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HOT-SPOT ANALYSIS OF E-COMMERCE LOGISTIC CHAIN SINGLE USE VS REUSABLE SOLUTIONS

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HOT-SPOT ANALYSIS OF E-COMMERCE LOGISTIC CHAIN SINGLE USE VS REUSABLE SOLUTIONS

[Text]

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[Text]

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ABBREVIATIONS

EoL	End-of-Life
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment

General Limitations and Reliance

This report has been prepared by Ramboll Italy ("Ramboll") exclusively for the intended use by the client FEFCO – European Federation of corrugated board Manufacturers in accordance with the agreement (proposal reference number 330002550, dated 22nd April 2021 between Ramboll and the client defining, among others, the purpose, the scope and the terms and conditions for the services. No other warranty, expressed or implied, is made as to the professional advice included in this report or in respect of any matters outside the agreed scope of the services or the purpose for which the report and the associated agreed scope were intended or any other services provided by Ramboll.

In preparation of the report and performance of any other services, Ramboll has relied upon publicly available information, information provided by the client and information provided by third parties. Accordingly, the conclusions in this report are valid only to the extent that the information provided to Ramboll was accurate, complete, and available to Ramboll within the reporting schedule.

EXECUTIVE SUMMARY

Ramboll has been appointed by European Federation of corrugated board Manufacturers – FEFCO to conduct a hot-spot analysis of the logistic chain comparing recyclable corrugated packaging with a reusable solution for e-commerce for small personal and household items using alternative solutions. The hot-spot analysis is intended as an environmental meta study and focuses on alternative options for e-commerce with the aim of identifying possible strategies for improvement/areas for innovation to reduce packaging impacts. This report investigates single-use (SU) and multiple-use (MU) packaging solutions. These two solutions could be made of different materials (e.g., corrugated board, plastic bags, rigid plastic crates, paper bags, flexible packaging).

The main focus of this analysis is the e-commerce supply chain, such as information related to online shops (and platforms), automatization of processes, digital purchasing, shipping of products, as well as other relevant aspects, such as product damage, packaging void, empty load transport, logistics, return transport or weight of the packaging. For this the system boundaries are defined as: *Business to Customer (B2C) commerce of small and personal items, in the European geographical context, delivered using packaging made of cardboard or plastic.*

To meet client expectation, Ramboll performed the following activities:

- Definition of the used methodological approach including background information and definition of hotspot;
- Description of the performed hotspot analysis, including: source screening, quality criteria definition, source ranking, identified hotspots and preliminary findings;
- Conclusions and recommendations.

For the purpose of the analysis, Ramboll considered the definition **of hotspot** by the "Life Cycle Initiative": *"A life cycle stage, process or elementary flow which accounts for a significant proportion of the impact of the functional unit (see UN Framework)"*[1].

The methodological approach used by Ramboll is defined based on the suggestion for identifying hotspots reported by UN Environment (2017) and includes the following five steps:

Step 1: Source screening and data gathering

The aim is to identify the existing body of knowledge via desktop-based research and conducting expert interviews. The first step for the identification of sources to be screened is the definition of the system and to identify its boundaries. The source screening led to the identification of **48 sources of information** (i.e., scientific papers; scientific papers funded by private company; commercial papers and interviews with relevant identified stakeholders), each one ranked using specific quality criteria and an overall weighted approach.

Step 2: Quality criteria definition

To define the relevance of the source, **11 quality criteria** are defined to rank the sources. Each criterion represents a particular feature of each source within the boundaries that are set in the previous step.

Step 3: Source ranking

[1] *Source:* https://www.lifecycleinitiative.org/resources/life-cycle-terminology-2/

The quality criteria identified in the previous step are subsequently used to evaluate the relevance of the identified sources, using a qualitative score for each source. A final score is then assigned to each source, which is the sum of all relative scores for each criterion. The higher the score, the greater the relevance of the source in determining hotspots in the final step.

Step 4: Hotspot analysis

Based on the outcome of the adopted methodological approach **51 hotspots** were identified, then grouped in **9 homogenous thematic categories**: bureaucratic aspects, physical characteristics, type of product, characteristics of using MU solutions, energy, social aspects, logistics, environmental aspects, economic aspects. All identified hotspots are evaluated to define a ranking list.

Step 5: Interpretation and discussion

Ramboll identified possible actions for innovation/improvement of the **top 15 highest ranking hotspots**. They could lay the basis for a common understanding of current hotspots in the packaging e-commerce logistic chain sector, whose consideration might attempt at improving the current situation. The possible actions for innovation/improvement of the **top 5 highest ranking hotspots are summarized in the following table.**

Possible actions for innovation/improvement

Hot-spot	Possible actions for innovation/improvement	Target group	Type of packaging solution(s)
Real number of uses for MU solutions	Promoting studies to define the real number of uses for MU packaging to better implement LCA analysis as a support to the decision-making process.	Institutions, Research Institutes, packaging producers	MU
Logistics parameters	There is an intrinsic limitation to possible improvement of distances, however optimization of logistics (e.g. storage space, truck filling rate) can play a role (e.g. to increase number of packaging for each delivery).	E-commerce and logistic/shipping operators	MU, SU
Percentage of recycled material used in production	Implement rules for the use of recycled material content in packaging solutions.	Institutions, Research Institutes, packaging producers	MU, SU
Quantity of material used for packaging	Optimize the amount of material used for packaging production	Packaging producers, Research Institutes	MU, SU

Hot-spot	Possible actions for innovation/improvement	Target group	Type of packaging solution(s)
Number of recycling/composting and washing facilities available	Increase and optimize the number of recycling/composting facilities should be carried out (also by regulatory/incentives schemes) to define the optimal value, considering the contribution to emissions of respective life-cycle stages. Increase and optimize number of washing service centers, considering that washing is needed for MU packaging that need to meet hygienic standards.	Institutions, Waste industry, Washing services operators	MU, SU

1. INTRODUCTION

Ramboll has been appointed by European Federation of corrugated board Manufacturers – FEFCO (FEFCO or the client) to conduct a hot-spot analysis of the logistic chain comparing recyclable corrugated packaging with a reusable solution for e-commerce for small personal and household items using alternative solutions. The hot-spot analysis is intended as an environmental meta study, and it will focus on alternative options for e-commerce with the aim of identifying possible strategies for improvement/areas for innovation to reduce packaging impacts. This report investigates single-use (SU) and multiple-use (MU) packaging solutions. These two solutions could be made of different materials (e.g., corrugated board, plastic bags, rigid plastic crates, paper bags, flexible packaging).

An iterative approach is undertaken for gathering data, refining assumptions, and defining hotspots in order to effectively focus on prioritizing actions.

The main focus of this analysis is the e-commerce supply chain, such as information related to online shops (and platforms), automatization of processes, digital purchasing, shipping of products, as well as other relevant aspects, such as product damage, packaging void, empty load transport, logistics, return transport or weight of the packaging.

To meet client expectation, Ramboll performed the activities that are summarized in the following sections of the report:

- Definition of the used methodological approach including background information and definition of hotspot;
- Description of the performed hotspot analysis, including: source screening, quality criteria definition, source ranking, identified hotspots and preliminary findings;
- Conclusions and recommendations.

1.1 Project framework

This study is part of a project consisting of three different assignments: i) A peer-reviewed comparative LCA study on B2B transport packaging solution for the food segment comparing a recyclable corrugated solution with a reusable plastic crate; ii) this hot-spot analysis of the logistic chain comparing the recyclable corrugated packaging with a reusable solution on e-commerce, and iii) a white paper discussing the current reuse ambitions of the EC to respond to the Green Deal and how this will impact the overall EU environmental agenda. Ramboll´s understanding is that FEFCO is willing to communicate sustainability performances of corrugated packaging solutions. Ramboll was engaged for the first two assignments.

Outcomes of studies i) and ii) are meant to provide a background for the preparation of the white paper.

2. METHODOLOGICAL APPROACH

2.1 Hotspot definition

For the purpose of the analysis presented in this report, Ramboll considered the definition of hotspot (used in the context of environmental assessment) by the "Life Cycle Initiative", which is hosted by the UN Environment and aims at providing and sharing credible knowledge about Life Cycle Assessment:

> **"A life cycle stage, process or elementary flow which accounts for a significant proportion of the impact of the functional unit (see UN Framework)"[2].**

2.2 Description of the methodological approach

The methodological approach used by Ramboll is defined based on the suggestion for identifying hotspots reported by UN Environment (2017). It includes the following steps:

- Step 1: Source screening and data gathering
- Step 2: Quality criteria definition
- Step 3: Source ranking and highlight of relevant hotspots
- Step 4: Hotspot analysis
- Step 5: Interpretation and discussion

2.2.1 Step 1: Source screening and data gathering

The aim is to identify the existing body of knowledge via desktop-based research and conducting expert interviews. The following activities are taken:

1. Definition of the system boundaries
2. Identification of keywords based on the scope of this assessment
3. Database and literature screening (via identified key words) on different sources (e.g. scientific peer-reviewed articles, corporate social responsibility reports, EU reports, single-issue studies)
4. Interview sessions with relevant stakeholders.

[2] *Source:* https://www.lifecycleinitiative.org/resources/life-cycle-terminology-2/

2.2.2 Step 2: Quality criteria definition

To define the relevance of the source, a set of quality criteria must be defined to rank the identified sources. Each criterion represents a particular feature of each source within the boundaries that are set in the previous step.

As an example a possible list of criteria is given here:

- Type of audience (e.g. scientific, commercial, expert interview);
- Geographical reference;
- Time reference;
- Industrial segment;
- Type of investigated product/system, including expected alternatives;
- Supply chain stage investigated.

2.2.3 Step 3: Source ranking

The quality criteria identified in the previous step are subsequently used to evaluate the relevance of the identified sources. A scale made by quantitative scores is used for each criterion, based on the degree of accordance to each criterion, as explained below:

- Full accordance with the criterion (score 2);
- Partly in accordance with the criterion (score 1);
- No accordance with the criterion (score 0).

A *final score* is then assigned to each source, which is the sum of all relative scores for each criterion. This final score represents a structured way to rank the sources based on their accordance to the quality criteria.

The higher the score, the greater the relevance of the respective source in determining hotspots in the final step. The final score, as well as quality criteria for each source, are given in general form in Table 1.

Table 1. Screening table (example) with final scores

Source	Quality criteria 1 (e.g. Audience)	…	Quality criteria n	Final score of each source
Source 1	Scientific	…	…	Final score for the source 1
…	…	…	…	…

2.2.4 Step 4: Hotspot analysis

Since the methodological approach is iterative, more hotspots are identified as more sources are screened; therefore, similar sources of impacts are grouped under the same definition of a hotspot to avoid double counting. A **hotspot table** includes a list of the most frequent hotspots

identified in the screening table. Multiple sources may be listed for each hotspot, and a *relative score* is given for each source:

- Relative score = 1: if the hotspot has been identified by the source;
- Relative score = 0: if the hotspot has not been identified by the source.

A *final weighted score* is given to each hotspot as a sum of the products of the final score of each source multiplied by the relative score of each hotspot. These results are summarized in the hotspot table, given as example in Table 2. The specific hotspots identified during the analysis of all the sources are described more thoroughly in Table 4.

Table 2. Hotspot table (example)

Hotspot	Source 1	…	Source n	Final weighted score
	Final score of source 1	…	Final score of source n	
Hotspot 1	Relative score = 0	…	Relative score = 1	Σ Relative score x Final score
…	…	…	…	…

2.2.5 Step 5: Interpretation and discussion

Hotspots found in the previous step are ranked from the highest final weighted score to the lowest in a tabular format.

This analysis is aimed at suggesting areas for innovation and at giving recommendations. The hotspot analysis and consequent prioritization of actions might be used as background for enabling decision-making.

3. PERFORMED HOTSPOT ANALYSIS

The following sections include the outcomes of the application of the methodological approach.

3.1 Source screening and data gathering

The first step for the identification of sources to be screened is the definition of the system and to identify its boundaries. For this specific case study, the system boundaries are defined as:

> ***the Business to Customer (B2C) commerce of small and personal items, in the European geographical context, delivered using packaging made of cardboard or plastic***

Because e-commerce is an emerging market that has been developing only recently, it is important to take into consideration the time reference. This should be as close as possible to the time frame in which this study is carried out[3].

Once the boundaries are identified, it is possible to proceed with the identification of the sources of information. This identification is carried out using general key words (e.g. e-commerce, packaging, single use, reusable, LCA, hotspot analysis, personal household items), and specific ones (e.g. transport, logistics, sustainability, washing, waste generation, littering, theft). The following scientific databases are used: Scopus, Elsevier, Springer, Tylor and Francis and google scholar.

Two kinds of sources can be distinguished: scientific sources and commercial publications for advertisement purposes. Scientific sources could be considered reliable source of information because they are subjected to third-party review. However, in general, hotspot analyses regarding e-commerce are not common in scientific literature. This might be because the e-commerce sector has bloomed only recently. For this reason, commercial publications (e.g. sustainability reports, white papers), which are funded by companies to present the performance of a specific product/system, are considered in this study. Since the aim of this study is to evaluate critical aspects linked to the e-commerce supply chain to find potential improvements, and although the consideration of commercial publications might be debatable for scientific purposes, they could be used to present a broad overview of the topic by taking into consideration stakeholders' perspectives. The perspective of producers, for example, could help at identifying relevant aspects in the e-commerce supply chain and identifying hotspots that were not mentioned by scientific sources. Moreover, interviews with stakeholders of the e-commerce supply chain were conducted.

Ramboll has identified 48 different sources of information, divided in 4 different categories:

- scientific papers;
- scientific ("client driven") papers funded by private company;
- commercial papers (classified into 3 other types: sustainability report, white papers, pamphlet)
- outcomes of interviews with relevant identified stakeholders (identified by FEFCO members).

The graph below shows the number of sources belonging to each category.

[3] The research was carried out between May and September 2021

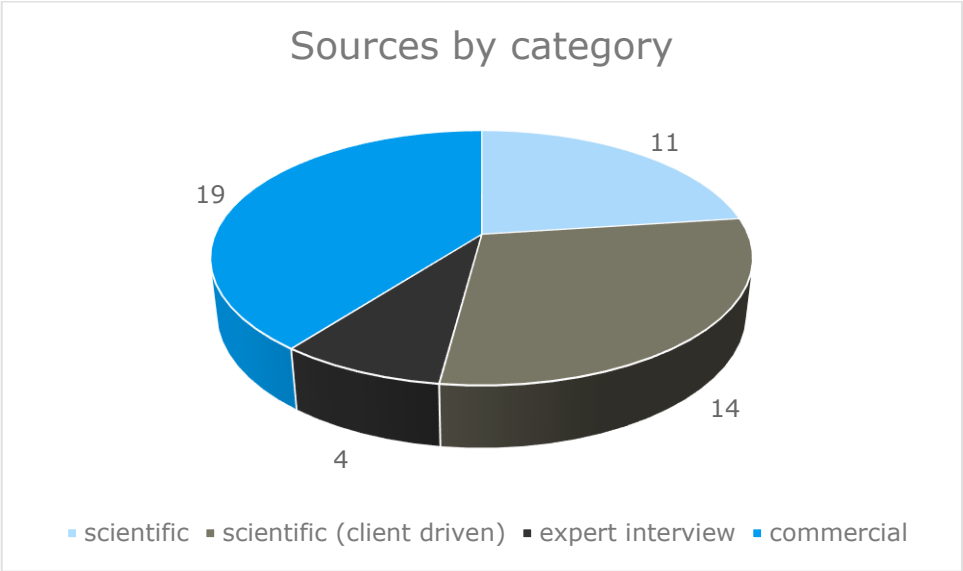

Figure 1. Sources by category

As reported in the graph, scientific peer reviewed papers represent only about one fourth (11) of the screened sources.

The findings of this screening are reported in Appendix 1 (where commissioner of the work, authors, title, source category, presence of a peer review and main claims are reported).

The following main claims are identified:

- MU solutions could generate lower **potential environmental emissions** than a SU solutions in the impact category Climate change;
- The real **number of uses** is a key parameter. For instance, the study commissioned by the Stiftung Initiative Mehrweg (SIM) (Fraunhofer Institute for Building Physics IBP 2018) claims that plastic crates could be used 50 times, while IFCO's study (IFCO 2019) states that they could be used 30 to 120 times. Certainly, by taking into account different boundary conditions and assumptions, different conclusions and findings could be drawn. One of the most important factors is indeed the source of information and its reliability, whose consideration might drive the findings of a study. In some studies, these sources of information are even not mentioned or cited. Lack of official, consistent data is clearly an obstacle for reliability of information. For the analysis of sources and to evaluate their reliability, the following questions should arise: Is this specific, relevant parameter trustful enough? Are the findings of the study based just on claims or on statistical data? Has the study used a scientific approach to estimate a specific parameter?
- **Return rate**[4] widely varies, ranging between 70% and 97%. This aspect is also linked to the theft of MU solutions, which is not generally considered in the literature. The only study in Europe is the one commissioned by the Austrian Federal Ministry of Agriculture and Forestry (Pladerer et al. 2008), which carries out a comparative LCA on the use of cup systems at sporting events.

