THE
TRANSDISCIPLINARY
JOURNAL

GAIA

3 | 2020

ECOLOGICAL PERSPECTIVES FOR SCIENCE AND SOCIETY
ÖKOLOGISCHE PERSPEKTIVEN FÜR WISSENSCHAFT UND GESELLSCHAFT

- MOBILITÄT, SUFFIZIENZ UND SPRACHE
- KOSTENWAHRHEIT IN DER KLIMAPOLITIK
- REFLECTING ON TRANSDISCIPLINARITY WITH *I2S*

oekom verlag

GAIA is available online at *www.ingentaconnect.com/content/oekom/gaia*
www.oekom.de | B 54649 | ISSN print 0940-5550, online 2625-5413
GAIAEA 29/3, 137–208 (2020)

Single-use vs. reusable packaging in e-commerce: comparing carbon footprints and identifying break-even points

The market share of online retail has continued to grow over the past few years, most recently accelerated by the COVID-19 pandemic. Individual shipments give rise to additional shipping packaging. Our carbon footprint comparison shows that reusable packaging is environmentally advantageous if it is reused often enough. To achieve this, however, political and economic incentives seem necessary.

Till Zimmermann, Rebecca Bliklen

Single-use vs. reusable packaging in e-commerce: comparing carbon footprints and identifying break-even points
GAIA 29/3 (2020): 176–183

Abstract
In Germany, the revenue of e-commerce amounted to over 68 billion euros in 2018 with over two billion shipments being delivered. Up to 30 percent of online retail's carbon footprint comes from the use of shipping packaging. Reusable packaging could make a significant contribution to resource savings and waste avoidance. Few valid findings exist as to the environmental performance of reusable packaging systems in online retail. It is also difficult to ascertain which factors influence these results most (such as material, weight, number of cycles). Against this backdrop, we examined two types of reusable shipping packaging in terms of their CO_{2eq} emissions: a reusable PP box and a reusable shipping bag. Both were then compared with single-use alternatives. Compared to a single-use LDPE bag, the reusable shipping bag offered an environmental advantage after a few cycles, with the absolute carbon footprint of both bags depending on whether recycled material was used. For the reusable PP box, the break-even point was between 32 and 81 cycles, depending on which assumptions were made. For a broader application of reusable shipping packaging, further challenges arise, such as the cost-efficient design of return logistics or the optimization of the packaging design.

Keywords
carbon footprint, e-commerce, packaging waste, reusable packaging

Dr. Till Zimmermann | zimmermann@oekopol.de
https://orcid.org/0000-0002-5330-7255

Rebecca Bliklen, MSc | r.bliklen@bfgroup.org

both: Ökopol Institute for Environmental Strategies | Nernstweg 32–34 | 22765 Hamburg | Germany | +49 40 3910020

https://doi.org/10.14512/gaia.29.3.8
Submitted March 22, 2020; revised version accepted September 23, 2020 (double-blind peer review).

E-commerce gives rise to additional packaging

In Germany, the revenue of online retail (e-commerce) amounted to 68.1 billion euros in 2018, with constant but slightly declining growth (BEVH 2019). The share of total retail sales generated online also shows steady growth and amounted to 10.8 percent in 2018 (compared to 7.8 percent in 2014); for the non-food sector it was around 15 percent (HDE 2019). This results in significantly increasing deliveries via courier, express and parcel services: from 2014 to 2018 the number of consignments in this sector increased by 740 million to over 3.5 billion, which represents a growth of 27 percent (BIEK 2019).

With 31 percent of their total trading volume, electrical and electronic products are particularly frequently ordered online, followed by clothing (fashion and accessories) and books (27.7 percent each) (HDE 2019). Clothing (19 percent) and electronic goods (18 percent) also account for the largest shares of all online sales.

Further significant growth in online shopping – in Germany, where online transactions have been increased by 60 percent in April 2020 compared to the previous year, as well as in other countries – can be observed as a result of the coronavirus pandemic (EY and WI 2020, McKinsey 2020).

