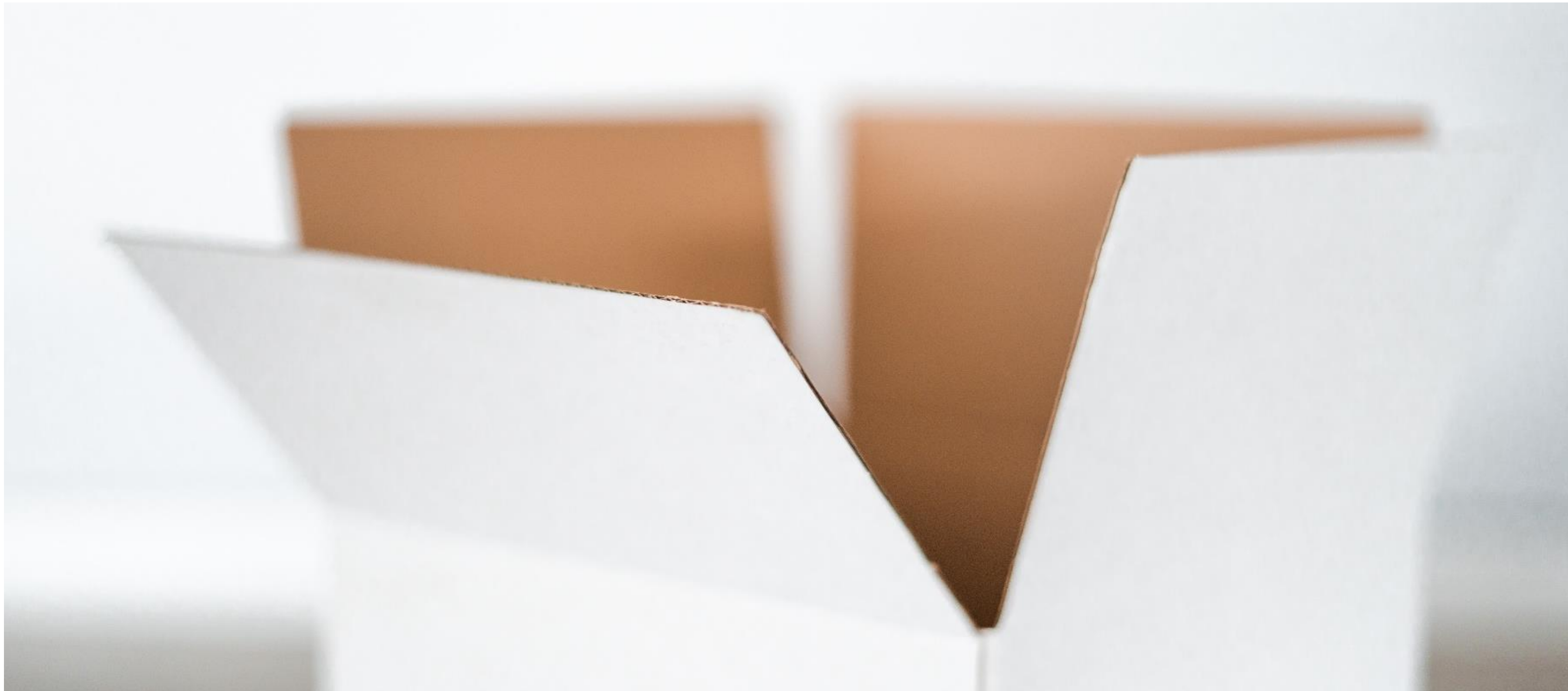
6 Key takeaways

The two case studies highlight some important impacts in case regulations would force the market to shift from corrugated cardboard boxes to reusable plastic crates:

- Transport costs would increase substantially, due to less efficient logistics resulting in additional shipments and more kilometers spanned along the supply chain. This is driven by two factors. First, in the forward flow, more empty space is shipped due to the low potential for customization of reusable packaging size to product size. Second, the shipment distances in the reusable return flow are higher than in the single use case.
- The impact of a shift to reusable packaging on GHG emissions depends on the application. With the assumptions taken, the model indicates that the impact on GHG emissions of shifting to reusable packaging for the transport of biscuit boxes would be minimal. For packaging of furniture kits, the impact of reuse on GHG emissions would be negative and increase the overall emissions. Indeed, reuse decreases the emissions related to production thanks to a lower need for new crates, but induces significant additional transport emissions that can lead to overall higher emissions.
- The need for storage and associated storage costs are higher in a reusable system, due to the increase in crate size in the forward flow, the extra thickness of folded crates and the need for additional crates to cover for seasonality and other fluctuations all along the supply chain.

In summary, legal obligations that impose reuse would lead to substantial logistics challenges all along the supply chain. If markets do not succeed in re-optimizing and structurally standardizing product sizes all along the supply chain, single use corrugated cardboard would be less emission-intensive than reusable crates. Product standardisation would require an industry-wide effort to allow for an almost perfect adjustment between products, packaging sizes and pallets. Such a structural market change across countries as well as market actors will for many applications be difficult to bring into reality.

Shifting to reusable packaging would also induce many practical issues. For example, the need to find alternative solutions for the shock absorption and scratch prevention that corrugated cardboard offers. Also, in case reusable packaging concerns sales packaging, the shift from single use packaging with well-established collection facilities for recycling, to reusable alternatives with collection systems for reuse that probably require more effort and temporary storage, particularly affects end consumers. This effect is difficult to monetize, but the burden for end-consumers might be significant.



7 Annex

7.1 Model Assumptions

Table 10 presents the throughput related assumptions which are utilised in the calculation of the model baseline with corrugated cardboard and impact analyses of reusable solutions.

Table 10: Assumptions of analytical model on throughput

Parameter	Unit	Data
Total corrugated volume in Europe[37]	tonnes/year	28,019,000
Biscuit corrugated packaging volume share out of total corrugated volume[38]	%	5.0%
Furniture corrugated packaging volume share out of total corrugated volume[39]	%	0.9%
Biscuits - Corrugated Box Specifics: L[40]	m	0.58
Biscuits - Corrugated Box Specifics: W[41]	m	0.39
Biscuits - Corrugated Box Specifics: H[42]	m	0.23
Biscuits - Corrugated Box Specifics: Weight[43]	kg	0.65
Furniture - Corrugated Box Specifics: L[44]	m	1.15
Furniture - Corrugated Box Specifics: W[45]	m	0.77
Furniture - Corrugated Box Specifics: H[46]	m	0.60
Furniture - Corrugated Box Specifics: Weight[47]	kg	3.10
Biscuits - Crate Box Specifics: Weight[48]	kg	1.66
Furniture - Crate Box Specifics: Weight[49]	kg	11.64

[37] FEFCO website. URL : https://www.fefco.org/sites/default/files/files/Fefco_AnnualEvaluation_2021%288%29.pdf
[38] Rough estimation based on Eurostat categories and finetuning from inputs during interviews. Affects magnitude of effects, but not relative results between scenarios. Eurostat. https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_TA_TG__custom_6075279/default/table?lang=en
[39] Eurostat. https://ec.europa.eu/eurostat/databrowser/view/ROAD_GO_TA_TG__custom_6075279/default/table?lang=en
[40] FEFCO code 0201 box specifics https://www.fefco.org/sites/default/files/documents/2022/FEFCO_LCA_2022.pdf
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[44] FEFCO code 0201 box with multiplying by 2
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[46] FEFCO code 0201 box with multiplying by 3
[47] FEFCO website. URL: https://www.fefco.org/sites/default/files/documents/2022/FEFCO_LCA_2022.pdf
[48] IP group. URL: https://www.ip-group.com/products/plastic-crates/compact/plastic-crate-eg-600x400x220-mm/#
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Kaiser kraft URL: https://www.kaiserkraft.be/bakken-voor-het-opbergen/vouwboxen/vouwbox-van-polypropyleen/inhoud-200-liter-met-scharnierdeksel/p/M7940/
Auer packaging URL: https://www.auer-packaging.com/be/nl/Vouwboxen-zonder-deksel/FB-86445.html