The two hotspots "real number of uses" and "return rate" have to be considered as different parameters:

  - "real number of uses": this parameter can be considered a "statistical" number. It affects a MU system, and it is based on assumptions (e.g., boundaries of the system) made by different authors in the body of literature. In general, it is considered a process of generalization and abstraction;
  - "return rate": it is a parameter related to customers' and operators' behaviors, whose consideration is relevant either in B2B and in B2C. This parameter highlights the probability that a multiple-use packaging solution could be returned for washing operations in the reverse logistics.

- Customized products are subject to higher **theft rate**. According to the study commissioned by the Austrian Federal Ministry of Agriculture and Forestry (Pladerer et al. 2008) focusing on UEFA EURO 2008™ event, fans can take cups home as a "souvenir" of the event. For this reason, in the sensitivity analysis of the study a parameter accounting for this phenomenon has been defined. However, other sources (American bakers association, n.d.; Beverage industry 2015) highlight that the theft of plastic crates is an increasingly common issue in North America, where they are stolen to be sold as plastic granules. According to the American Bakers Association, this phenomenon has caused 30% loss of reusable plastic trays each year, generating $10 million annual replacement costs.
- MU solutions are easier to **use for small items** that do not need protection. In fact, if the packaging is made of flexible material, it can be folded to reduce space once it is returned. This means that each item is lighter than a structured one and many more pieces can be transported with the same backhauling trip, thus reducing potential environmental impacts.
- Return rate of **fashion items**[5] (the most significant delivered product regarding small household items) is very high. In fact, the return trips these articles make is a very important contribution to pollution. For this reason, some companies like Zalando have been trying to implement systems for reducing the number of returned items. Two solutions have been suggested: the company facilitate shopping by giving advice via specific algorithms, or the company introduces and implements a "CO_2 account" that displays the sustainability of customers' return behaviors.
- The **energy requirement for reconditioning multiple-use system** is under investigation for decades and present high environmental impacts. Even if some plastic packaging is designed to be wear-resistant, with higher mechanical properties or with increased thickness to last more, it could have a limited lifetime and needs to be reconditioned and/or recycled at end-of-life. A recent study (Rietveld and Hegger 2015b) compared different industrial drums used to transport chemicals: steel drums, plastic bottles, and different plastics that differ in shape. The authors highlighted that reconditioning process showed high potential environmental impacts, and that plastic drums showed lower emissions once compared to steel drums. This is due to the high energy requirements for the reconditioning process of steel drums. The findings pointed out that the plastic drums could still present the lowest emissions among the other

[5]The term "Fashion items" means apparel (clothes)

alternatives even if the emissions generated by the end-of-life treatment of plastic drums is almost a third of the aggregated impact results.

- **Regulations** play an important role, especially with packaging used in food contact. Saica sustainability report (Saica 2019), for example, pointed out that it is difficult to produce 100% recycled packaging for transporting food in Europe, due to specific regulations that prohibit direct contact of food with recycled material. This is due to potential contamination that might occur. Although increasing the share of recycled or certified sustainable sources used in production processes is possible at industry level, using 100% recycled packaging materials for food contact is, however, technically difficult, as argued in a report by Huhtamaki (Huhtamaki 2020).

Although many studies in literature have pointed out difficulties in evaluating hotspots, a generalization of results/claims is attempted. Via a literature screening it is indeed difficult to elaborate generalized results that take into consideration different geographical contexts, different timeframes and different types of packaging.

3.2 Quality criteria definition

Eleven quality criteria are defined to rank the sources. The following table present an overview of criteria and their description.

Table 3. Quality criteria table

Quality criteria	Description of the quality criteria
Source category (scientific OR commercial OR expert interview)	It defines the audience. Considered very relevant when a third-party review is conducted and if it is not driven by lobby
Geographical reference	Preference is given to European studies, as core of the assignment
Time reference	Preference is given to the most recent sources, as more relevant for an action plan
Supply chain (stage)	Preference is given to the whole supply chain. However, for this assignment it could be modified from warehouse to customer (in a way this criterion is redundant to Domain)
Core segment: e-commerce?	Preference is given to the e-commerce supply chain, but an extension of the topic is required due to lack of information
Core goods: small personal and household items?	Preference is given to personal and household items, but an extension of the topic is required due to lack of information
Core alternatives	Since the core is the corrugated board box alternatives, preference is given to the comparison versus plastic. However, it could be modified following indications of the steering group

Quality criteria	Description of the quality criteria
Core: Domain	The domain B2C is the core of this assignment. However, due to lack of information, the topic is extended
Environmental hotspots	Although environmental analysis and relevant hotspots in this are the focus, extension of the field is required (therefore also economic, logistics, and social aspects could be considered, and they receive a partial score)
Economic hotspots	Focus of the source is the economic aspect (economic saving, …).
Social hotspots	Focus of the source is the social aspect (number of accidents, hiring workers with disabilities, …).

The criteria reported above are based on the sources screened in the previous step. Each criterion helps to define the relevance of the content with respect to the case study. By evaluating all the aspects, a quantitative definition of the level of accuracy and robustness of each source can be established. This approach allows the comparison of different sources and the identification of relevant hotspots in a structured and transparent way. It should be noted, however, that this approach attempts to generalize specific aspects that each source highlights. Each source is related to a very specific topic/issue about either a particular sector, a product, or a subject. Defining a balance between specification and generalization is the challenge of this study in order to present an overall picture and try to identify potential actions steps.

The quality criteria presented in the previous table are described in detail in the following sections.

3.2.1 Source category (scientific OR commercial OR expert interview)

The type of source is used in this study to distinguish between sources subjected to review and non-subjected to review. The review process confers credibility to a study. In particular, 19 out of the 48 sources under investigation have been subjected to the review process. The identified sources could be further grouped in four categories: scientific publications, scientific publications whose work was funded by a company (which could be subjected to the review process or not), commercial sources, or expert interviews.

3.2.2 Geographical reference

The geographical context is a very important factor that could influence the outcome of a study. This is due to the presence of different infrastructures, specific regulations (e.g. hygienic requirements, recycled material for direct food contact), or socio-economic conditions in a particular area under investigation. Since this study has the focus at European level, priority is given to studies conducted in the EU, and geographies outside Europe are out of scope. Two thirds of analyzed sources have been conducted in the EU, and sometimes they have in-depth analysis of specific countries (e.g. Germany, Netherlands, Italy, UK).

3.2.3 Time reference

Regarding the time reference, particular attention is given to the most recent sources. However, as said before, e-commerce is a new market that has bloomed only recently so it has not been studied deeply and scientific sources are few. Nowadays changes happen quickly and scientific investigation of new phenomena requires time. More than a half of the sources used in this study have been published in the last five years, which report the most up-to-date data, making it possible to have a more realistic representation of the actual situation.

3.2.4 Supply chain (stage)

To present completeness of information, the supply chain stage is considered as a criterion. In fact, if a study considers only a section of the supply chain it could overlook some significant parameters or report incomplete information. Twenty sources out of all the screened ones refer to the whole supply chain, while 14 consider only a supply chain stage, and 14 give no indication.

3.2.5 Core segment

The core segment represents one of the most relevant quality criterion. This criterion investigates whether a source has as e-commerce supply chain as the main focus. It should be noted that only 17 out of 48 screened sources focus – at least partially - on e-commerce as a core segment.

3.2.6 Core goods

Considering that in e-commerce it is possible to buy different kind of goods, it is necessary to define if the core goods of each source correspond to the one under study. Unfortunately, only 13 sources have small household items as main or partial core good focus.

3.2.7 Core alternatives

The criterion regarding core alternatives helps at identifying sources that are essentially white papers (defending a single specific solution) and other sources that can be less biased because they compare different alternatives. However, it is important to remember that comparative analyses are not always objective because they can be funded by companies with interest in promoting a specific product. In these analyses, almost half of the sources compared different solutions while the others focused on a single product. This criterion helped the definition of hotspots not only by analyzing sources related to cardboard products but also considering alternative products from which strength and weaknesses of cardboard could be inferred as opposed to those of other materials.

3.2.8 Core: Domain

This criterion is defined to evaluate which is the target market of each source. On the one hand, if a product is intended for B2C, product design is indeed main factor for increase customers' willingness to buy it. On the other hand, if a product is intended for B2B, design features are not requested. The core domain in some cases is not specified in the screened sources. However, B2C is the most relevant domain among the sources that highlight the core domain. Since e-commerce is generally a B2C market, considering sources related to this sector helps at having better view of current market conditions.

3.2.9 Environmental, Economic and Social hotspots

Finally, the last three quality criteria are related to the main topics addressed in each analyzed source. Each source could focus on environmental aspects such as pollution, waste generation or greenhouse gas emissions. On the other hand, it could be related to economic aspects like the savings obtained by using a specific product or the investment needed to change a whole stock of product for an eco-friendlier one. A source could also consider social aspects as the perception of quality related to the use of a specific packaging. Of course, all three aspects could be present at the same time in the same source. Unsurprisingly, the focus of almost all sources' is the environmental impacts. 19 out of 48 sources discuss economic aspects, such as feasibility assessment of substitution of a product with a more sustainable one, or economic advantages of using a specific product. Lastly, only 11 out of 48 analyzed sources contained information about social aspects such as generation of satellite jobs or increased workers safety due to implementation of warehouse automatic systems. This study focuses on environmental aspects. However, the evaluation of social and economic aspects could help at identifying additional hotspots that might consider angles that were previously overlooked.

3.3 Source ranking

A qualitative score is given to each source and each quality criterion: 0 (no accordance), 1 (partly in accordance) and 2 (full accordance). All the scores are then summed up. The table summarizing the results of this step with the overall ranking for each source can be found in Appendix 2: SOURCE RANKING TABLE.

The 7 sources with the highest ranking are the following:

- "Expert Interview #4.", 2021
- "Expert Interview #1.", 2021
- Coelho P. M.et al., 2020. "Sustainability of Reusable Packaging–Current Situation and Trends." Resources, Conservation and Recycling: X 6 (April): 100037.
- Zimmermann, Till, and Rebecca Bliklen. 2020. "Single-Use vs. Reusable Packaging in e-Commerce: Comparing Carbon Footprints and Identifying Break-Even Points." Gaia 29 (3): 176–83.
- Wyman, Oliver. 2021. "Is E-Commerce Good for Europe?"
- Jääskeläinen, Petra, and Rossella Recupero. 2019. "The Story of RePack," 8.
- Nederland Institute for Sustainable Packaging, and Utrecht University. 2018. "CO2 Voetafdruk Vergelijking."

3.3.1 Preliminary findings based on source with highest ranking

According to the highest-ranking sources, one of the most important topics in e-commerce is the **shape of the package**. In fact, shape optimization reduces the volume of empty space present in vehicles during delivery which decreases the efficiency and increasing emissions due to the lower number of items that can be loaded in the vehicles per trip. To avoid this problem, a customization of packaging according to the product transported should be implemented. Furthermore, optimizing the shape of packaging reduces the amount of material used during packaging production and consequently, the amount of generated waste which are other two very important factors to take into consideration when comparing different packaging solutions. When

using MU solutions is important to consider that it is not possible to have too many sizes in storage, so the share of empty spaces is likely to be higher especially if different articles are packaged together. Moreover, some MU solutions are difficult to recycle once they have ended their service life thus considerably reducing the benefit gained by multiple uses due to emission related to waste disposal.

The most difficult parameter to define, however, is the real **number of uses for MU packaging.** In each source this parameter is defined with a different value, for which a source is either never reported or is attributed to a personal communication with a company. This lack of consistent scientific data can be detrimental for the whole study because the main advantage of using MU solutions is that emissions due to its manufacturing can be spread over the years of service life. Thus, it is very difficult to establish the real number of uses, which is a vital parameter for the evaluation of environmental sustainability.

Another important consideration related to use of MU solutions is the **return rate**. To have an efficient supply chain, MU solutions must be returned in high numbers otherwise there could be a shortage of products. A low return rate can cause an increase in emissions due to the need for producing new items to replace the unreturned ones.

A very important claim that can be found in these sources is that e-commerce can help reduce traffic and emissions in urban areas. In fact, a single delivery trip can save many single trips from customers going to physical shops, decreasing the number of circulating vehicles.

When shipping products for e-commerce, the **type of product to be delivered dictates most of the characteristics of its packaging**. For example, the mechanical resistance required to protect the content can limit the choice of packaging that can be used. Another problem is related to the use of MU solutions, as there could be the need to respect hygienic standards and MU solutions should be washed and sanitized. This in turn leads to the issue related to **energy and water consumption due to washing**. In general, the bigger the washing machine the more optimized the process, so big washing centers should be preferred to obtain better environmental performances. However, this means that the number of MU packaging could not be sufficient for logistic operations, and that the transport distance would increase, with consequent decrement of potential environmental benefits produced by more efficient washing processes.

Distribution centers are currently present within each country. From a B2C perspective, this means that there are no bureaucratic aspects to take into consideration when delivering packaging to the customer. However, in view of an increasing globalization of the market, there is going to be an increase in the number of **cross-country deliveries**, especially from a B2B point of view. This perspective raises two issues: the presence of different regulations in each country and the increasing travelled distance covered by packaging. Regarding regulations, in Europe there is a lack of communal laws covering different aspects related to e-commerce. For example, regulations about the content of recycled material for direct food contact packaging are different across European countries and this influences the production of both MU and SU packaging, reducing the efficiency of the recycling process. Furthermore, hygienic requirements are also defined by country-specific regulations and this can result in non-compliance of some products after crossing borders either during delivery or backhauling. Considering transport distances, the further a package is being transported the higher the potential emissions related to backhauling. This means that it is more convenient, from an environmental point of view, to use SU packaging

if the transport distance is higher than a certain value. In addition to that, even if using MU solutions is convenient considering transport distance, another important issue is the distance from the cleaning centers. The length of the trip for a backhaul could be significantly increased due to the need for reaching these specific facilities. However, if a specific SU packaging is chosen it is important to consider the limited number of recycling facilities, which can increase the travel distance and thus increase the emissions related to disposal and decrease the efficiency of the recycling process.

3.4 Identified Hotspots

3.4.1 Identification

Starting from the identified potential sources of impact, a critical assessment procedure is implemented to examine and compare potential sources of impacts, identified in each analyzed source. After identifying those with similar characteristics, they are grouped in the same hotspot definition. The list of identified hotspots is summarized in Table 4.

Table 4. Hotspot table

Number	Hotspot	Description
I	Situation (financial, commercial)	E.g. Pre-COVID19 and Post-COVID19 are very different scenarios
II	Empty space	Octagonal shape
III	Logistics parameters	For return packages (storage space, distance, number of packages for each delivery, sorting)
IV	Tamper-evident technology	-
V	Legal aspects related to EU/states cross-border transportation	-
VI	Packaging shape	Volume for food, e.g. apples, is precise, and it is known from the beginning) - amazon dictates the shape for returnable packages (square) different available sizes
VII	Requirements of the goods	For fresh food, e.g. humidity, temperature, hygienic requirements (plastic crates may contain plastic bags inside to preserve hygienic requirements)
VIII	Type of the product (e.g., Generally, warehouses do not know the type of products they are going to ship to customers)	A standardization of packaging system is unrealistic when completely different products should be packed together
IX	Contamination of the containers	-
X	Lack of information for parametrization on the e-commerce supply chain	-
XI	Real number of uses for MU solution	It could be different from the producer specifications
XII	Percentage of recycled material used in production	-
XIII	Weight optimization	For MU solution it lowers emission from transport
XIV	Return rate	If low, emissions increase

Number	Hotspot	Description
XV	Energy and water heating consumption for washing	Possible lack of data, washing at home can be more energy consuming, backhauling could be energy consuming, optimization of water use
XVI	Customer awareness about green packaging and packaging issues related to environmental preservation	-
XVII	Quantity of material used for packaging	-
XVIII	Returned goods	Returned goods need to be treated before they are put again on the market or they are discarded
XIX	Emission due to product delivery	-
XX	Reduction of pollution and traffic in urban areas due to home delivery	-
XXI	Incorrect recycling information provided by manufacturers	-
XXII	Greenwashing practices	-
XXIII	Limit for recycling	Material can suffer degradation after recycling, presence of contaminants (e.g. ink, labels)
XXIV	Customer perception of quality based on packaging design	-
XXV	Higher cost of some eco-friendly packaging	-
XXVI	Waste generation	-
XXVII	Sustainable use of resources	E.g. Forest for paper production, renewable energy use share
XXVIII	Efficient energy and water management in facilities	Also share of renewables used
XXIX	Tracking systems	E.g. RFID
XXX	Number of recycling/composting facilities available	Long trips to reach them
XXXI	Physical limit to number of washings	Degradation of material due to chemicals
XXXII	Economic evaluation of convenience of using MU solution	-
XXXIII	Product design used to increase selling	-
XXXIV	Trial period to test product	-

Number	Hotspot	Description
XXXV	Application of specific taxes	Fee for use of MU solutions could discourage customers, taxes on SU solutions to discourage use
XXXVI	Littering	-
XXXVII	Coordinated system to re-distribute containers among shops	-
XXXVIII	Emission and use of resources due to recycling	-
XXXIX	Legal aspect related to recycled content for food contact packaging	-
XL	Warehouse automatic system for higher worker safety	-
XLI	Use of renewable sources for material production	E.g. plant, fibers
XLII	Accounting of scope 3 emissions	-
XLIII	Require code of conduct from suppliers	-
XLIV	Decrease in use of VOC producing materials	E.g. solvent free ink
XLV	Impossibility of using only MU solutions	-
XLVI	Reduction of land use for e-shops	-
XLVII	Generation of satellite job	-
XLVIII	Additional items for continuous availability	-
XLIX	Legal aspects related to EU regulation	(Hygiene, backtracking, ...)
L	Ability of preserving the product from damage	-
LI	Theft/misuse	-

As shown by Table 4, the total number of identified hotspots is relatively high due to the following aspects:

- Investigated system complexity;
- Absence of a hotspot identification standard procedure;
- Diverse identified sources of information, mainly not scientific papers, claims.