Environmental impacts arise along the process chain of online retail; that is, in the processes of ordering, (shipping) packaging, storage and commissioning, distribution, and transport (including last mile and delivery to the customer). The contribution of each process may vary significantly depending on the product and number of products per purchase, the shipping packaging, the size of the online retailer and the organisation of the logistical processes, the delivery (especially on the last mile), and other characteristics of the individual online purchase.

A broad review of studies (Wiese 2013, DCTI 2015, Edwards et al. 2011, Edwards et al. 2010, Oláh et al. 2019, Hischier 2018, van Loon et al. 2015, Mangiaracina et al. 2015, Gombiner 2011, Kahlenborn et al. 2018, Mottschall 2015, Weber et al. 2008) looking into the environmental impacts of a variety of online purchases as well as publications from online retailers (Zalando 2019, Otto

Group 2019, Tchibo 2016) provides some orientation regarding the contribution of the individual elements to the total online-retail related CO_{2eq} (CO_2 equivalents) emissions which can be considered representative for the majority of cases:

- order/IT-related emissions: << one percent to ten percent (van Loon et al. 2015, Mottschall 2015, Gombiner 2011, Kahlenborn et al. 2018),
- shipping packaging: five percent to 30 percent (Weber et al. 2008, van Loon et al. 2015),
- warehouses and distribution centres: four percent to 15 percent (Otto Group 2019, Tchibo 2016, Zalando 2019, Mangiaracina et al. 2015, Oláh et al. 2019),
- transports to the destination parcel centre: five percent to 20 percent (Edwards et al. 2011, Edwards et al. 2010, Wiese 2013, DCTI 2015, Mangiaracina et al. 2015, Oláh et al. 2019),
- last mile: ten percent to 40 percent (Edwards et al. 2011, Edwards et al. 2010, Wiese 2013, DCTI 2015, Mangiaracina et al. 2015, Oláh et al. 2019).

This review shows that the contribution of shipping packaging, which is used additionally in e-commerce compared to stationary trade, to the total (online) trade-related CO_{2eq} emissions can vary greatly from case to case, but in many cases accounts for a share of about ten to 30 percent. The indication of an average share of packaging in the total emissions is hardly possible on the basis of available data and would also be somewhat meaningless due to the diversity of cases. For example, if ten pairs of socks were supplied in a plastic bag of an appropriate size, the packaging-related emissions share would normally be at the lower end of the range given, whereas if a memory stick was packed in a somewhat oversized cardboard box with additional filling material, this case would be at the upper end of the range given. Irrespective of this, the additional shipping packaging used in online retailing results in considerable resource consumption and waste. The total amount of shipping packaging used in Germany in online retail ("classic" e-commerce and private online sales; including letter service) in 2018 can be estimated at around 830,000 tons of paper and board packaging and 34,000 tons of light packagings (Reitz 2020) which roughly corresponds to 25 million filled 240-litre waste bins.

The reuse of products or packaging makes more efficient use of the environmental resources used in their manufacture (Jepsen et al. 2016, Cooper and Gutowski 2017, Jepsen et al. 2019). This is confirmed by existing life-cycle assessment studies specifically for packaging systems (other than shipping packaging), provided that a certain number of use cycles is achieved (Wood and Sturges of Edge 2010, Franklin Associates 2017, Raugei et al. 2009). However, up to now, there have been hardly any studies specifically for shipping packaging and findings on the specific relevance of package design, transport distance and numbers of cycles are barely available.

Against this background, we carried out a comparative analysis of CO_{2eq} emissions from the use of single-use and reusable shipping packagings. For this purpose, different single-use shipping packagings were compared with suitable reusable alternatives. The modelling of the reusable packagings is based on two currently available systems that are already in use in a small scale.