Average thickness of a folded corrugated cardboard – biscuits (B flute)[50]	m	0.006
Average thickness of a folded corrugated cardboard – furniture (A flute)[51]	m	0.01
Average thickness of a folded plastic crate[52]	m	0.07
Footprint of a pallet with corrugated packaging / plastic crate is considered as 1,2m x 0.8m		
Maximum height (m) of a loaded pallet for both corrugated and crate[53]	m	1.30
Biscuits; crate efficiency loss due to standardisation (impacting the box height)[54]	%	20%
Furniture; crate efficiency loss due to standardisation (impacting the box height)[55]	%	20%
Average life cycle of plastic crate (times usage in the cycle for a lifetime)[56]	times	25
Pressed corrugated bale volume reduction vs folded corrugated[57]	%	40%

shows the assumptions considered for analysing the impact of transportation with the corresponding resources.

Table 11 shows the assumptions considered for analysing the impact of transportation with the corresponding resources.

Table 11: Assumptions of analytical model on transport

Parameter	Unit	Data
Transport mode is considered as Road with Mega Trailer (13,6m // 33 pallets) for all the flows[58]		
Biscuits - % of international export between brand owners to retailers[59]	%	90%
Furniture - % of international export between brand owners to retailers[60]	%	90%
Biscuits - % of international export from retailer depot to point of sale to end customer[61]	%	10%
Furniture - % of international export from retailer depot to point of sale to end customer[62]	%	20%
For load efficiency, Table 12: Load Efficiency Matrix is considered[63]	%	
For biscuits; Table 13: Biscuits Average Distance Matrix - Corrugated is considered for distances of corrugated flow[64]	km	
For furniture; Table 14: Furniture Average Distance Matrix - Corrugated is considered for distances of corrugated flow[65]	km	

[50] Cardboard fundamentals. URL: https://www.boxgenie.com/blogs/news/cardboard-thickness-guide
[51] Cardboard fundamentals. URL: https://www.boxgenie.com/blogs/news/cardboard-thickness-guide
[52] Auer packaging. URL: https://www.auer-packaging.com/in/en/Product-specification/FB-6427.pdf
[53] Deloitte assumption
[54] Based on interviews
[55] Based on interviews
[56] Ecology centre. https://ecologycenter.org/plastics/ptf/report4/#:~:text=Reusing%20containers%20is%20one%20of,becoming%20too%20damaged%20for%20reuse
[57] Deloitte assumption
[58] Deloitte assumption
[59] Deloitte assumption
[60] Deloitte assumption
[61] Deloitte assumption
[62] Deloitte assumption
[63] Deloitte assumption
[64] Deloitte assumption
[65] Deloitte assumption

For biscuits; Table 15: Biscuits Average Distance Matrix - Crate is considered for distances of plastic crates flow[66]	km	
For furniture; Table 16: Furniture Average Distance Matrix - Crate is considered for distances of plastic crates flow[67]	km	
For average transport cost per km, Table 17: Transport Cost Matrix is taken into account[68]	€/km	

Table 12 outlines the assumptions on the truck efficiency at each node of the supply chain.

Table 12: Load Efficiency Matrix

	Brand owner	Retailers	Return flow of corrugated	Return flow of crate
Packaging producer	90%			
Brand owner		90%		
Retailers		70%	90%	80%

Table 13, Table 14 Table 14, Table 15 and Table 16 Table 16show the considered average distance between each node of the supply chain for both use cases in both condition of using corrugated cardboard and reusable plastic crate.