The identified hotspots have been grouped in nine homogenous thematic categories: bureaucratic aspects, physical characteristics, type of product, characteristics of using MU solutions, energy, social aspects, logistics, environmental aspects, economic aspects. The grouping of hotspots is implemented for ease of comprehension.

Table 5. Thematic categories and belonging hotspots

Category	Hotspots
Bureaucratic aspects	-Situation (financial, commercial); -Legal aspects related to EU/states cross-border transportation; -Application of specific taxes; -Legal aspect related to recycled content for food contact packaging -Legal aspects related to EU regulation.
Physical characteristics	-Empty space; -Tamper-evident technology; -Packaging shape; -Percentage of recycled material used in production; -Weight optimization - Quantity of material used for packaging; -Limit for recycling; -Ability of preserving the product from damage.
Type of product	-Requirements of the goods; -Type of the product (e.g., generally, warehouses do not know the type of products they are going to ship to customers); -Contamination of the containers; -Returned goods;
Characteristics of using MU solutions	-Real number of uses for MU solutions; -Return rate; -Physical limit to number of washings; -Coordinated system to re-distribute containers among shops.
Energy	-Energy and water heating consumption for washing; -Sustainable use of resources; -Efficient energy and water management in facilities; -Use of renewable sources for material production; -Accounting of scope 3 emissions.
Social aspects	-Customer awareness about green packaging and packaging issues related to environmental preservation; -Incorrect recycling information provided by manufacturers; -Greenwashing practices; -Customer perception of quality based on packaging design; -Product design used to increase selling; -Warehouse automatic system for higher worker safety; -Require code of conduct from suppliers; -Impossibility of using only MU solutions; -Generation of satellite job.

Category	Hotspots
Logistics	-Logistics parameters; -Lack of information for parametrization on the e-commerce supply chain; -Tracking systems; -Limited number of recycling/composting facilities available; -Additional items for continuous availability.
Environmental aspects	-Emission due to product delivery; -Reduction of pollution and traffic in urban areas due to home delivery; -Waste generation; -Littering; -Emission and use of resources due to recycling; -Decrease in use of VOC producing materials; -Reduction of land use for e-shops.
Economic aspects	-Higher cost of some eco-friendly packaging; -Economic evaluation of convenience of using MU solutions; -Trial period to test product; -Theft/misuse.

The first category is defined **"Bureaucratic aspects",** and it accounts for legal requirements and regulations that need to be respected, such as legal aspects related to cross-border transportation or regulations about maximum content of recycled material for food contact products. An example is the study commissioned by Amazon (Wyman 2021) where it is stated that cross-border e-commerce currently shows a higher annual growth then domestic e-commerce, though this trend could change in the future due to the introduction of new regulations. Moreover, in different sources (Del Borghi et al. 2021; The Coca-Cola Company 2019; Saica 2019), attention is drawn to the fact that European countries have different regulations about the use of recycled material for food contact products. For example, Italian laws prohibit the use of such material for this purpose, and this limits the maximum percentage that can be used for the production of a whole class of packaging.

The second category, **"Physical characteristics"**, includes hotspots related to the physical characteristics of the packaging like shape, presence of empty spaces and tamper-proof technologies. According to Recircle (Zero Waste Europe 2018) their MU solutions are optimized to fit in restaurant dishwashers, increasing the number of items that can be washed at the same time, which in turn reduces the amount of energy and water used. For a similar reason, Repack (Jääskeläinen and Recupero 2019) produces packaging of different sizes in order to better fit the product to be delivered.

The third category, **"Type of product"**, takes into account the requirements of the transported goods, such as environmental conditions for perishable food. These conditions require a specific treatment for MU solutions to avoid contamination before using it for another delivery. However, for the purpose of this study, the requirements of perishable products like food are out of scope since the focus is on small personal items. Conversely, the need to treat returned items is very

relevant because clothes, which can be considered personal items, are always inspected after they are returned (Holding and Gendell 2019).

The fourth category, **"Characteristics of using MU solutions"**, considers hotspots related to the use of MU solutions, such as real number of uses (which can be different from the one indicated by the producer) or physical limit to the number of washing a packing item can sustain. Regarding the number of uses, each source (Del Borghi et al. 2021; Zimmermann and Bliklen 2020; Waste & Resources Action Programme 2007; Jääskeläinen and Recupero 2019; Goellner and Sparrow 2014) defines a different number. However, as stated above, it is difficult to identify the most reliable value because there is never a clear definition of the source of this value, or the source is confidential and consequently cannot be verified. Furthermore, Recircle (Zero Waste Europe 2018) states that a restaurant subscription to the system includes a service for redistribution of containers in case of imbalances between shops and substitution of worn out items.

The fifth category is related to **energy** use, which can be related to the production of an item or to its use. Many companies claim to have decreased their overall energy consumption or to have increased the share of renewable energy (Holding and Gendell 2019; The Coca-Cola Company 2019; Huhtamaki 2020; Saica 2019; Rietveld and Hegger 2015a) while some sources point out that the energy used for washing or backhauling can be a significant part of the overall consumption (Zimmermann and Bliklen 2020; Just Salad 2020; Giraffe Innovation 2018; IFCO 2019).

The sixth category takes **social aspects** into consideration. One hotspot considers the generation of satellite jobs due to the different supply chain of e-commerce with respect to the supply chain of physical shops (Plaine Products 2019; Wyman 2021; IESE - Universidad de Navarra 2008), while another hotspot accounts for incorrect recycling information provided by manufacturers. In fact, incorrect information can influence customers' opinion and promote the purchase of a specific product.

The seventh category, **"Logistics",** includes hotspots such as logistic parameters (e.g. storage space, distance, number of packages for each delivery, sorting), presence of tracking systems (e.g. RFID, GPS) or the limited number of recycling/composting facilities which requires longer trips. Regarding use of RFID technology, a publication by Carreño M. (Carreno 2013) explains how the application of this technology is limited by a number of factors. For example, many retailers are unaware of its existence while those who knows it are held back by the need for consistent investments for the application of this systems. Furthermore, they claim a lack of benefits coming from use of RFID technology because none of their clients uses this technology along the supply chain. Logistic parameters can refer to different aspect of packaging use. For example, in order to be ready to ship a parcel as soon as it is ordered, it is important to have some packaging ready to be used. For very big companies, this can be very challenging and require significant storage space because of the considerable amount of shippings to manage. Another logistic parameter is the number of packages in each delivery. If the same package is used to deliver more than one product, it is possible to optimize the void space inside the packaging and the vehicle use for the delivery in order to reduce the number of trips and thus the emissions produced by the vehicle. Furthermore, distance from producer or from the final customer is a source of environmental emissions due to transportation. However, this parameter is not easy to modify since it is very difficult to reduce distances from either the producer or the final customer.

The eighth category accounts for **environmental aspects** such as the decrease of pollution in urban areas due to home delivery, which is possible thanks to avoided trips by single customers, or emissions related to the recycling process. Ecommerce Europe (Ecommerce Europe 2020) claims that e-commerce deliveries reduce the number of shopping trips by customers, therefore reducing traffic and emissions. The same source highlights that IKEA Retail aims at substituting its delivery vehicles fleet by 2025 with electric or zero-emission vehicles to reduce emissions. Moreover, Coca-Cola states that producing 100% recycled PET bottles reduces emission by 25% (The Coca-Cola Company 2019).

The last identified category takes into consideration **economic aspects**. For example, Escursell et al. (Escursell, Llorach-Massana, and Roncero 2021) point out that some eco-friendly packages are more expensive than traditional products, such as alternative biodegradable starch-based peanuts with respect to EPS packing peanuts. Another example is the claim of Borealis (Borealis 2021), stating the need to provide a MU solution at an affordable price. Additionally, the study by the Waste & Resources Action Programme (WRAP) (Waste & Resources Action Programme 2007) states the need to define variables that can influence the costs of MU solutions to try to predict and control their trends, and to evaluate the economic feasibility of using MU solutions.

3.4.2 Ranking

After ranking all the sources and listing all hotspots described in each source, all identified hotspots are evaluated to define a ranking list. Even if the following table shows all identified hotspots grouped based on their belonging thematic category, the evaluation of their relative importance is defined considering each hotspot on its own. The full table with the ranking of all identified hotspots can be found in Appendix 3: HOTSPOT FINAL SCORE.

Since the overall number of hotspots is very high, only the first 15 highest-ranking hotspots were considered as most significant. They naturally belong to all defined categories. However, no hotspot classified either as an economic or bureaucratic aspect is present in the highest ranking. Most of the highest-ranking hotspots belong to the class grouping physical characteristics of the packaging. In fact, there are 6 hotspots of this category. Furthermore, the sum of the ranking of the first five highest-ranking hotspots makes up almost a half of the sum of the first 15 highest-ranking hotspots, which means that their relative importance does not decrease linearly but instead it has an exponential trend. In Table 6, the top 15 highest ranking hotspots are reported with their absolute score and relative score (the relative score refers to the top 15 highest-ranking hotspots only).

Table 6. Top 15 highest ranking hotspot

Number	Hot-spot	Type of packaging solution(s)	Category	Absolute weighted score	Relative score [%]
XI	Real number of uses for MU solutions	MU	Characteristics of using MU solutions	181	14.40
III	Logistics parameters	MU, SU	Logistics	158	12.57
XII	Percentage of recycled material used in production	MU, SU	Physical characteristics	116	9.23

Number	Hot-spot	Type of packaging solution(s)	Category	Absolute weighted score	Relative score [%]
XVII	Quantity of material used for packaging	MU, SU	Physical characteristics	86	6.84
XXX	Number of recycling/composting/ washing facilities available	MU, SU	Logistics	85	6.76
VI	Packaging shape	MU, SU	Physical characteristics	83	6.60
XXVI	Waste generation	MU, SU	Environmental aspects	76	6.05
XIV	Return rate	MU	Characteristics of using MU solutions	73	5.81
XVI	Customer awareness about green packaging and packaging issues related to environmental preservation	MU, SU	Social aspects	66	5.25
VII	Requirements of the goods	MU, SU	Type of product	62	4.93
XXIII	Limit for recycling	MU, SU	Physical characteristics	58	4.61
II	Empty space	MU, SU	Physical characteristics	57	4.53
XIII	Weight optimization	MU, SU	Physical characteristics	56	4.46
XX	Reduction of pollution and traffic in urban areas due to home delivery	MU, SU	Environmental aspects	52	4.14
XV	Energy and water heating consumption for washing	MU	Energy	48	3.82

According to the implemented ranking system, considering all the identified sources, the highest-ranking hotspot is the real **number of uses**. This is a very difficult number to define because there is no indication of certain data (e.g. statistics), and sources are often covered by non-disclosure agreements or noted as personal communications with a stakeholder. It depends on transport distance and backhauling efficiency.

The second most important hotspot is defined as **logistics parameters**. This hotspot takes into account the need for storage, transport distances, number of packages in each delivery, and need for sorting. Logistics is a very important aspect to determine the overall efficiency of the system but there is an intrinsic limitation to possible improvement. For example, transport distances have a significant impact on emissions, but it is generally not feasible to move closer to each other the production site (e.g. vegetable plantations) and the final client.

The third ranking hotspot is represented by the **percentage of recycled material used in production**. This is another important topic because this value is tied to regulations, which are different across Europe. In fact, in some European countries like Italy, regulations do not allow use of recycled material for direct food contact packaging. This is obviously a limitation to recycling because after this process the new material cannot be used for the same purpose, but it must be moved to a different supply chain.

The fourth ranked hotspot is the **need to reduce quantity of material used for packaging**. This topic is very important because reducing material reduces packaging weight and volume, which in turn reduced emissions during transport. However, there is a physical limit to the reduction because the packing must still show good mechanical properties. Using MU solutions could show some limitations in this context because it would not be possible to use different kinds of packaging for products with different needs (e.g. glasses and clothes).

The fifth ranking hotspot is related to the **limited number of available facilities for product reconditioning** and/or recycling/composting. These facilities are generally washing facilities used to clean and sanitize MU packaging. Facilities used for disposal can be either recycling or composting facilities. The latter can obviously be used only for compostable materials. If the overall number of these facilities is limited, the average transport distance increases and consequently the emissions related to transport. However, the efficiency of these facilities increases with the size of the plant. For this reason, increasing the number of facilities to have a capillary network, could not be the best solution. A study for the optimization of the number of reconditioning and recycling/composting facilities should be carried out to define the optimal value, considering the contribution to emissions due to transport and the contribution due to reconditioning and disposal processes.

The sixth ranking hotspot is related to the **packaging shape**, which is another relevant aspect that influences the kind of delivered product. An optimal packaging should have a shape as close as possible to the contained product. However, considering the wide range of product that can be bought through e-commerce, it is unrealistic to consider the possibility of having optimized packaging for every kind of object.

Another relevant issue is the generation of **waste due to packaging production and disposal processes**. These processes do not have 100% efficiency and they inevitably produce waste which needs to be disposed. This represents a source of emissions impacting on the overall evaluation of packaging lifecycle.

Considering the use of multiple use packaging, a parameter to take into consideration is the **return rate**. If this parameter is low, it means that some items do not immediately go back to the reuse cycle if ever. This can lead to a shortage of packaging products and thus either lead to an increase in emissions due to either the purchase of new packaging or a delay in delivery caused by lack of packaging.

Customer awareness is another important factor, which is related, for example, to the so-called "green packaging" and environmental preservation. In fact, the use of a specific kind of packaging could influence customer perception and willingness to purchase a specific product. Increasing awareness about green solutions for packaging could help customers making choices based on more objective considerations.

When designing or producing a specific **type of packaging**, it is necessary to take into consideration the requirements of the goods. Some products need to be better protected from mechanical stress, while others need to be protected by atmospheric agents. The shape and amount of material used – which are described above as the highest-ranking hotspots – depend on the degree of protection that is required.

Another aspect to take into consideration is the physical **limit for recycling** of a certain packaging material..

Related to the issue of packaging shape is the design with the aim of reducing **empty space**. This optimization can reduce the volume occupied by each item during delivery, increasing the number of packages that can be delivered with a single trip. In this way, the efficiency of the whole process should increase. However, to minimize empty spaces without compromising mechanical properties of a packaging solution, the latter should be specifically designed for each kind of transported product. Unfortunately, this option is quite unrealistic due to technical difficulties in producing and storing too many types of packaging solutions. Another possibility would be using wrapping paper that can eliminate empty spaces, but this option would not be able to protect the product itself.

The issue defined by **weight optimization** is very similar to the fourth highest-ranking hotspot. In fact, as for reducing the quantity of material used for production, there is a physical limit to the weight reduction that can be implemented because the packaging must still show good mechanical properties to be able to protect the contained product.

A very interesting aspect that can be a positive contribution to the growth of e-commerce is related to the **decrease of traffic and pollution in urban areas** due to home deliveries. Some sources (Escursell, Llorach-Massana, and Roncero 2021; Plaine Products 2019; Tua et al. 2017; Wyman 2021) pointed out that each delivery trip with a single vehicle substitutes many trips by customers to reach physical shops to buy the same products, producing an environmental benefit and improving the quality of life in urban areas.

Finally, an aspect that should not be ignored is related to the **amount of energy used for washing** – considering MU packaging – which is used both for operating the washing machine and for heating the amount of water used in this process. Considering that each country across Europe has a different percentage of produced renewable energy, this aspect could be a point of concern considering that washing.

4. CONCLUSIONS

Ramboll conducted a hot-spot analysis of the logistic chain comparing recyclable corrugated packaging with a reusable solution for e-commerce for small personal and household items using alternative solutions. The performed hot-spot analysis is intended as an environmental meta study, and it will focus on alternative options for e-commerce with the aim of identifying possible strategies for improvement/areas for innovation to reduce packaging impacts. The study investigated single-use (SU) and multiple-use (MU) packaging solutions.

The methodological approach used to identify hotspots (according to UN Environment an hotspot is defined as *"A life cycle stage, process or elementary flow which accounts for a significant proportion of the impact of the functional unit"*) included the following steps:

- Step 1: Source screening and data gathering
- Step 2: Quality criteria definition
- Step 3: Source ranking and highlight of relevant hotspots
- Step 4: Hotspot analysis
- Step 5: Interpretation and discussion

The source screening step led to the identification of **48 sources of information** (i.e., scientific papers; scientific papers funded by private company; commercial papers and interviews with relevant identified stakeholders), each one ranked using specific quality criteria and an overall weighted approach.