Comparing shipping packaging options: model and approach

For the comparison of the different shipping packages, the relevant processes of single-use and reusable packaging systems were identified and used to model and calculate the CO_{2eq} emissions. Based on this, a comparative analysis was carried out.

The modelling and the derivation of appropriate assumptions were carried out in coordination with the actors involved in online retail, logistics and packaging production. Supplementary data for the production of the various materials, as well as for energy and transport activities, were taken from life-cycle assessment databases and from studies by various associations.

Figure 1 (p. 178) shows the system boundaries for the reusable packaging system. The processes considered can be divided into manufacturing and reprocessing, transport processes and end-of-life (EoL) treatment. As shown in table 1, the system boundaries for modelling the single-use packaging system differ from figure 1 insofar as no pool management of the packaging with the corresponding transports takes place, but the packaging is always sent to an EoL treatment after it has reached the customer.

For the basic processes such as the provision of fossil fuels and electricity, water supply, transport and disposal by thermal recycling, as well as for the production of packaging, data from various sources were used, most of which relate to the study area of Germany or have a close technological connection to the examined system (Umweltbundesamt 2019 a, b, 2015, Keith 2010, Pro Carton 2019, EPA 2015, Franklin Associates 2018).

>

TABLE 1: Considered processes for single-use and reusable packaging systems.

SINGLE-USE PACKAGING SYSTEM	REUSABLE PACKAGING SYSTEM
production of packaging	
provision and production of basic and auxiliary materials and material resources such as water	
distribution of the packaging from the manufacturer to the goods distribution centre/warehouse	
transport of the packaging from goods distribution centre/warehouse to the customer including the last mile with smaller transport vehicles	
provision of energy sources such as crude oil, natural gas, coal or electricity etc.	
N/A	return of the packaging to the reprocessing facility (pool management)
N/A	reprocessing of the returned packaging
end-of-life treatment of disposed packaging	

Emissions from packaging production can vary significantly depending on the material quality and type (material/polymer type, film or rigid material, primary or recycled material, food contact quality). The possible ranges from different data sources for the production-related CO_{2eq} emissions of polystyrene (PS), polypropylene (PP), polyethylene terephthalate (PET), polyethylene (PE) and linear low, low and high density polyethylene (LLDPE, LDPE, HDPE) are shown in figure 2 (Pro Carton 2019, Keith 2010, Plastics Europe 2005, EPA 2015, Umweltbundesamt 2015, Franklin Associates 2017, 2018). With regard to the figure, it should be noted that flexible (disposable) plastic shipping packaging usually weighs between 20 and 30 grams, while cardboard boxes weigh between 50 and 430 grams, depending on their size.

In addition to the possible effects from using different data sets for the respective polymers, the results of the environmental assessment depend on a number of central parameters. In the following, the central model parameters are briefly explained and their influence on the overall model is described.

Within a reusable system, the rejects, namely, the quantity of reusable packaging that is not kept in the cycle but leaves it as waste, determine the number of cycles that a single reusable packaging can achieve on average. In the event of a high level of rejects, for example, because the reusable packaging is not returned by the customer but is disposed of, the individual packaging achieves on average only a few cycles before it has to be replaced by a new one in order to keep the total quantity in the packaging pool constant. The assumed reject rate is therefore decisive for the average number of cycles of each reusable packaging and thus determines to a large extent the functioning of the reusable system, its resource consumption and environmental balance. For the rejects, two possible levers were used in the model: the rejects from the customer, through incorrect or careless disposal of the reusable packaging instead of return shipment, and the rejects of defective reusable packaging during reprocessing.

In the context of recycling, there is often a reference to recycling quotas or rates, as well as collection rates. In our model these terms are used as following:

- *separate collection rate:* the share of total packaging material that is collected as input to the recycling process;
- *recycling rate:* the share of total packaging material that is recovered as output of the recycling process in the form of recyclate (taking into account material losses during the recycling process).