Table 13: Biscuits Average Distance Matrix - Corrugated

From / To	Brand owner	Retailers (export)	Retailers (domestic)	Waste collector	Paper mill	Corrugated producer
Corrugated producer	80					
Brand owner		600	140			
Retailers		150	80	50		
Waste collector, sorter and trader					150	
Paper mill						50

Table 14: Furniture Average Distance Matrix - Corrugated

From / To	Brand owner	Retailers (export)	Retailers (domestic)	End customer	Waste collector	Paper mill	Corrugated producer
Corrugated producer	80						
Brand owner		1500	140				
Retailers		500	150	50			
End customer					50		

[66] Deloitte assumption
[67] Deloitte assumption
[68] Benchmark from other Deloitte projects

Waste collector, sorter and trader						150	
Paper mill							50

Table 15: Biscuits Average Distance Matrix - Crate

From / To	Brand owner	Retailers (export)	Retailers (domestic)	Crate collector	Reusable Cleaner + Sorter
Packaging producer	200				
Brand owner		600	140		
Retailers		150	80	50	
Crate collector					200
Reusable Cleaner + Sorter	100				

Table 16: Furniture Average Distance Matrix - Crate

From / To	Brand owner	Retailers (export)	Retailers (domestic)	End customer	Crate collector	Reusable Cleaner
Packaging producer	200					
Brand owner		1500	140			
Retailers		500	150	50		
End customer					50	
Crate collector						200
Reusable Cleaner	100					

Table 17 specifies the recommended transport costs per kilometer to be considered for different distance ranges.

Table 17: Transport Cost Matrix

Distance from	Distance to	€/km
0	500	€ 1.24
500	1000	€ 1.23
1000	1500	€ 1.16
1500	2000	€ 1.14

Table 18 shows the assumptions considered to calculate CO_{2e} emission of transport and packaging production.

Table 18: Assumptions of analytical model on environment

Parameter	Unit	Data
CO_{2e} emission of road transportation[69]	kg CO_{2e}/tonne-km	0.06
CO_{2e} emission of corrugated packaging production[70]	tonne CO_{2e}/tonne	0.49
CO_{2e} emission of reusable crate production[71]	tonne CO_{2e}/tonne	2.79

Table 19 provides the items considered in the calculation of storage impact.

Table 19: Assumptions of analytical model on storage

Parameter	Unit	Data
# of working days of warehouses[72]	days/year	230
Average days on stock is considered as per Table 20: Days on Stock - Corrugated and Table 21: Days on Stock - Crate[73]	days	
Average storage cost per pallet per month for a pallet of 1.3m height (proportionally change based on pallet height)[74]	€/pallet	5
Extra buffer of crates to absorb abnormalities (unpredictable return flow, imbalance, seasonality, lost/damage etc)[75]	%	20%
Time horizon to spread/allocate the impacts of buffer production	Years	4

Table 20 and Table 21Table 21 show the considered average days of finished product stock at each node of the supply chain for both corrugated and crate packaging.

Table 20: Days on Stock - Corrugated

	Packaging producer	Brand owner (filled)	Brand owner (empty)	Retailer & end customer	Return Flow
Biscuits	10	3	3	5	1
Furniture	10	3	3	5	1

Table 21: Days on Stock - Crate

	Packaging producer[76]	Brand owner (filled)	Brand owner (empty)	Retailer & end customer	Return Flow
Biscuits	0	3	3	5	4

[69] Benchmark from other Deloitte projects
[70] FEFCO website. URL: https://www.fefco.org/sites/default/files/documents/2022/FEFCO_LCA_2022.pdf
[71] European Environment Agency, Greenhouse gas emissions and natural capital implications of plastics, 2021.
[72] Deloitte assumption
[73] Deloitte assumption
[74] Safestore. URL: https://www.safestore.com/nl/en-nl/self-storage-prices/#:~:text=According%20to%20the%20Self%20Storage,per%20week%20per%20square%20metre
[75] Deloitte assumption
[76] The model considers that crate production is on demand with bespoke specifications such that no stock is kept by the packaging producer

Furniture	0	3	3	5	6

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