Based on the outcome of the adopted methodological approach **51 hotspots** were identified (it should be noted that the absolute weighted scores of each hotspot strongly depend on the analyzed sources. Therefore, if further sources are considered, these scores and consequently the results of the study might change); however, Ramboll identified possible actions for innovation/improvement of the **top 15 highest ranking hotspots**. They could lay the basis for a common understanding of current hotspots in the packaging e-commerce logistic chain sector, whose consideration might attempt at improving the current situation.

Main reasons for the definition of hotspots for the **top 5 highest ranking hotspots** are listed here with possible actions (details of the overall ranking are disclosed in Appendix 4):

1. **real number of uses:** this hotspot is considered very significant only for MU solutions. It is cited in one third (17) of the analyzed sources. Furthermore, eight of these sources (Zimmermann and Bliklen 2020; Jääskeläinen and Recupero 2019; Nederland Institute for Sustainable Packaging and Utrecht University 2018; Del Borghi et al. 2021; Giraffe Innovation 2018; Pladerer et al. 2008; Borealis 2021) received a ranking equal to or higher than 11 (50% of the maximum possible ranking which is 22). The real number of uses is considered a hotspot because it determines decisive **variation of environmental performances in MU solutions**. However, information and data (e.g., statistics) used in literature to determine this parameter is not certain, and sources of information are often covered by non-disclosure agreements or noted as personal communications with stakeholders. Furthermore, this parameter is highly dependent on **transport distance and backhauling efficiency**. Consequently, the average values of this parameter in some sources seem too high compared to the lifetime of MU solutions, implying a too fast backhauling of a MU packaging solution that does not sound very convincing.

A possible action for innovation/improvement is to promote further studies to search for a more accurate value for this parameter.

2. **Logistic parameters**: this hotspot is cited in 15 sources (Wyman 2021; Nederland Institute for Sustainable Packaging and Utrecht University 2018; Rigamonti, Biganzoli, and Grosso 2019; Del Borghi et al. 2021; Su et al. 2020; Stora Enso 2021; Alander et al. 2016; Plaine Products 2019; Mulholland et al. 2019; Waste & Resources Action Programme 2007; Goellner and Sparrow 2014; Rietveld and Hegger 2015a; EKUPAC 2008) out of the 48 analyzed sources. This hotspot considers the need for companies to optimizing storage, transport distances, number of packages in each delivery, and sorting to minimize costs. Logistics is an important aspect, whose consideration could be useful to improve the overall efficiency of a system, either SU or MU. On the one hand, by decreasing transport distances, overall environmental impacts of could be reduced. On the other hand, sometimes it might be not feasible to reduce distances, for example, between a production site (e.g., vegetable growing sites) and a final client. Storage space is also a relevant aspect, which should be optimized to avoid shortage of packaging solutions. This might lead to the need of purchasing new packaging solutions (economic aspect), with consequent increment of emissions (environmental aspect). But this could lead also to delaying in delivery, caused by lack of packaging. Finally, reverse logistics, reconditioning (including washing operations), and their related transportation activities could increase environmental emissions in a MU system.

   Although potential improvements of some parameters could be foreseen (e.g., distances, storage space, truck filling rate), in some cases intrinsic limitations (e.g., due to space limitations, truck volume limitations) might limit an overall optimization.

3. **Percentage of recycled material used in production**: this hotspot is cited in 11 sources (Zimmermann and Bliklen 2020; Del Borghi et al. 2021; Holding and Gendell 2019; Su et al. 2020; Huhtamaki 2020; Plaine Products 2019; Goellner and Sparrow 2014; European Environment Agency 2006; Rietveld and Hegger 2015a) of the 48 analyzed ones. In general, the increment of recycled content of a packaging solution could lay the basis for improving environmental burdens, either of SU or MU solutions. This might lead at reducing the amount of potential waste disposed in landfill and preserve natural resources. This aspect might also determine an economic advantage in some cases. This parameter could be influenced, however, by sectoral regulations, which are different across Europe. For example, regulations in Italy do not allow using recycled materials for direct-food contact packaging solutions. This aspect might limit in this sector the use of recycled packaging solutions. It is pointed out in literature that, in general, recycled materials may have nevertheless different mechanical characteristics with respect to virgin ones.

   A possible action for innovation/improvement could be implement rules for the use of recycled material content in packaging solutions.

4. **Quantity of material used for packaging:** this hotspot is cited in 8 sources (Holding and Gendell 2019; Escursell, Llorach-Massana, and Roncero 2021; Su et al. 2020; Ecommerce Europe 2020; Plaine Products 2019; Just Salad 2020; EKUPAC 2008) of the 48 analyzed sources. This parameter has a significant impact on packaging weight and volume, which in turn could reduce potential environmental emissions within the production, transport, and waste treatment processes. However, there is a physical limit

to the reduction of weight and volume of packaging solutions, since they should still preserve suitable mechanical properties. In general, it might not be possible to use different kinds of packaging solutions for products with different needs in a MU system – packaging solutions' requirement for glasses or clothes are, for example, very different – and this could be a limitation. Some e-shops[6] implemented the "One parcel policy" to reduce parcel volume, with consequent reduction of the amount of packaging material required for a single delivery.

A possible action for innovation/improvement could be to optimize the amount of material used for packaging production.

5. **Number of recycling/composting/washing facilities**: this hotspot is cited in 8 sources (Holding and Gendell 2019; Giraffe Innovation 2018; Stora Enso 2021; Heineken 2019; Ross and Evans 2003; Rietveld and Hegger 2015a) of the 48 analyzed sources. This hotspot is relevant to both SU and MU solutions:

    a. SU: it is related to waste management (recycling/composting or disposal).

    b. MU: it is related to both waste management (recycling/composting or disposal) and washing facilities for cleaning and sanitizing packaging solutions.

    Based on the literature screening, many countries still lack waste management infrastructures (especially composting facilities) and washing facilities, and this could determine an increase of average transport distances, and consequently their related potential emissions. Two aspects are relevant: size and number of facilities. On the one hand, the efficiency of facilities increases with their size. On the other hand, the need of having a capillary network would lead to increasing the number of facilities.

    Further research on optimizing the number and size of reconditioning and recycling/composting facilities is envisaged for reducing potential environmental emissions. Furthermore, as reported by some expert interview sessions, some companies prefer to send their MU solutions to facilities abroad for washing instead of washing internally, due to internal procedures. This could however lead at reducing the environmental sustainability of their packaging solutions. Balancing between companies' procedures, economic aspects, and environmental ones should be considered.

Possible actions for innovation/improvement for the other 10 of top 15 highest ranking hotspots are discussed below.

Improvement in recycling processes: to decrease the amount of generated waste. Promoting studies to improve efficiency could be a valid starting point, and it should be encouraged. However, it might happen that current recycling processes have reached the maximum achievable efficiency. Considering this issue, studies on alternative recycling processes should be promoted too.

Packaging shape: its optimization could help at avoiding generated waste and emissions; however, an important obstacle is the very wide variety of products that are currently shipped in e-commerce. Optimizing packaging shape and adapting to the transported product is not easy task, because packaging producers would need to provide too many different types of packaging

[6] Zalando

solutions. Therefore, further research is required to find proper strategies for improving this challenging aspect.

Return rate for multiple-use solutions: since these solutions needs to be returned by the final customer, a possible strategy to increase the return rate is to promote a reward system for returned products. Furthermore, workers' awareness in B2B context should be improved: careless handling of MU packaging might result in broken or lost items, reducing the overall return rate.

Information campaigns: to increase customers' perception could shift the balance of a particular market sector: explaining hidden costs of certain products or technologies could help people to choose a specific product instead of another, even if the first one is more expensive or difficult to manage. In this context, the distribution of informative materials through different channels (flyers, videos, …) could help customers and authorities to make informed decisions.

Requirements of the goods: a suggestion is, once again, defining common rules for all European countries to avoid non-compliance issues.

Another aspect which could be improved is the high **number of single deliveries to the same customer**. This is related to the use of different secondary packaging solutions for each delivery, which increases the overall amount of packaging material. Grouping deliveries for the same customer could decrease the void ratio inside packaging. Moreover, a discount system for grouped deliveries could be implemented.

From an environmental point of view, the promotion of studies to increase **efficiency of manufacturing and recycling processes** could help at decreasing the emissions released in the environment due to these processes. However, further improving technologies might be not technically feasible, and the focus might be shifted to investigate new technologies instead of improving the current ones. Another issue related to this category is the need for identifying new uses for waste as a raw material. In fact, waste disposal is an important source of emissions and, if waste can be used for other purposes eliminating the need for disposal, the whole supply chain could benefit from it. Furthermore, increasing the number of electric or non-polluting vehicles in the whole supply chain, from delivery to final customer to handling material inside production facilities, could reduce the toll suffered by the environment.

Finally, an aspect that should not be ignored is related to the **amount of energy used for washing** – considering MU packaging – which is used both for operating the washing machine and for heating the amount of water used in this process. Considering that each country across Europe has a different percentage of produced renewable energy, this aspect could be a point of concern considering that washing is needed for MU packaging, especially considering the current pandemic situation.

4.1 Summary of possible actions for innovation/improvement

Considering the top 15 highest ranking hotspots, the possible actions for innovation/improvement are reported indicating the target group that could be involved to implement them: Institutions (at EU and member states level), Research Institutes, Environmental Agencies, packaging producers, logistic/shipping operators, e-commerce operators, washing services operators, waste industry operators. The following table presents suggestions for possible actions for innovation/improvement for the top 15 ranking hotspots.

Table 7. Possible actions for innovation/improvement

Hot-spot	Possible actions for innovation/improvement	Target group	Type of packaging solution(s)
Real number of uses for MU solutions	Promoting studies to define the real number of uses for MU packaging to better implement LCA analysis as a support to the decision-making process.	Institutions, Research Institutes, packaging producers	MU
Logistics parameters	There is an intrinsic limitation to possible improvement of distances, however optimization of logistics (e.g. storage space, truck filling rate) can play a role (e.g. to increase number of packaging for each delivery).	E-commerce and logistic/shipping operators	MU, SU
Percentage of recycled material used in production	Implement rules for the use of recycled material content in packaging solutions.	Institutions, Research Institutes, packaging producers	MU, SU
Quantity of material used for packaging	Optimize the amount of material used for packaging production	Packaging producers, Research Institutes	MU, SU
Number of recycling/composting and washing facilities available	Increase and optimize the number of recycling/composting facilities should be carried out (also by regulatory/incentives schemes) to define the optimal value, considering the contribution to emissions of respective life-cycle stages. Increase and optimize number of washing service centers, considering that washing is needed for MU packaging that need to meet hygienic standards.	Institutions, Waste industry, Washing services operators	MU, SU
Packaging shape	No identified point of improvement. Packaging shape depends on the shape of the contained product which cannot be modified.	-	MU, SU

Hot-spot	Possible actions for innovation/improvement	Target group	Type of packaging solution(s)
Waste generation	Promoting studies to improve efficiency of both packaging production and packaging recycling processes should be further encouraged to reduce waste generation. New and alternative specific recycling processes should be promoted too.	Institutions, Research Institutes, packaging producers, waste industry	MU, SU
Return rate	Increase workers awareness (B2B) to avoid careless handling of MU packaging that might result in broken or lost items.	Institutions, logistic and e-commerce operators	MU
Customer awareness about green packaging and packaging issues related to environmental preservation	Promote information campaigns. Distribution of informative materials through different channels (flyers, videos ,…).	Institutions, packaging producers, logistic and e-commerce operators	MU, SU
Requirements of the goods	Defining common rules for all European countries to avoid non-compliance issues.	Institutions	MU, SU
Limit for recycling	Improve recycling processes to avoid material degradation. Promote studies to find new recycling processes.	Institutions, Research Institutes, packaging producers, waste industry	MU, SU
Empty space	Study logistic schemes and incentives (e.g. discounts) to promote grouping of different products for delivery to the same customer to optimize filling ratio of boxes.	Institutions, E-commerce operators	MU, SU
Weight optimization	There is a physical limit to the weight reduction that can be implemented, however research in this filed could be promoted to reduce the amount of material used for packaging production	Research Institutes, packaging producers	MU, SU

Hot-spot	Possible actions for innovation/improvement	Target group	Type of packaging solution(s)
Reduction of pollution and traffic in urban areas due to home delivery	Increase the share of electric or non-polluting vehicles used for delivery	Institutions, logistic and e-commerce operators	MU, SU
Energy and water heating consumption for washing	Large washing centers should be preferred to obtain better environmental performances together with an increase of the share of renewable energy used.	Institutions, logistic and e-commerce operators, Washing services operators	MU

REFERENCES

Alander, Johanna, Christian Fickler, Mikaela Granberg Lomyr, and Tobias Jakobsson. 2016. "Climate-Smart Returnable Crates Have Replaced over Two Billion Packages."

American bakers association. n.d. "REUSABLE PLASTIC TRAY THEFT."

Beverage industry. 2015. "Rehrig Pacific Co. White Paper Highlights Strategies to Reduce Loss." 2015. https://www.bevindustry.com/articles/88699-rehrig-pacific-co-white-paper-highlights-strategies-to-reduce-loss.

Borealis. 2021. "Shrewsbury Cup Scheme."

Borghi, Adriana Del, Sara Parodi, Luca Moreschi, and Michela Gallo. 2021. "Sustainable Packaging: An Evaluation of Crates for Food through a Life Cycle Approach." *International Journal of Life Cycle Assessment* 26 (4): 753–66. https://doi.org/10.1007/s11367-020-01813-w.

Carreno, Miguel. 2013. "Exploring RFID Technology Adoption in Spanish Oranges Suppliers That Handle RFID-Tagged Pallets."

Ecommerce Europe. 2020. "Collaborative Report on Sustainability and E-Commerce," no. September: 1–15.

EKUPAC. 2008. "Reusable Transport Packaging in Europe."

Escursell, Sílvia, Pere Llorach-Massana, and M. Blanca Roncero. 2021. "Sustainability in E-Commerce Packaging: A Review." *Journal of Cleaner Production* 280: 124314. https://doi.org/10.1016/j.jclepro.2020.124314.

European Environment Agency. 2006. *Paper and Cardboard — Recovery or Disposal?* https://www.eea.europa.eu/publications/technical_report_2006_5/file.

"Expert Interview #2." 2021.

"Expert Interview #3." 2021.

"Expert Interview #4." 2021.

Fraunhofer Institute for Building Physics IBP. 2018. "Carbon Footprint of Packaging Systems for Fruit and Vegetable Transports in Europe."

Giraffe Innovation. 2018. "CupClub Sustainability Report 2018 A Comparative Life Cycle Assessment (LCA) of 12oz CupClub Cup and Lid."

Goellner, Kai N., and Eph Sparrow. 2014. "An Environmental Impact Comparison of Single-Use and Reusable Thermally Controlled Shipping Containers." *International Journal of Life Cycle Assessment* 19 (3): 611–19. https://doi.org/10.1007/s11367-013-0668-z.

Heineken. 2019. "Good Cup, Bad Cup: Ranking and Recommendations."

Holding, Ashley, and Adam Gendell. 2019. "Polybags in the Fashion Industry - Evaluating the Options," no. December: 42. https://fashionforgood.com/polybag-research.

Huhtamaki. 2020. "Annual Report 2020."

IESE - Universidad de Navarra. 2008. "Análisis Del Impacto Económico y Medioambiental de Las Industrias de Embalajes de Cartón Ondulado versus Plástico Reutilizable."

IFCO. 2019. "Reducing Waste , Emissions and Water Use with IFCO RPCs."

Jääskeläinen, Petra, and Rossella Recupero. 2019. "The Story of RePack," 8.

Just Salad. 2020. "ENVIRONMENTAL SUSTAINABILITY REPORT 2020."

Mulholland, Erin, John Jewell, Malcolm Hegeman, Jahred Liddie, Christoph Koffler, and Maggie Wildnauer. 2019. "Comparative LCA of Liviri Fresh vs. Disposable Food DeComparative Life Cycle Assessment of Reusable and Disposable Packaging for Meal Delivery Services," 65. https://liviri.com/wp-content/uploads/2019/07/Liviri-Fresh-Comparative-LCA-Report.pdf.

Nederland Institute for Sustainable Packaging, and Utrecht University. 2018. "CO2 Voetafdruk Vergelijking."

Pladerer, Christian, Markus Meissner, Fredy Dinkel, Mischa Zschokke, Günter Dehoust, and Doris Schüler. 2008. "Comparative Life Cycle Assessment of Various Cup Systems for the Selling of Drinks at Events." *Bmlfuw*, no. September: 137. http://www.meucopoeco.com.br/environmental_study.pdf.

Plaine Products. 2019. "2019 SUSTAINABILITY REPORT."

Rietveld, Eelco, and Sander Hegger. 2015a. "Life Cycle Assessment of Newly Manufactured and Reconditioned Industrial Packaging," 1–31. https://doi.org/10.32964/tj14.10.

———. 2015b. "Life Cycle Assessment of Newly Manufactured and Reconditioned Industrial Packaging - REVISED VERSION."

Rigamonti, Lucia, Laura Biganzoli, and Mario Grosso. 2019. "Packaging Re-Use: A Starting Point for Its Quantification." *Journal of Material Cycles and Waste Management* 21 (1): 35–43. https://doi.org/10.1007/s10163-018-0747-0.