Capacity utilisation of transport vehicles is another lever for the environmental balance of transport processes. If the vehicles are not fully utilised, the environmental balance of the individual transport processes deteriorates. This can be set separately in the model for each of the transport processes, from packaging production to dispatch to the customer and back to recycling.

In theory, complete utilisation of the transport vehicles can never be achieved mathematically, as part of the route is always covered without load. For example, during transport to the customer, the transport vehicle continuously becomes emptier as the number of packages delivered increases. Thus, the calculation of the average capacity utilisation results in a maximum of 50 percent capacity utilisation for the transport process, assuming that it departs from the parcel centre at full capacity and returns empty.

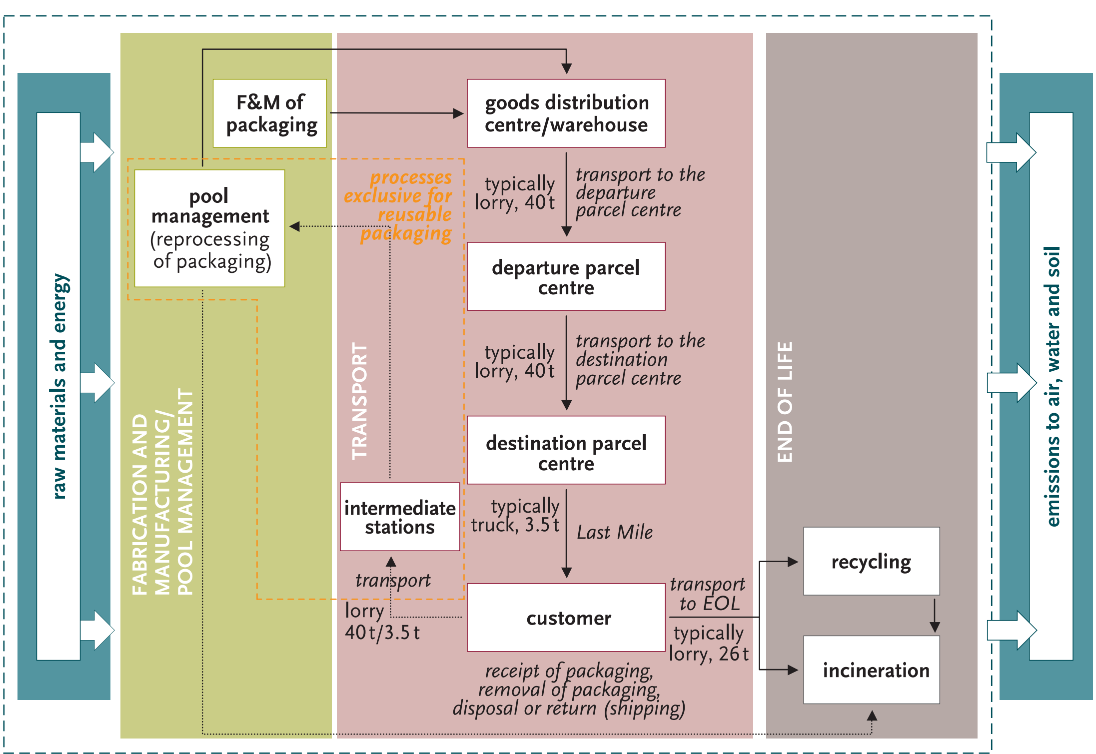

FIGURE 1: Schematic illustration of the system boundaries for the reusable packaging system. F&M: fabrication and manufacturing, EOL: end of life.