Ross, Stuart, and David Evans. 2003. "The Environmental Effect of Reusing and Recycling a Plastic-Based Packaging System." *Journal of Cleaner Production* 11 (5): 561–71. https://doi.org/10.1016/S0959-6526(02)00089-6.

Saica. 2019. "Sustainability Report 2019."

Su, Yuehuan, Huabo Duan, Zinuo Wang, Guanghan Song, Peng Kang, and Dongjie Chen. 2020. "Characterizing the Environmental Impact of Packaging Materials for Express Delivery via Life Cycle Assessment." *Journal of Cleaner Production* 274: 122961. https://doi.org/10.1016/j.jclepro.2020.122961.

The Coca-Cola Company. 2019. "2019 BUSINESS & SUSTAINABILITY REPORT."

Tua, Camilla, Simone Nessi, Lucia Rigamonti, Giovanni Dolci, and Mario Grosso. 2017. "Packaging Waste Prevention in the Distribution of Fruit and Vegetables: An Assessment Based on the Life Cycle Perspective." *Waste Management and Research* 35 (4): 400–415. https://doi.org/10.1177/0734242X16688259.

UN Environment. 2017. "Hotspots Analysis - An Overarching Methodological Framework and Guidance for Product and Sector Level Application."

Waste & Resources Action Programme. 2007. *Reusable 'Carrierpac' Packaging for Kitchen Worktops at B&Q*. www.wrap.org.uk.

Wyman, Oliver. 2021. "Is E-Commerce Good for Europe?"

Zero Waste Europe. 2018. "The Story of Recircle," 1–8.

Zimmermann, Till, and Rebecca Bliklen. 2020. "Single-Use vs. Reusable Packaging in e-Commerce: Comparing Carbon Footprints and Identifying Break-Even Points." *Gaia* 29 (3): 176–83. https://doi.org/10.14512/GAIA.29.3.8.

SCREENING TABLE

Source ID	Commissioner / Funds	Authors (institution)	Title	Source category	Third party review?	Claims (if commercial) / Findings (if scientific)
1	Svenka Retoursystem	Alander et al. (2016) LCA Master thesis (in Swedish)	Climate-smart returnable crates have replaced over two billion packages	scientific (client driven)	yes	- Analysis of wholesaler's distribution to 7 grocery stores (model is very complex) - limitations: not possible to include all influencing factors during the LCA - Results: multi-use is better under many assumptions - boundaries: are important!
2	Stiftung Initiative Mehrweg (SIM)	Hannes Krieg - Fraunhofer IBP (2018)	Carbon Footprint von Verpackungssystemen für Obst- und Gemüsetransporte in Europa	scientific (client driven)	yes (PRÜFBERICHT DER KRITISCHEN PRÜFUNG)	- Results: Plastic crates result in 60% lower greenhouse gas emissions (GWP) to provide the same transport performance compared to cardboard crates - Times/cycles: After the 6th rotation, plastic crates have lower greenhouse gas emissions than cardboard crates per rotation - In practice, plastic crates can be used for over 50 rotations
3	University (Ontario agricultural college)	Dr Keith Warriner (Director of the Food Safety and Quality Program, Department of Food Science)	Microbiological Standards for Reusable Plastic Containers within Produce Grower Facilities within Ontario and Quebec	scientific	no	- 10% of plastic crates had visible dust or organic residues - 30% had labels from previous users some of which had signage "Product of Mexico" - 43% of RPC's failed due to high ATP readings, 73% exceeded the TAC criteria with 51% and 35% failed in terms of enterobacteriacece and coliform levels respectively - unsanitary status of RPC with no improvements being observed compared to the 2013 study
4	Expert interview #1	-	Interview on 22.06.2021 with the board of FEFCO	expert interview	-	-empty space in packaging is a very important parameter -returned packaging need storage space. The distance travelled by returned packaging a another significant parameter -packages are transported across borders of different countries inside EU -> possible lack of compliance due to different country rules -impossibility of changing packaging shape (e.g., Amazon dictates the shape for returnable packages - square) -for some products a higher level of hygiene must be guaranteed (food) -a standardization of packaging system is unrealistic when completely different products should be packed together (generally warehouses don't even know the type of product they are going to ship)
5	Netherlands Institute for Sustainable Packaging (KIDV, Kennis Instituut Duurzaam Verpakken)	Coelho et al. (2020)	Sustainability of reusable packaging–Current situation and trends	scientific	yes	- Core topic: Boxes, containers, soft packages: Customers receive the product in reusable packaging which is returned by door delivery/pick up, or through the post office. - Reusable packaging for transport or shipping of perishables or non-perishables: B2C: for moving home or office location or e-commerce delivery of apparel, furniture or perishables. - Loop (circular shipping platform) in EU: subscription-based e-commerce for major brands. The ownership of the packaging is retained by the brand. After home delivery, the packaging is picked up, cleaned and refilled by Loop before being resold. - Standardization of reusable packaging for e-commerce is essential to introduce reusable packaging at scale, as was done for pallets and crates in the past. This would make logistics more efficient for companies and carriers, and also facilitate automation (F. Smoes, personal communication, June 7, 2019). - WRAP Program in the UK: reusable packaging systems for furniture, kitchen appliances, and kitchen top shelves. Carrierpac is a reusable transit packaging for kitchen worktops replacing cardboard boxes. After 10 reuses, the Carrierpac breaks-even cost-wise compared to cardboard boxes. An Outpace customer makes on average 50 trips with the same packaging. The company has been avoiding over 1000 tons in cardboard boxes while reducing damage to the kitchen worktops. For some of the packaging, there is a repair service, keeping the material in the loop for longer (T. Hutchinson, personal communication, April 29, 2019). However, in the beginning, bags did get lost due to inadequate communication of new staff and third-party logistics, demonstrating that training of users is needed as well as monitoring of the bags (WRAP, 2007). - The use of cardboard boxes is the primary option for e-commerce delivery. - In e-commerce, two companies developed reusable packaging systems and are operating in different business models: 1) Repack in Finland leases packaging for products that do not need hard packaging protection in B2C ecommerce, such as clothes, towels, backpacks. Once the consumer receives the product, the packaging, which comes with a return label offered by RePack, is folded and sent to the company by regular mail. Repack then cleans and checks the quality of the packaging before directing it back to stores. The brands choose how the reusable packaging is offered to customers, e.g. as a paid option at checkout, for free over an expended amount or for free with the company absorbing the delivery cost (J. Berbee, personal communication, April 17, 2019). 2) Returnity in the USA sells reusable boxes, bags and envelopes to different brands. In B2B (such as warehouse to store): the packaging is kept in circulation, saving costs compared to single-use. In B2C in the e-commerce lease of apparel (resulting in significant financial savings for the company since the packaging will be returned at the end of the leasing period), and return of unwanted products in regular e-commerce (which is around 30-40% of the products sold online). In the last case, since 60–70% of the packaging is not returned, some brands invest in a reversible tote bag with an appealing design that can be reused by consumers afterwards.
6	science	Rigamonti et al. (2018)	Packaging re-use: a starting point for its quantification	scientific	yes	A parametrization for reusable logistics is required (iter) 1) Identification of the reusable packaging 2) Qualitative characterization. For each type of packaging, one should collect information about: • the material (steel, aluminum, cardboard, wood, plastic, and glass), • the business application ("business to business"— B2B—or "business to consumer"—B2C—markets), • the need of reconditioning and the type of reconditioning process, • the sector of use, • the main basic characteristics (such as the average size and/or average weight), • the type of service on which it is managed (e.g., rental vs. purchase), if it is a primary or secondary or tertiary packaging. 3) Quantitative characterization. For each type of identified packaging, data about the following parameters should be collected, typically on an annual basis: • population: the total number (or weight) of items [8]; it can be assumed as the material stock available, • number of rotations: the number of times the packaging is used before it is sent to disposal/recycling [8], • rotated packaging: the population multiplied by the number of rotations; it can be assumed as the material flow, • newly manufactured packaging, • prepared for re-use packaging, • overall lifetime: the average age of the packaging [4]. Results: - wooden boxes that used to be re-used in the fruit and vegetable sector are nowadays a single-use packaging, for sanitary reasons. - Moreover, plastic octabins and plastic collars are two recent types of reusable packaging that can replace cardboard octabins and wooden collars, respectively. - Plastic bags are used only in the B2C market. Five types of packaging (i.e., steel gas cylinders, gas cylinder for CO2, other gas cylinders in aluminum, glass bottles for water and soft drinks, and bottle carriers) are used both in the B2B and in the B2C markets. All the others are used only in the B2B market.

Source ID	Commissioner / Funds	Authors (institution)	Title	Source category	Third party review?	Claims (if commercial) / Findings (if scientific)
7	Holmen	IVL Swedish Environmental Research Institute	ENVIRONMENTAL BENEFITS OF FRESH FIBRE-BASED PAPER PRODUCTION	scientific (client driven)	yes	-Producing mechanical paper from fresh wood resources requires significantly more energy compared to a paper produced from recycled resources. However, if low-emission renewable energy resources are used for the fresh fiber production, these effects can be significantly reduced.
8	science	Del Borghi et al. (2020)	Sustainable packaging: an evaluation of crates for food through a life cycle approach	scientific	yes	-The environmental impacts result lower for multiuse plastic crate due to its possibility of being reused during its lifetime, avoiding the high impacts of the manufacturing. The best option among the single-use systems is the solid wood crate. -a breakage rate of 0.4%, a washing treatment before reuse for the 97.6% of the multi-way plastic crate, a direct recirculation after the inspection of the remaining 2%.
9	science	Koskela et al. (2014)	Reusable plastic crate or recyclable cardboard box? A comparison of two delivery systems	scientific	yes	Transportation played a very important role in the environmental impacts of the analyzed systems. Therefore, changes, e.g. in the weights of products and their secondary packaging or the transportation distances could affect the results considerably.
10	science	Zimmermann et al. (2020)	Single-use vs. reusable packaging in e-commerce: comparing carbon footprints and identifying break-even points	scientific	yes	-the comparative analysis of single-use and reusable shipping packaging systems has shown that the reusable systems are environmentally advantageous, provided that a certain number of cycles is achieved (for PP vs cardboard boxes 81 cycles if cardboard boxes produced with recycled material, 61 if produced with primary material. -Compared with a single-use LDPE shipping bag weighing 30 grams, the reusable bag achieves the same emissions per cycle as the single-use bag after about eight cycles, the reusable bag made from 100 percent PCR from about three cycles on. -Compared to the LDPE shipping bag made from 80 percent PCR, the reusable bag has lower emissions from the 20th cycle on, the reusable bag made from PCR from about five cycles on) -a relevant improvement in environmental performance can be achieved by using recycled plastics. Also, weight reduction can improve the environmental performance of reusable packaging. Factors such as the capacity utilization of transport processes and transport distances are less decisive. -If "only" 70 percent of the reusable packaging is returned by the customer, this results in on average less than three use cycles per packaging. To achieve an average of eight or more use cycles, the return rate has to be well above 90 percent. -washing process not considered
11	science	Su et al. (2020)	Characterizing the environmental impact of packaging materials for express delivery via life cycle assessment	scientific	yes	-Since the data of transportation distance, the vehicles used, and the energy consumed is difficult to obtain and may be inaccurate, logistics and transportation of express delivery (packaging materials) are also not considered in this study. -The rapid growth of annual express delivery volumes is the key reason for the increasing impact (GHGs emissions) from EDPM. It is urgent to encourage express delivery companies and the public to choose simple and green packaging instead of blindly pursuing 'layers and layers' of EDPM. -By quantifying the GHGs emissions of the EDPM, the raw materials stage of EDPM produces a majority of CO2e by 9.3 Mt CO2e in 2018 and accounting for 68.4% of the total emissions while the GHGs emissions at the manufacturing stage and the EoL stage were 18.9% and 12.7%, respectively. -According to scenarios-based analysis, we learned that reducing the use of EDPM, and improving the recycling rate can achieve significant reduction purposes. The maximum reduction rate of GHGs emissions can reach 35% than BAU. Therefore, it is necessary to provide guidance on green packaging actions and promote relevant implementation plans. Meanwhile, establishing a complete recycling system is required.
12	science	Carreño Asúa (2013)	Exploring RFID technology adoption in Spanish oranges suppliers that handle RFID-tagged pallets	scientific	no	-lack of knowledge of RFID technology from fruit producers -possible automation of the procedures due to implementing RFID technology -better economic situation helps increase use of new technologies (e.g., RFID) -lack of employee expertise in RFID technology -difficulty in getting funds to finance investments in RFID
13	Sustainable Packaging Coalition + Retail Industry Leaders Association	Fashion for good (2019)	POLYBAGS IN THE FASHION INDUSTRY: EVALUATING THE OPTIONS	commercial (flyer)	no	-industry returns rates can be anywhere from around 30-50%. Garments will typically be inspected and, if of good quality, packed in a new polybag and the old polybags discarded. -In Europe, the majority of plastic packaging waste is sent to landfill or incinerated (energy recovery), with recycling rates of around 41% - Even though the plastic currently used for packaging – LDPE (low density polyethylene) is technically recyclable, the recycling rate could be much better, and contaminants such as ink and paper limit the use of the recycled material in many products -Brands say their sustainability priorities for polybag packaging are the end of use management (and recyclability) of the waste, a reduction in the amount of plastics used and the lowering of its carbon impact. -incoming policy changes may encourage brands to move towards packaging that is recyclable or contains recycled content -Incorporating recycled content is feasible and getting more feasible. Doing this will support the recycling value chain, and replace virgin, fossil-based LDPE with a lower carbon alternative. Biobased LDPE can also be included which has a lower footprint than its fossil-based counterpart. -- bio-based and compostable plastics and paper-based alternatives should also be collected for recycling or composting. -Compostable materials are interesting for many brands but the infrastructure to actually collect and then compost these materials is currently lacking in most places.
14	EC	Ecommerce Europe	Collaborative Report on Sustainability and e-Commerce	commercial	no	-the majority of retailers can directly resell 80% or more of returns as A-goods (except for food). -There can be different reasons why returns do not qualify as A-goods anymore: in most cases (71%), the quality of the product suffered too much so that it cannot be refurbished anymore. High costs that make the refurbishment uneconomic only play a role for 20% of retailers. Another 20% do not sell them as A-goods to maintain the value of their products. -goods that cannot be resold as A-goods gets in the majority of cases (54%) resold as B-goods. - highlighting product that fulfil one or more sustainability criteria on a website (Zalando) encourage customers to buy it -in order to reduce the number of returned items, some companies (e.g., Zalando) provide shopping advice using specific algorithms. another proposed option is implementing a "CO2 account" that displays the sustainability of the return behavior (resulted more effective on women) -Zalando implemented the "one parcel policy" to reduce parcel volume -Tchibo, Otto and Avocadostore have been testing RePack -By 2025, IKEA Retail aims for 100% home deliveries by electric vehicles or other zero-emission solutions -e-commerce deliveries don't contribute significantly to traffic, in fact where the average distance from customers to shops is higher, it reduces the number of shopping trips by customers reducing traffic