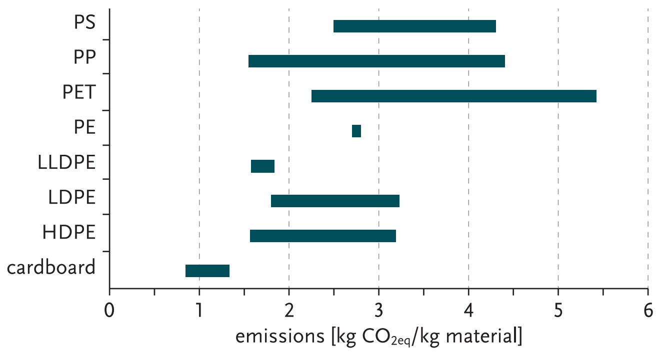

FIGURE 2: Ranges of CO_{2eq} emissions from material production and packaging fabrication and manufacturing. PS: polystyrene, PP: polypropylene, PET: polyethylene terephthalate, PE: polyethylene, LLD: linear low density, LD: low density, HD: high density.

Based on the statistics of the German Federal Motor Transport Authority on the transport of German heavy-duty vehicles in December 2018 for all tours (with and without load), the average utilisation rate of the transport performance ranges from 28.5 percent for 3.5-ton delivery trucks to 41.5 percent for 40-ton lorries (KBA 2018).

Analysing different types of reusable packaging

Two different types of reusable shipping packaging were examined, with their weights and material composition based on reusable packaging available on the market and used in practice. One is a hard plastic (PP) returnable box, the other is a plastic (PP) shipping bag.

A plastic box can be used instead of a cardboard single-use box and has an increased protective function. The *Memo Box,* a reusable box used by a German online retailer as an alternative shipping packaging, serves as a model for the type of material and weight. It is made of polypropylene and weighs 1.7 kilograms. For the return shipment, the box is handed in at a parcel store.

The reusable shipping bag examined is a polypropylene bag weighing 0.118 kilograms. The modelling here is also based on reusable packaging that is actually available and used. Here – for modelling polymer type, weight and transport distances – the *RePack* has been used, a reusable plastic bag which is provided along with a low-threshold return logistic (the empty *RePack* can be returned via any mailbox in the EU).

The central parameters used in the modelling of both reusable packaging types are summarized in table 2. With the exception of the transport to and from reprocessing which is based, in case of the plastic bag, on the distance of Tallinn (location of *RePack* reprocessing facility) to Frankfurt, Germany, and, in case of the box, on the distance from a place in southern Germany (location of the *Memo* reprocessing facility), the transports distances are based on the study by DCTI (2015) and can be considered representative for the situation in Germany.

For both packagings, as no primary data on material and packaging production has been available, calculations with three different emission factors were carried out as part of a sensitivity analysis (Keith 2010, Plastics Europe 2005, EPA 2015).

Results: re-usable plastic box

The greenhouse gas emissions (in CO_{2eq}) per (use) cycle for different numbers of use cycles achieved on average per packaging are shown graphically in figure 3. The average number of use cycles is defined by the average number of deliveries to the customer realized per shipping packaging and the associated processes.

The reduction of emissions per cycle – due to the fact that the emissions associated with the manufacture of the packaging are distributed over the number of uses of the packaging – is clearly evident.

On the other hand, the relevance of emissions associated with transport and reprocessing increases at a higher number of cycles. Furthermore, displayed as a min-max range, the graph shows the influence of the selection of different emission factors for the production of the plastic box on the total emissions.

If only one cycle is achieved, in the case that the packaging is disposed of after a single shipment, a total of 6.8 kilograms CO_{2eq} is generated for all processes from production to transport and disposal. The sensitivity analysis showed a range of 3.3 kilograms CO_{2eq} (EPA 2015) to 8.1 kilograms CO_{2eq} (Plastics Europe 2005). Besides emphasising the importance of achieving a high number of use cycles, this example shows the enormous impact the use of different data sets for the production of the packaging can have on the overall results. Especially for the comparison with other reusable or single-use shipping packaging, the selection of the appropriate data basis, namely, a database that comes as close as possible to the specific product systems under consideration, is therefore important.

>

TABLE 2: Parameters in modelling re-usable packaging.