Source ID	Commissioner / Funds	Authors (institution)	Title	Source category	Third party review?	Claims (if commercial) / Findings (if scientific)
15	science	Escursell (2020)	Sustainability in e-commerce packaging: A review	scientific	yes	-e-commerce is an effective choice for non-urban delivery over long distances as it avoids using private means of transport to reach urban areas, which is where malls are usually located. -Package weight and volume are also important because they influence energy use for transport. -67.75% of manufacturers to provide incorrect recycling information -98% of labels to be false or the result of greenwashing practices intended to deceive customers. -Packaging materials should not only be environmentally friendly, but also pose little problem over 'the last mile', which is the greatest hindrance to e-commerce expansion at present. Companies are struggling to deliver lighter packages as expeditiously as possible, but obviously at a cost. -'Dematerialization' is a widespread approach to reducing material and energy use, production of solid waste and CO2 emissions. -some recycled materials such as cardboard do not have the same properties as the pure materials (recycled fibres save trees from felling in addition to 1% of water and 30% of electricity per ton of paper but they haver poor mechanical properties) -Standard stores are increasingly using paper bags instead of corrugated board packages for home delivery thereby saving 80% on energy -new form of packaging can alter consumers' perception and lead them into believing that the product it contains is of lesser quality. -Alternative biodegradable starch-based peanuts are more expensive than are EPS packing peanuts
16	WRAP program	Waste & Resources Action Programme	Reusable 'Carrierpac' packaging for kitchen worktops at B&Q	commercial	no	As well as confirming that the Carrierpac was fit for purpose, the trial identified the variables that will determine its commercial viability. These include the: relative purchase cost of the single-trip packaging versus Carrierpac; number of reuses of Carrierpac that can be achieved; loss rate of Carrierpacs per delivery cycle; difference in product damage rates between single-trip packaging and Carrierpac; time and resources required for packing and handling using single-trip packaging versus Carrierpac; cost of operating a closed loop system to track, inspect and clean Carrierpac; length of time taken for the Carrierpac to complete each distribution and return cycle.
17	Repack	Zero waste europe	THE STORY OF RePack ZERO WASTE CONSUMPTION & PRODUCTION	commercial	no	-RePack's reusable packages are made of durable and recycled polypropylene and come in three adjustable sizes. The packages are designed to fold in letter size when empty to be simply returned via a mailbox, anywhere in the world. The packages are made to last at least 20 cycles. -Although their packaging design did not work really well, they've realized that the customers loved the idea so much that they were given a feedback rating of 9.5 out of 10. -Statistics show that RePack reduces up to 96% of total packaging waste. -Moreover, RePack's system has significantly contributed on the social sustainability aspect, as packages are handled by social workers associations, employing people with disabilities.
18	Plaine Products	Plaine Products	2019 SUSTAINABILITY REPORT	commercial	no	-Our reuse process also supports the local economy. By cleaning and reusing our bottles, Plaine Products is able to create jobs. Research indicates that reuse and remanufacture create nearly twice as many jobs per thousand tons of material compared to traditional recycling -Our work to eliminate single-use plastic and reuse bottles, pumps and packaging not only helps reduce greenhouse gases and prevent deforestation, it also helps reduce pollution and waste that often ends up on land and in the ocean. -This past year, we also were able to reduce the company's overall waste at the manufacturing level by partnering with a new box supplier. -Researchers from the MIT Center for Transportation & Logistics found that traditional brick-and-mortar shoppers have more than double the environmental impact of online shoppers. -Our new partner uses 100% recycled materials
19	Just Salad	Just Salad	ENVIRONMENTAL SUSTAINABILITY REPORT 2020	commercial	no	-reduction of CO2 emission by using bike or cars for delivery -reduction of packaging related emission by eliminating plastic pouches and providing single-use utensils only if required by customers - saving of natural resources by reducing the size of delivery bags -introduction of reusable bowl program (bowls washed at home and then refilled in the store) -breakeven point for the reusable bowl is 3 when compared to PET disposable bowl -pre-COVID use of compostable single use items: various items made of bagasse (sugarcane production by-product) and straws made of reed stems -use of paper cups with paper coming from FSC-certified production -minimization of energy consumption in stores -choice of energy provider connecting renters to 100% renewable energy
20	Pieter Pot	Nederland Institute for Sustainable Packaging / Università di Utrecht	CO2 Voetafdruk vergelijking	commercial	no	-using reusable glass containers can help decrease the production of waste. -glass containers are attractive to customer -washing parameters (use of water, use of detergent,…) change if different machines are used (industrial washing, industrial grade dishwashers, home grade dishwashers, handwashing)

Source ID	Commissioner / Funds	Authors (institution)	Title	Source category	Third party review?	Claims (if commercial) / Findings (if scientific)
21	CupClub	Giraffe Innovation	CupClub Sustainability Report 2018 A comparative Life Cycle Assessment (LCA) of 12oz CupClub cup and lid	scientific (client driven)	currently under review process	■ All the environmental impacts of CupClub's 12oz cup and lid over 132 uses including washing, drying and recycling were lower than using 132 PLA lined 12oz paper cups and PLA lids at 1% recycling rate; ■ The carbon footprint of the paper cups was over 87% higher, and up to 10 further factors were more than double that of CupClub; ■ However, at 1% recycling rate the disposable paper cups would have a lower impact than CupClub if the CupClub cups and lids were not used more than 72 times; ■ The paper cups with the exception of the PLA lined composted cup and lid, could also have a comparable carbon footprint at 132 uses if the recycling rate for them was at least 80%; ■ At 80% recycling rate CupClub's carbon footprint at 94 uses was lower than the composted PLA lined cup and PLA lid; ■ CupClub needs to be used at least 100 times to have a lower impact than the EPS 12oz cup and lid. Eight of the 18 impact for EPS were lower than CupClub at 132 uses; ■ At 132 uses all the environmental impacts bar the water use was lower for CupClub than a ceramic cup. After 800 uses the ceramic cup would have a comparable impact to CupClub; ■ Sourcing the CupClub cups and lids from China will increase all the environmental impacts by up to 3.3%; ■ Increasing the distance, the cups and lids are transported for washing and drying by tenfold would only increase the overall impact by up to 2%; and ■ Decreasing the energy use by 10% for the washing and drying of the cup and lids would decrease the majority of the impacts by at least 8%.
22	Globelet	Globelet	Creating Better Events with Reusable Systems	commercial	no	-design of specific washing machine to better clean, sanitize and dry reusable cups. -two different designs based on the need of the client (mobile for large scale event, flight type for quickly washing many cups) -Remote System Monitoring for dishwashers for solving mechanical issues (mobile type) -Tracking Software allows to track inventory, reward users, and monitor landfill diversion -cups have a 97% return rate at past festivals and large events -80% of our clients generate a net positive outcome by using reusable cups
23	Heineken	Heineken	Good cup, bad cup: ranking and recommendations	commercial	no	-a reusable cup requires at least 10 uses to outperform a single-use cup - 3 L of water used for washing one reusable cup 75 times
24	Green Globlet	hopesolutions	IT DOESN'T STACK UP... How disposables compare to reusables	commercial	no	-Even when they are recycled, single use cups have a significantly higher environmental impact due to the cumulative impact of manufacturing. -A reusable cup has a lower environmental impact than a single use cup after less than 3 uses
25	Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management and Swiss Federal Environment Authority	Österreichisches Ökologie-Institut, Carbotech AG and Öko-Institut e.V. Deutschland	Comparative Life Cycle Assessment of various Cup Systems for the Selling of Drinks at Events	scientific (client driven)	yes	-reusable cups are recommended for major events such as UEFA EURO 2008TM -The sensitivity examinations show that even the excellent reusable cup systems can be optimized further if certified ecopower is used for operating the washing plants. -An important influence on the results is due to the number of cups that are taken home, their influence on the circulation numbers and the type of domestic use, which has been specified for the LCA.
26	Borealis	Borealis	Shrewsbury Cup scheme	commercial	no	-single-use paper cups typically have a polyethylene (PE) lining that makes them difficult to recycle -t Shrewsbury Cups breakeven after just three uses - a local supermarket's tests showed Shrewsbury Cups held up after a thousand washes in a commercial dishwasher -recyclable and reusable packaging that is low cost, insulated -highly durable and attractive to consumers
27	reCircle	Zero Waste Europe	THE STORY OF RECIRCLE, ZERO WASTE CONSUMPTION & PRODUCTION	commercial	no	-spherical shape makes it fit perfectly in restaurants' dishwashers -intense purple color, which makes them easily recognizable and helps spreading the system -leak-proof container with volume measurement lines -different shapes available (useful for a variety of meals) -perfect to store the remaining food (helps preventing food waste) -Restaurants join Recircle through a three months trial period - Once in the system, restaurants get a Recircle sticker for their door and they are added to Recircle's map. Thanks to this, customers know which restaurants sells food in reusable boxes, (bring-back point for returning lunch boxes after use) -Recircle encourages restaurants to charge a fee on disposables to encourage using reusable but restaurants are still reluctant to implement it, as they fear losing clients -the Canton of Bern is considering introducing a specific tax on single-use boxes -subscription includes re-distribution of boxes in case of imbalances between restaurants, renewal of overused boxes and communication materials -single use lunch boxes are not reusable and can produce litter (quick filling of waste bins)

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28	Liviri Fresh by otter products	thinkstep	Comparative Life Cycle Assessment Reusable and Disposable Packaging for Meal Delivery Services	scientific (client driven)	yes	-the Liviri Fresh has lower impact than the disposable corrugated alternative in 8 of 9 indicators considered -Liviri Fresh system advantages are due to raw materials and manufacturing can be allocated across its many use cycles (a benefit that cannot be offset by its increased transportation mileage) -the higher weight of the Liviri Fresh cooler itself is offset by a 50% reduction in ice pack loading due to its superior insulation properties so that the Liviri Fresh unit weighs in only slightly higher than the corrugated cooler with ice packs and other accessories. -The one indicator where Liviri Fresh showed a higher result than the corrugated cooler in the baseline scenario was GWP100 including biogenic carbon which was mainly driven by the carbon removals and their partial sequestration in landfills associated with the recycled cotton fibres used as an insulation material for shipping as well as the wooden shipping pallets (a scenario analysis demonstrated that the result for this indicator depends on the normative choice of the applied carbon accounting approach) -the corrugated cooler's sole advantage of sequestering some of the biogenic carbon contained in the cotton insulation will only materialize itself in practice if landfill parameters like the climate zone, landfill gas (LFG) capture rate, and split between flaring and energy recovery allow for it. -the landfilled cotton fibers do not carry any upstream burden of primary cotton fiber production under the cut-off EoL allocation approach
29	RIPA (Reusable Industrial Packaging Association)	Ernst & Young Accountants LLP Eelco Rietveld Sander Hegger	Life Cycle Assessment of Newly Manufactured and Reconditioned Industrial Packaging	scientific (client driven)	no	-The drums and IBCs are collected by truck and transported to a reconditioning facility. There, they are reconditioned as explained above and sold to customers again. -it is possible to recycle steel an indefinite number of times -Some recycling plants, as in energy recovery facilities, generate electricity and heat -It should be stressed that the drums with thicker sheet can be reconditioned and can be reconditioned more often.
30	IFCO	IFCO	Reducing waste, emissions and water use with IFCO RPCs	commercial	no	-Using IFCO reusable plastic containers (RPCs) instead of single-use packaging means a significant reduction in CO2 because of possibility of reusing them -IFCO RPCs reduce the creation of solid waste by 86% thanks to their long lifespan and the fact they are fully recyclable. -Each is used between 30 – 120 times -at the end of its life, each is granulated and used to create new RPCs. -Water-recycling technology at many of our state-of-the-art wash centers reduces water use by over a third for each wash -single-use packaging systems use 80% more water during production, recycling and disposal
31	Saica	Saica	Sustainability Report 2019	commercial	no	-production of pellets of recycled plastic as an alternative to landfilling -improvement in separation of waste reduced the production of waste destined to landfill -impossibility of producing a packaging made of 100% recycled material because of European regulations -recycled paper has a high printing quality that allows for customization of finish -efficient warehouse energy management (self-driving electric vehicles, generation of energy during descent and braking manoeuvres) -improved workers safety by using an automatic system for achieving zero-accident zone (prevention of vehicles collisions) -increase in renewable energy use (biomass boiler installed in 2019 in Venezuelan plant) -reduction of water consumption
32	Coca-cola	Coca-cola	2019 BUSINESS & SUSTAINABILITY REPORT	commercial	no	-16 markets offer beverages packaged in 100% recycled PET (rPET) bottles, with more to come. -From the end of 2019, 7 out of 10 of all bottles in Australia are now being made entirely from recycled plastic. -In multiple markets, Sprite packaging was changed from green to clear bottles, which makes them more valuable by improving the efficiency of the recycling stream. -100% rPET will be used for all plastic bottles in Sweden beginning in 2020, eliminating the use of 3,500 tons of virgin plastic and reducing emissions by 25%. -In Brazil, all 2-liter bottles across Trademark Coca-Cola, Fanta and Sprite brands are sold in refillable "universal bottles" that are the same shape, size and color, which increases the efficiency of collection, cleaning and filling -Over 650,000 metric tons of CO2 emissions—equivalent to burning approximately 1.5 million barrels of oil—have been averted through use of our PlantBottle, which incorporates 30% plant-based material. -We introduced refillable, microchipped cups that interact with Coca-Cola Freestyle at select cruise lines, amusement parks and universities. -54% of our priority ingredients volume was sourced sustainably in 2019, compared to 44% in 2018.
33	huhtamaki	huhtamaki	Annual Report 2020	commercial	no	-Huhtamaki Group Lost Time Incident Frequency Rate: 1.7 -The Employee Engagement index was 74% in 2019. -Zero food contact compliance related claims reported -Innovations related to plastic substitution with fiber-based materials, improving recyclability and use of recycled content. -More than 98% of all fiber was sourced from recycled or certified sustainable sources. -Scope 3 emissions reported for the first time, commitment to set science-based emission targets. -All plants in water-stressed areas have a water management plan -In 2020, 92.5% of key suppliers accepted the Code of Conduct for Huhtamaki Suppliers, and 4.7% provided their own Code of Conduct which was approved after review -In 2020, the share of renewable materials of all materials used across Huhtamaki was 67% -in 2020 and 97% of our fiber raw materials (excl. recycled fiber) were certified with PEFC™, FSC® or SFI® Chain of Custody certifications, which guarantee that the fiber is traceable to sustainably managed forests -In 2020, our total energy consumption decreased to 2,142 GWh (2,252 GWh) -he share of renewable energy increased to 2% -In 2020, our absolute Scope 1 emissions decreased 2% from 2019. -Our Scope 2 emissions decreased 9% in 2020 when compared to 2019 -We also use water based printing inks, which are solvent free and do not result in VOC emissions, but they do, instead, require more energy for evaporation. In 2020, 13% (16%) of printing inks used in Huhtamaki were water- or oil-based.

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34	science	Tua	Packaging waste prevention in the distribution of fruit and vegetables: An assessment based on the life cycle perspective	scientific	yes	-customer drives more than 7 km in total, the corresponding CO2 emissions result higher than the overall emissions of the alternative home delivery box scheme. -the use of reusable plastic crates along the entire cycle of distribution should be promoted in the box scheme otherwise there an increase in the generated waste with respect to traditional distribution. -In case of dedicated car travel to a drop-off point (a 10 km round trip just for the crate collection), the system shows an upsurge of the potential impacts when compared with any scenario of the traditional distribution. The negative performance is mainly due to the car travel itself -The impacts of the box scheme decrease with a non-dedicated travel (purchase of other four items at the drop-off point) -The box scheme with home delivery is indeed generally better -sensitivity analysis: by considering 100 km distribution distance (instead of 700 km) and by substituting disposable wooden crates with reusable plastic crates in home delivery, there's a significant improvement for all indicators in the box scheme -the study also highlighted that a complete abandonment of the traditional system is hardly possible. -the respective potential impacts significantly worsen when the consumer purchases a small amount of carrots. -Unlike carrots distribution, the transportation distance to the distribution hub was not changed as the supply of apples has proven to be local (within 100 km). With the crates replacement, the box scheme is generally better than the traditional distribution of apples in primary packaging or than the loose distribution with a partial filling of the bag for the purchase
35	Email Ltd	Ross, Evans	The environmental effect of reusing and recycling a plastic-based packaging system	scientific (commercial driven)	yes	-The proposed system recycles EPS-HIPS components back into HIPS resin: produce enough resin to avoid virgin inputs of BTX and ethane, excess HIPS is available for use by other product systems. -the impact of the reusable HIPS/EPS +PE packaging were less than the single use option -Recycling or, better still, reuse of plastic products can significantly reduce the energy required across the life-cycle because the high energy inputs needed to process the requisite virgin materials greatly exceeds the energy needs of the recycling or reuse process steps. -This study has also indicated that the energy consumed during transportation is negligible when compared to the overall energy consumption of the system (often cited as a reason for not pursuing recycling possibilities)
36	science	Goellner, Sparrow	An environmental impact comparison of single-use and reusable thermally controlled shipping containers	scientific	yes	-The reusable logistical approach has shown to impose a significantly smaller environmental burden in all impact categories of interest. A sensitivity analysis has shown some leeway in the degree of the environmental advantage of the reusable approach, but it confirms the conclusion as no case proved otherwise. Among the factors investigated in the sensitivity analysis are mass requirements for the single-use approach, transportation distance during the use-phase, fraction recycled, and supplier-to-supplier transportation distance assumption -Reusable container inventory sustains losses of 10 % per year -Use-phase emissions make up almost entirely of transportation emissions and contribute the majority of all impact categories for the reusable packaging approach and contribute the bulk of EP and HTP emissions for the single-use approach. -Shipping distances between suppliers are assumed to be 1,000 km when no primary data are available, assuming a regional and national supply chain -single-use container emissions are more sensitive to the average transportation distance than are those of the reusable container due to its heavier shipping weight, which results in greater use-phase transportation emissions given the baseline case Sensitivity to the average transportation distance is notably smaller than to material mass requirements. -Current component recycling fractions are unknown -Despite this increased travel per use, the reusable case had reduced use-phase transportation emissions due to the considerable differences in container mass between these logistical approaches. -Although PUR insulation inflicts a greater environmental burden than does EPS insulation per kg of product during production, the increased mass of EPS required for equivalent thermal performance results in increased production and transportation emissions, making it a less desirable single-use insulation option over the product lifespan. -Maximum reduction in supplier–supplier distance was shown to reduce the GWP for the single-use approach up to 8.6 %. -The environmental break-even point between the two logistical approaches occurs after as few as six shipments for PCOP and as many as 17 shipments for HTP emissions

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37	Amazon	Oliver Wyman	IS E-COMMERCE GOOD FOR EUROPE? Economic and environmental impact study	scientific (client driven)	no	-delivery vans reduce car traffic by between 4 and 9 times the amount they generate. -Land use for e-commerce is lower than for physical retail, when logistics, selling space, and related parking space are included. -E-commerce generates 1.2 indirect jobs in fulfilment and delivery for each direct job, compared with 0.2 required for physical retail. -in the e-commerce business model the delivery is almost fully outsourced, and fulfilment is carried out (outsourced or not) by operators, which have to pick consumer units instead of pallets of goods. -The cost per fulltime employee is 15 to 20 percent higher in e-commerce than physical retail for direct jobs — but comparable once indirect jobs are taken into account. - Offline retail causes 1.5 to 2.9 times the amount of CO2e as online retail. -Fashion has the biggest impact of the three categories (fashion, consumer electronics and books) in both types of channel and in all the countries considered. -Variations in passenger last-mile transportation, delivery last-mile transport, and merchandise transport (between the vendor, warehouses, and stores) do not change the overall impact gap between e-commerce and physical retail. -Considering all categories and geographies together, more than 80 percent of customers return less than 10 percent of their online orders -Recent trends show a higher annual growth rate for cross-border e-commerce (parcels not originating from the destination country) than for domestic e-commerce (11 percent96 over 2014-2019). However, recent changes in regulation might slow growth in the near future. -Emissions related to production are indeed higher than those for delivery -Physical retail accounts for 89 percent of total retail sales across France, Germany, Italy, the Netherlands, Poland, Spain, Sweden, and the UK -The e-commerce share of retail sales is higher in countries where retail is more organized, as established organized retailers have moved faster toward omnichannel retailing. -e-commerce has been growing according to different structures in different countries which reflect how organized physical retailers have reacted to the rise of e-commerce -There are fewer outlets in the eight countries, but the total store surface remained stable, as stores grew larger. -The next trends in retail most likely will combine a further shift to organized retail, greater online sales, an emphasis on service, new uses of social media, and sustainable practices -Fashion has the biggest CO2e impact of the three categories (fashion, books and consumer electronics) in both types of channel and in all the countries considered. -transport from a non-national warehouse represents less than 4% of the e-commerce impact -less than 10 percent of online shoppers show systematic interest in the environmental impact of their online orders, while a third may be sensitive to the topic. -Greater distances between fulfilment centers and consumptions areas are increasing the CO2e impact of transportation.
38	FEFCO	EKUPAC	Reusable Transport Packaging in Europe	commercial	no	-The Discounters in Europe make predominant use of carton / corrugated packaging. Trends and Tests are nevertheless showing that in short term the usage of huge quantities of foldable crates will take place – especially in the area of fruit + vegetables and meat.-The – from the reusable packaging point of view – nearly unattended B2B sector will more and more enforce the usage of reusable packaging. Main reasons are hygiene, logistics and technique -There are a lot of legal requirements, regulations or guidelines in international goods traffic which are mandatory in their general application. This does not imply that National Law would have to be applicable (Transparency effect). EU Guidelines and EU Regulations override country national law within the European Union member states (direct applicability).
39	FEFCO	dr.ir. J.G. Vogtländer (TUDelft)	Corrugated Board Boxes and Plastic Container Systems: An analysis of costs and Eco-costs	scientific (commercial driven)	no	- the corrugated board systems are better in all cases from the environmental point of view - transport by means of the plastic containers is only cheaper in 600*400 containers for short distances (shorter than 500 km) - for very long transport distances (longer than 2000 km), the re-packing of vegetables and fruit, from the corrugated box into the containers of the retailers sees the best current system solution (better than transporting the plastic containers over long distances) - an attempt should be made to introduce re-usable “transfer plates” which are to be used at the retailer’s distribution center, to make the corrugated board box compatible with the retailer’s internal transport system; such a solution seems to be attractive for distances longer than 1000 km.

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40	Pro Carton	Tim Barker, Truffula Ltd.	Comparison of Carton and Plastic Packaging Sustainability	scientific (commercial driven)	no	-Based on data from Eurostat, more than double the proportion of paper and cardboard packaging is sent for recycling (82.6%) compared to the recycling rate for plastic packaging (39.8%). -While technically most plastics can be recycled, in practice it is often difficult to ensure it is properly segregated in volumes sufficient to make it economically attractive to collect. -82% of the litter collected on European beaches is plastic, while only 2% is paper or cardboard. -paper-based packaging can break down within months but plastics can take decades or even centuries to degrade. -oxo-degradable plastics, which are treated with additives so they break-up after a period of time, do not degrade fully but rather fragment into 'microplastics' smaller than 5mm -for certain applications, the key benefits of plastic (durability and lightweight) can be redundant or insufficient overall for it to be considered an automatic choice -The primary raw material for plastic manufacture is oil and gas, which makes up 90% of the feedstock -Packaging accounts for nearly 40% of all plastic demand in Europe -Bioplastics, which can be bio-based (derived from plants) or degradable (they biodegrade or fragment and may be plant or fossil-based) currently only account for about 1% of global plastic production. -40% of plastic packaging is collected for recycling in Europe (most significantly PET bottles) and a further 31% is recovered by other means such as incineration -The European paper industry as a whole uses 86% renewable raw materials – about 46% is fiber from paper for recycling and 40% is virgin wood pulp – plus about 14% non-fibrous material such as calcium carbonate -90% of the wood used by the European industry comes from within the European Union and 60% of it is third-party certified as coming from well-managed forests -The most common types of carton boards are White Lined Chipboard (WLC) which is mostly made from recycled fiber, Folding Box Board (FBB) which is mostly made from virgin fiber, Solid Bleached Board (SBB) and Solid Unbleached Board (SUB), both of which use virgin fiber. -In Europe, 83% of paper and board packaging (including cartons) is recycled, with a further 7% collected for recovery of some of its value through other means such as incineration -64% of Swedish consumers perceive plastic as the least environmentally friendly packaging material (compared to only 4% for paper/cardboard) -pulp and paper appears to utilize renewable energy (biomass) to a much greater degree. -It is thought that there is a theoretical upper limit to the recycling rate of the paper industry (not just packaging) of about 78% because it is not possible to collect or recycle some (destroyed or contaminated in use - hygiene products, kept for the long term - books) -Plastics are ingested by sea birds, fish and other organisms, and experts warn that some of it is already finding its way into the human food chain
41	Intressentföreningen Packforsk (IFP)	RISE Innventia	BioPackLCA – Closing the gap: Extending LCA to reflect the sustainability contributions of bio-based packaging	scientific (commercial driven)	no	-There is a tendency to assume that bio-based means biodegradable, but this is not the case. -Bio-based does not always mean low carbon. Even if it is generally the case, most materials include other (non-bio) constituents within their make-up. -compared to total emissions for each system considering other end-of life options, emissions from degradation of plastics in the environment (in the form of litter) are relatively small. -Developing a complete and comprehensive environmental impact category for littering that can be used in life cycle assessment is problematic. -omitting the impact of littering disadvantages biobased materials that are inherently compostable and therefore offer a reduced environmental impact with regards to litter. -Using this method, the kraft paper mailer bag has an extremely small primary microplastics generation potential
42	European Environment Agency	European Topic Centre on Resource and Waste Management (ETC/RWM)	Paper and cardboard — recovery or disposal? Review of life cycle assessment and cost-benefit analysis on the recovery and disposal of paper and cardboard	scientific (commercial driven)	no	**LCA studies** -geographical differences are not large enough to result in incineration or landfilling being more favorable. -Generally, the LCA studies analyzed, which were selected from existing literature on the basis of a set of quality criteria, arrive at similar results. -differences are not found primarily to be due to actual differences in the environmental impacts from the paper systems studied, but rather to differences in the way the LCA methodology is applied (definition of the paper system and its boundaries) **CBA studies** -half of the conclusions find that recycling is the preferred waste management option. -If the time cost is excluded, the preference for recycling becomes more explicit.
43	science	IESE - Universidad de Navarra	Análisis del impacto económico y medioambiental de las industrias de embalajes de Cartón Ondulado versus Plástico Reutilizable	scientific (commercial driven)	no	-the analysis carried here compares the impact of the production and use of (equivalent) corrugated cardboard boxes and reusable plastic crates. This focus differs from that of other studies with an input-output model that compare emission of CO2 per euro of end product manufactured.
44	Beverage industry	Rehrig Pacific Co. white paper highlights strategies to reduce loss | 2015-08-31 | Beverage Industry (bevindustry.com)	Rehrig Pacific Co. white paper highlights strategies to reduce loss	commercial	no	-In the bakery industry, it is estimated that 30 percent of trays are lost to theft each year. - 20 million to 25 million milk crates go missing, mainly from theft
45	American bakers association	Reusable Plastic Tray Theft | American Bakers Association	REUSABLE PLASTIC TRAY THEFT	commercial	no	-The cyclical delivery process becomes interrupted when reusable plastic trays are misused or stolen. -Some companies try to evade capital expenditure costs by stealing other companies' reusable plastic trays -The retailer uses the reusable plastic trays for a different purpose than is intended -It is estimated that companies in the industry lose 30 percent of its reusable plastic trays and spend well over $10 million annually in replacement costs. - Reusable plastic trays can positively impact production, warehousing, distribution, quality, safety, order selection, and retail delivery costs. -Today's supply chains are under constant pressure to mitigate the negative effects of contamination.

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46	Expert interview #2	-	Interview on 13.09.2021	expert interview	-	-different regulations in different countries (e.g., percentage of recycled material for direct food contact -> recycled test not used for fresh product packaging) -different regulations means the composition of boxes is different -important hotspot: mileage and fitting (transported air -> empty spaces) -CPR (Italian pooler) says 6% of plastic crates are lost on average and they work with high number of rotations (4 in 10 years) but there are few washing centers -an advantage of paper packaging is the possibility of customize with a brand -> only printing on the external layer so the impact of deinking is lower -in EU the average transport distance (for fruits and vegetables) is 700 km -> after 650 km cardboard becomes more sustainable -sustainable management of forests (green certification) -recycled material used in production is between 80/90% -fruit and vegetables are produced by small companies -> too many variables -washing for plastic crates is not carried out if they transport packaged vegetables ready to eaten -no regulation about hygienic requirements (only a German one that consider only temperature) -recycling for cardboard in Italy is 90% -for cardboard you can define the weight of the packaging based on the product to be transported (economic gain) -on average boxes are filled with 8 kg of product because it's difficult to fill them more (watermelons and citruses can reach 14 kg)
47	Expert interview #3	-	Interview on 1.10.2021	expert interview	-	-it's difficult to reduce void space because of secondary packaging -the cost is higher if the weight of the product is higher, not because of increased volume -organized shipment (shipment of only one kind of product) can reduce the void space -cross border regulations are not a problem because distribution centers are inside each country -possible damage due to too many washing for reusable -some properties (mechanical and aesthetic) can change due to the weather (plastic can become brittle due to freezing) -packaging protection can be increased by using additional packaging -recycling rate depends on consumer behavior -use of primary packaging can help reach hygienic requirements for reusable crates
48	Expert interview #4	-	Interview on 14.10.2021	expert interview	-	-impossibility to control what happens to packaging after use -> consumer behavior -plastic is more flexible so it can be reused more easily -paper is easier to recycle -customer perception of sustainability is important (brown is perceived as more sustainable -need to investigate return system -cost drivers for transportation are volume/dimensions -Repack sends reusable packaging to Estonia to be cleaned (not very sustainable) -easy to use design, auto-sealing -cardboard can be sent back for a discount -real number of uses seems too high (too fast in coming back, not very convincing) -product loss is generally due to incorrect address on packaging -Service provider doesn't provide storage for returnable packaging during idling -to reduce void space a fee is charged to a customer if the package is always too big -repackaging is done only if the package is opened for inspection in sorting centers (addition of only tape for sealing) -some clients repack items for the same customer increasing the amount of secondary packaging

SOURCE RANKING TABLE

Source ID / Quality criterion	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Source category (scientific OR commercial OR expert interview)	2	2	1	1	2	2	2	2	2	2	2	1	0	0	2	0	0	0	0	0	1	0	0	0	1	0	0	2	0	0	0	0	0	2	2	2	1	0	1	1	1	1	1	0	0	1	1	1
Geographical reference	2	2	0	2	2	2	2	1	2	2	0	2	1	1	1	1	1	0	0	2	1	0	0	2	2	2	0	0	0	0	1	0	0	2	0	0	1	1	2	1	1	1	2	0	0	2	2	2
Time reference	1	2	1	2	2	2	2	2	1	2	2	1	2	2	2	0	2	2	2	2	2	2	2	0	0	2	2	2	1	2	2	2	2	2	0	1	2	0	0	2	2	0	0	1	2	2	2	2
Supply chain (stage)	1	2	0	2	2	2	2	2	2	2	2	1	2	0	0	1	1	1	0	0	2	2	0	0	2	2	2	1	1	0	0	2	2	2	2	1	0	0	1	2	0	0	0	1	1	1	1	1
Core segment: e-commerce?	0	0	0	2	2	0	0	0	0	2	2	1	2	2	2	0	2	0	1	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	2	0	0	0	0	1	1	2
Core goods: small personal and household items?	0	0	0	2	2	1	0	0	0	0	0	0	2	1	1	0	2	2	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	2
Core alternatives	0	2	1	2	2	2	0	2	2	2	0	0	0	0	0	2	2	0	0	2	2	0	2	2	2	0	0	2	0	0	2	0	0	2	0	0	0	0	2	2	2	0	2	0	0	0	0	2
Core: Domain	1	0	0	2	1	1	2	2	1	2	2	0	2	2	2	2	2	2	2	2	2	0	2	2	2	2	2	0	0	0	2	2	2	2	2	0	2	1	0	0	0	0	0	0	0	0	0	2
Environmental hotspots?	2	2	0	2	2	2	2	2	2	2	2	1	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	2	2	2	2	2	0	0	2	2	2
Economic hotspots?	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	2	2	2	1	0	2	2	2	2	0	1	1
Social hotspots?	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	2	2	2	0	0	0	2	0	0	1	0	0	0	0	0	0	1	1
Final ranking	**9**	**12**	**3**	**17**	**17**	**14**	**12**	**13**	**12**	**16**	**12**	**9**	**13**	**10**	**13**	**8**	**15**	**9**	**7**	**15**	**12**	**7**	**9**	**9**	**11**	**11**	**10**	**9**	**4**	**4**	**13**	**10**	**10**	**14**	**8**	**6**	**16**	**4**	**10**	**12**	**10**	**6**	**9**	**4**	**5**	**9**	**12**	**18**

HOTSPOT FINAL SCORES

Number	Hotspot	Category	Description	Absolute weighted score
I	Situation (financial, commercial)	Bureaucratic aspects	E.g., Pre-covid19 and post-covid19 are very different scenarios	33
II	Empty space	Physical characteristics	Octagonal shape	57
III	Logistics parameters	Logistics	For return packages (storage space, distance, number of packages for each delivery, sorting)	158
IV	Tamper-evident technology	Physical characteristics	-	31
V	Legal aspects related to EU/states cross-border transportation	Bureaucratic aspects	-	47
VI	Packaging shape	Physical characteristics	Volume for food, e.g., Apples, is precise, and it is known from the beginning) - amazon dictates the shape for returnable packages (square) different available sizes	83
VII	Requirements of the goods	Type of product	For fresh food, e.g., Humidity, temperature, hygienic requirements (plastic crates may contain plastic bags inside to preserve hygienic requirements), for fragile products additional packaging	62
VIII	Type of the product (e.g., Generally, warehouses do not know the type of products they are going to ship to customers)	Type of product	-> a standardization of packaging system is unrealistic when completely different products should be packed together	26
IX	Contamination of the containers	Type of product	-	46
X	Lack of information for parametrization on the e-commerce supply chain	Logistics	-	0
XI	Real number of uses for MU solutions	Characteristics of using MU solutions	It could be different from the producer specifications	181
XII	Percentage of recycled material used in production	Physical characteristics	-	116
XIII	Weight optimization	Physical characteristics	For MU solutions it lowers emission from transport	56
XIV	Return rate	Characteristics of using MU solutions	If low, emissions increase	73
XV	Energy and water heating consumption for washing	Energy	Possible lack of data, washing at home can be more energy consuming, backhauling could be energy consuming, optimization of water use, washing not always performed	48
XVI	Customer awareness about green packaging and packaging issues related to environmental preservation	Social aspects	-	66
XVII	Quantity of material used for packaging	Physical characteristics	-	86
XVIII	Returned goods	Type of product	Returned goods need to be treated before they are put again on the market or they are discarded	23
XIX	Emission due to product delivery	Environmental aspects	-	10
XX	Reduction of pollution and traffic in urban areas due to home delivery	Environmental aspects	-	52
XXI	Incorrect recycling info provided by manufacturers	Social aspects	-	13
XXII	Greenwashing practices	Social aspects	-	13
XXIII	Limit for recycling	Physical characteristics	Material can suffer degradation after recycling, presence of contaminants (e.g., Ink, labels)	58
XXIV	Customer perception of quality based on packaging design	Social aspects	-	31
XXV	Higher cost of some eco-friendly packaging	Economic aspects	-	13
XXVI	Waste generation	Environmental aspects	-	76
XXVII	Sustainable use of resources	Energy	E.g., Forest for paper production, renewable energy use share	39
XXVIII	Efficient energy and water management in facilities	Energy	Also share of renewables used	40
XXIX	Tracking systems	Logistics	E.g., RFID	39
XXX	Number of recycling/composting/washing facilities available	Logistics	Long trips to reach them	85
XXXI	Physical limit to number of washings	Characteristics of using MU solutions	Degradation of material due to chemicals	23
XXXII	Economic evaluation of convenience of using MU solutions	Economic aspects	-	37
XXXIII	Product design used to increase selling	Social aspects	-	45
XXXIV	Trial period to test product	Economic aspects	-	10
XXXV	Application of specific taxes/discounts	Bureaucratic aspects	Fee for use of MU solutions could discourage customers, taxes on single use items to discourage use. Discounts can be applied if packaging is sent back (cardboard)	28
XXXVI	Littering	Environmental aspects	-	20
XXXVII	Coordinated system to re-distribute containers among shops	Characteristics of using MU solutions	-	10
XXXVIII	Emissions and use of resources due to recycling	Environmental aspects	-	10
XXXIX	Legal aspect related to recycled content for food contact packaging	Bureaucratic aspects	-	36
XL	Warehouse automatic system for higher worker safety	Social aspects	-	13
XLI	Use of renewable sources for material production	Energy	E.g., Plant, fibres	33
XLII	Accounting of scope 3 emissions	Energy	-	10
XLIII	Require code of conduct from suppliers	Social aspects	-	10
XLIV	Decrease in use of VOC producing materials	Environmental aspects	E.g., Solvent free ink	10
XLV	Impossibility of using only MU solutions	Social aspects	-	14
XLVI	Reduction of land use for e-shops	Environmental aspects	-	16
XLVII	Generation of satellite job	Social aspects	-	34
XLVIII	Additional items for continuous availability	Logistics	-	4

Number	Hotspot	Category	Description	Absolute weighted score
XLIX	Legal aspects related to EU regulation	Bureaucratic aspects	(hygiene, backtracking, ...)	4
L	Ability of preserving the product from damage	Physical characteristics	-	8
LI	Theft/misuse/loss	Economic aspects	Loss is generally due to wrong address on packaging	27

TOP 5 RANKING HOTSPOTS

Details of overall ranking for hotspot "REAL NUMBER OF USES"				
Source ID	**Source**	**Type of packaging solution**	**Ranking of the source**	**Claim**
48	Expert interview #4	cardboard packaging vs polybags	18	Reportedly, real number of uses for polybags (MU) has never been studied. Data disclosed by producers appears unrealistically high; reportedly disclosed data implies too fast return system.
10	Zimmermann et al. (2020)	cardboard boxes, SU LDPE bags, MU PP boxes, MU PP bags	16	Breakeven point (real number of uses) is a decisive parameter for measure environmental performances of MU solution. The comparative analysis of SU and MU shipping packaging systems has shown that the MU solutions are environmentally advantageous, provided that a certain number of cycles is achieved (for PP vs cardboard boxes 81 cycles if cardboard boxes produced with recycled material, 61 if produced with primary material.
17	Repack	MU plastic bag vs SU cardboard and plastic packaging	15	The MU plastic bags are made to last at least 20 cycles. However, no official data about real number of uses has been disclosed.
20	Pieter Pot	MU glass containers vs paper and plastic SU containers	15	In this study the CO2 footprint of glass preserving jars and that of three categories of one-way packaging is presented. The main advantage of MU solution lies in the possibility of using containers more than once (real number of uses).
8	Del Borghi et al. (2020)	MU plastic crates vs cardboard and wooden boxes	13	Real number of uses is a decisive parameter for measure environmental performances of MU solution. The environmental impacts result lower for multiuse plastic crate due to its possibility of being reused during its lifetime, avoiding the high impacts of the manufacturing.
21	CupClub	PP MU cups vs SU paper cup (PE lined)/SU PLA cup/SU EPS cup/SU ceramic cup	12	Real number of uses is a decisive parameter for measure environmental performances of MU solution. All the environmental impacts of CupClub's 12oz cup and lid over 132 uses including washing, drying and recycling were lower than using 132 PLA lined 12oz paper cups and PLA lids at 1% recycling rate.
25	Österreichisches Ökologie-Institut, Carbotech AG and Öko-Institut e.V. Deutschland	MU vs SU cups	11	Real number of uses for MU solutions has never been studied. Since this is a decisive parameter for measure environmental performances of MU solution, two cases have been considered in this study: worst case considering circulation cycles equal to 60 and average value for circulation cycles equal to 170.
26	Borealis	MU cup made of resins and PP	11	Breakeven point (real number of uses) is a decisive parameter for measure environmental performances of MU solution. Shrewsbury Cups breakeven after just three uses.
18	Plaine Products	aluminum bottles	9	We package our products in aluminum bottles that are strong enough to survive a number of trips. However, no official data about real number of uses has been disclosed.
23	Heineken	MU cups (PP, composite, tritan, PC, steel cups) vs SU cups (r-PP, PP, r-PET, paper, PET, PLA, PS(GPPS) cups)	9	Breakeven point (real number of uses) is a decisive parameter for measure environmental performances of MU solution. A MU cup requires at least 10 uses to outperform a SU cup.
24	Green Globlet	MU cups (plastic, steel) vs SU cups (paper, plastic)	9	Breakeven point (real number of uses) is a decisive parameter for measure environmental performances of MU solution. A MU cup has a lower environmental impact than a SU cup after less than 3 uses.
28	Liviri Fresh (otter products) by thinkstep	Liviri Fresh cooler (MU) vs corrugated cooler (SU)	9	Otter Products' Liviri Fresh is a MU vacuum insulated panel (VIP) cooler. However, no official data about real number of uses has been disclosed.
46	Expert interview #2	cardboard boxes	9	Breakeven point (real number of uses) is a decisive parameter for measure environmental performances of MU solution. CPR (Italian pooler) says 6% of plastic crates are lost on average and they work with high number of rotations (4 in 10 years) but there are few washing centers.
16	WRAP program	MU plastic bag vs cardboard boxes (slightly mentioned)	8	The trial identified the variables that will determine its commercial viability which include the number of reuses of Carrierpac that can be achieved. However, no official data about real number of uses has been disclosed.
19	Just Salad	paragraph mentioning substitution of plastic cups with paper cups	7	Breakeven point (real number of uses) is a decisive parameter for measure environmental performances of MU solution. Breakeven point for the MU bowl is 3 when compared to PET SU bowl.
36	Goellner-Sparrow2014	"vacuum-insulated-panel (VIP) + phase-change-media-based (PCM) heat sinks packaging vs polystyrene (EPS) or polyurethane	6	Breakeven point (real number of uses) is a decisive parameter for measure environmental performances of MU solution. The environmental break-even point between the two logistical approaches occurs after as few as six shipments for PCOP and as many as 17 shipments for HTP emissions.
30	IFCO	(PUR) insulation + gel pack heat sinks packaging"	4	Real number of uses is a decisive parameter for measure environmental performances of MU solution. Using IFCO MU plastic containers (RPCs) instead of SU packaging means a significant reduction in CO2 because of possibility of reusing them. Each container is used between 30 – 120 times.

Details of overall ranking for hotspot "LOGISTIC PARAMETERS"				
Source ID	**Source**	**Focus option**	**Ranking of the source**	**Claim**
48	Expert interview #4	cardboard packaging vs polybags	18	Reportedly, Repack sends MU packaging to distant facilities to be cleaned. This is probably due to internal procedures. However, this choice could lead to a reduction of the environmental performance of their packaging solutions.
37	Oliver Wyman	N/A	16	Transport distance is a significant parameter in the evaluation of environmental performances. Increasing distances between fulfilment centers and consumptions areas are increasing the CO2e impact of transportation
20	Pieter Pot	MU glass containers vs paper and plastic SU containers	15	Transport distance is a significant parameter in the evaluation of the environmental performances of different solutions. To compare their carbon footprint, the same delivery profile is set for all packaging types.
6	Rigamonti et al. (2018)	Both corrugated paper board and MU plastic	14	The need for storage space for spare packaging is a logistic parameter that can be considered when evaluating environmental performances. For each type of packaging, one should collect information about population: the total number (or weight) of items; it can be assumed as the material stock available,
8	Del Borghi et al. (2020)	MU plastic crates vs cardboard and wooden boxes	13	Transport distance is a significant parameter in the evaluation of environmental performances. The SU network involves the manufacturing processes and the transportation activities from the crate production plant to the filling center, from the filling center to the distribution center, from the distribution center to customers and finally from the latter to the disposal/treatment plant.
11	Su et al. (2020)	express delivery packaging materials unit (different materials used)	12	Since the data of transportation distance, the vehicles used, and the energy consumed is difficult to obtain and may be inaccurate, logistics and transportation of express delivery (packaging materials) are also not considered in this study.
47	Expert interview #3	cardboard boxes	12	Transport distance is a significant parameter in the evaluation of environmental performances. Reportedly, distribution centers are inside each country
1	Svenka Retoursystem	crates (plastic pallets)	9	Logistic parameters are significant parameters in the evaluation of environmental performances thus information on storage space, peak variations and reverse logistic is required.
18	Plaine Products	aluminum bottles	9	Transport distance is a significant parameter in the evaluation of environmental performances. Aluminum bottles are used multiple times thus information about transport distances is required.
28	Liviri Fresh (otter products) by thinkstep	Liviri Fresh cooler (MU) vs corrugated cooler (SU)	9	Transport distance is a significant parameter in the evaluation of environmental performances. Liviri Fresh system advantages are due to raw materials and manufacturing can be allocated across its many use cycles (a benefit that cannot be offset by its increased transportation mileage)
46	Expert interview #2	cardboard boxes	9	Transport distance and fitting (transported empty spaces) are significant parameters in the evaluation of environmental performances.
16	WRAP program	MU plastic bag vs cardboard boxes (slightly mentioned)	8	Transport distance is a significant parameter in the evaluation of environmental performances. The impact of increased delivery mileage arising from replacing products damaged in transit could impact on the environmental performance of a solution.
36	Goellner-Sparrow2014	vacuum-insulated-panel (VIP) + phase-change-media-based (PCM) heat sinks packaging vs polystyrene (EPS) or polyurethane (PUR) insulation + gel pack heat sinks packaging	6	Logistic parameters are significant parameters in the evaluation of environmental performances. The MU logistical approach has shown to impose a significantly smaller environmental burden in all impact categories of interest. A sensitivity analysis has shown some leeway in the degree of the environmental advantage of the MU solution, but it confirms the conclusion as no case proved otherwise.
29	RIPA (Reusable Industrial Packaging Association)	IBC (PE+steel), steel drum, plastic drum (HDPE), multitank (HDPE container)	4	Transport distance is a significant parameter in the evaluation of environmental performances. The manufactured (both new and reconditioned) drums and IBC need to be transported to the client. The outbound transport is set at 200 miles, the truck load is set equal to the truckload of the inbound transport.
38	EKUPAC	only plastic solutions	4	Logistic parameters like reduction empty drive and decentralized storage are significant parameters in the evaluation of environmental performances

Details of overall ranking for hotspot "PERCENTAGE OF RECYCLED MATERIAL USED IN PRODUCTION"				
Source ID	**Source**	**Focus option**	**Ranking of the source**	**Claim**
48	Expert interview #4	cardboard packaging vs polybags	18	The percentage of recycled material used for producing packaging is a parameter that could influence the environmental performance of a solution. Reportedly cardboard packaging is made of 70% recycled material.
10	Zimmermann et al. (2020)	cardboard boxes, SU LDPE bags, MU PP boxes, MU PP bags	16	A relevant improvement in environmental performance can be achieved by using recycled plastics
8	Del Borghi et al. (2020)	MU plastic crates vs cardboard and wooden boxes	13	The use of recycled plastic materials for food packaging is regulated by Regulation EC 282/2008 and considering the Italian legislation in particular, plastic materials obtained from scrap or after use phase cannot be used to produce objects into direct contact with food, but recycled plastics can be used if a barrier material is inserted, avoiding the direct contact to food. Anyway, the recycled plastic materials are generally used to produce objects, also crates, not into contact with food.
13	Fashion for good (2019)	polybags	13	Even though the plastic currently used for packaging – LDPE (low density polyethylene) is technically recyclable, the recycling rate could be much better, and contaminants such as ink and paper limit the use of the recycled material in many products. Incorporating recycled content is feasible and getting more feasible. Doing this will support the recycling value chain, and replace virgin, fossil based LDPE with a lower carbon alternative.
11	Su et al. (2020)	express delivery packaging materials unit (different materials used)	12	No data on fraction of recycled material used in production is disclosed even if green packaging and recycling strategies are discussed.
33	huhtamaki	paper recyclable food packaging	10	The percentage of recycled material used for producing packaging is a parameter that could influence the environmental performance of a solution. Reportedly more than 98% of all fiber was sourced from recycled or certified sustainable sources.
18	Plaine Products	aluminum bottles	9	The percentage of recycled material used for producing packaging is a parameter that could influence the environmental performance of a solution. Reportedly Plaine Products' new partner uses 100% recycled materials
46	Expert interview #2	cardboard boxes	9	The percentage of recycled material used for producing packaging is a parameter that could influence the environmental performance of a solution. Reportedly recycled material used in production is between 80-90%
36	Goellner-Sparrow2014	vacuum-insulated-panel (VIP) + phase-change-media-based (PCM) heat sinks packaging vs polystyrene (EPS) or polyurethane (PUR) insulation + gel pack heat sinks packaging	6	No data on fraction of recycled material used in production is disclosed even if recycling is discussed.
42	European Topic Centre on Resource and Waste Management (ETC/RWM)	paper and cardboard	6	The percentage of recycled material used for producing packaging is a parameter that could influence the environmental performance of a solution. Reportedly recovered paper and virgin paper do not have the same quality/functionality. This implies that a higher mass has to be used per functional unit, when the paper has a high content of recycled fibre than a low content.
29	RIPA (Reusable Industrial Packaging Association)	IBC (PE+steel), steel drum, plastic drum (HDPE), multitank (HDPE container)	4	The percentage of recycled material used for producing packaging is a parameter that could influence the environmental performance of a solution. The recycled content of steel is set at the amount of steel that is recycled at the end of life.

Details of overall ranking for hotspot "QUANTITY OF MATERIAL USED FOR PACKAGING"				
Source ID	**Source**	**Focus option**	**Ranking of the source**	**Claim**
48	Expert interview #4	cardboard packaging vs polybags	18	The amount of material used for packaging could impact the environmental performance of packaging. Some clients repack items for the same customer increasing the amount of secondary packaging
13	Fashion for good (2019)	polybags	13	Brands say their sustainability priorities for polybag packaging are the end of use management (and recyclability) of the waste, a reduction in the amount of plastics used and the lowering of its carbon impact.
15	Escursell (2020)	only slight mention of cardboard	13	Package weight and volume are significant parameters in the evaluation of environmental performance because they influence energy use for transport.
11	Su et al. (2020)	express delivery packaging materials unit (different materials used)	12	It is urgent to encourage express delivery companies and the public to choose simple and green packaging instead of blindly pursuing 'layers and layers' of EDPM.
14	Ecommerce Europe	NA	10	Zalando implemented the "one parcel policy" to reduce parcel volume
18	Plaine Products	aluminum bottles	9	In addition to reusing our bottles, we don't send extra pumps and there's no plastic fill in our boxes.
19	Just Salad	paragraph mentioning substitution of plastic cups with paper cups	7	Saving of natural resources by reducing the size of delivery bags. Reduction of packaging related emission by eliminating plastic pouches and providing SU utensils only if required by customers
38	EKUPAC	only plastic solutions	4	Optimized packaging format with regard to logistics module sizes and sales quantities

Details of overall ranking for hotspot "NUMBER OF RECYCLING/COMPOSTING/WASHING FACILITIES AVAILABLE"				
Source ID	**Source**	**Focus option**	**Ranking of the source**	**Claim**
48	Expert interview #4	cardboard packaging vs polybags	18	The limited number of available facilities for washing could impact the environmental performance of packaging. Reportedly Repack sends MU packaging to distant facilities (foreign country) to be cleaned. However, this choice could lead to a reduction of the environmental performance of their packaging solutions.
13	Fashion for good (2019)	polybags	13	Compostable materials are interesting for many brands but the infrastructure to actually collect and then compost these materials is currently lacking in most places.
21	CupClub	PP MU cups vs SU paper cup (PE lined)/SU PLA cup/SU EPS cup/MU ceramic cup	12	Increasing the distance, the cups and lids are transported for washing and drying by tenfold would only increase the overall impact by up to 2%
47	Expert interview #3	cardboard boxes	12	Reportedly presence of sorting/recycling/collecting facilities varies among European countries, and it can impact on environmental performances.
23	Heineken	MU cups (PP, composite, tritan, PC, steel cups) vs SU cups (r-PP, PP, r-PET, paper, PET, PLA, PS(GPPS) cups)	9	The limited number of available facilities for washing could impact the environmental performance of packaging thus, the challenge lies in increasing the rate for material collection after consumer use
46	Expert interview #2	cardboard boxes	9	Reportedly a limited number of washing facilities is in place so far. It can have an impact on the correct functioning of MU solution and its environmental performance.
35	Ross-Evans_2003	EPS + PE vs EPS/HIPS + PS packaging	8	This study has also indicated that the energy consumed during transportation is negligible when compared to the overall energy consumption of the system. This is true even with the additional transport needs of the recycling and reuse steps. This is important, because transport emissions are often cited as a reason for not pursuing recycling possibilities.
29	RIPA (Reusable Industrial Packaging Association)	IBC (PE+steel), steel drum, plastic drum (HDPE), multitank (HDPE container)	4	The drums and IBC's are collected by truck and transported to a reconditioning facility. There, they are reconditioned as explained above and sold to customers again.