PARAMETER	PLASTIC BOX	PLASTIC BAG
weight	1700 g	118 g
material	Polypropylene (PP)	Polypropylene (PP)
transport to the goods distribution centre/warehouse	600 km	2000 km
transport to the departure parcel centre	200 km	200 km
transport to the destination parcel centre	50 km	50 km
transport to the customer (last mile)	30 km	30 km
return shipment to reprocessing	600 km	2000 km
transport to disposal	40 km	40 km
transport reprocessing – incineration	100 km	100 km
transport recycling – incineration	100 km	100 km

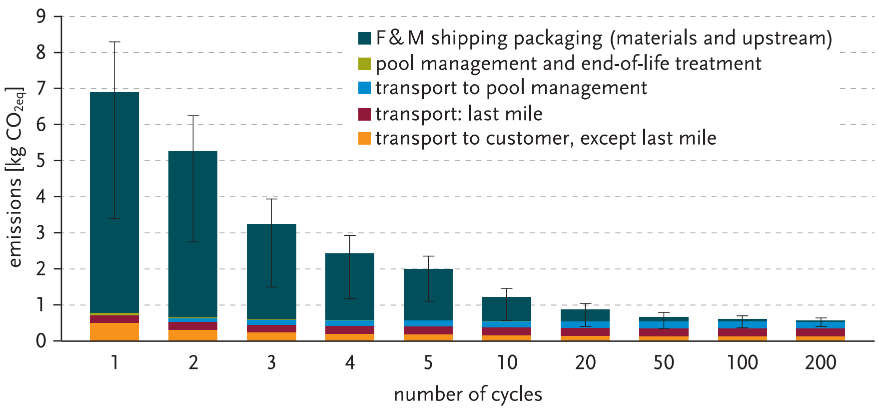

FIGURE 3: Emissions per cycle depending on the number of cycles achieved for a polypropylene (PP) box. The results vary with the emission factors used. F&M: fabrication and manufacturing.

Results: reusable plastic shipping bag

For the reusable plastic shipping bag, the greenhouse gas emissions which are emitted per cycle for different numbers of cycles achieved are shown in figure 4 along with the ranges of emissions resulting from using different emission factors. As with the PP box, the reduction of emissions per cycle is clearly evident.

If only one cycle is achieved, in the case the packaging is disposed of after a single shipment, a total of 0.38 kilograms CO_{2eq} is generated for all processes from production to transport and disposal. The use of alternative data for packaging production in the sensitivity analysis results in a range of 0.29 kilograms CO_{2eq} (EPA 2015) to 0.6 kilograms CO_{2eq} (Plastics Europe 2005).

Due to the long distance to the reprocessing facility, the transport of the shipping bag to the goods distribution centre of the retail trade generates the largest emissions within the transport processes. Transportation to the customer via the "last mile" is also significant, as smaller 3.5-ton transport vehicles which have significantly higher CO_{2eq} emissions per kilometre are used for this transport process.

Comparing reusable and single-use packaging

Our question is under which conditions one or the other system is environmentally advantageous. In order to make a realistic comparison between single-use and reusable packaging, packaging with similar functions and performance must be compared. This concerns in particular a comparable filling volume and product protection.

For the comparison, different common single-use shipping packagings were used with regard to weight, material and filling volume. Shipping bags made of PP and LDPE film are usually used for shipping clothing and are available in different sizes. If they are replaced by reusable packaging, this can be done by a reusable shipping bag. For goods with higher requirements regarding product protection, usually (cardboard) boxes of different sizes are used. These single-use shipping packages were compared with the reusable hard plastic (PP) box, which offers similar product protection.

Comparison of the reusable PP box with single-use cartons

For the comparison of reusable shipping boxes and single-use cartons, the reusable PP box with a volume of 14 litres and a weight of 1700 grams has been compared to a single-use cardboard box, also with a volume of 14 litres and with a weight of 180 grams. For the single-use system, the same transport distances were assumed except for the transport processes of the return shipment, which are not applicable here.

Figure 5 (p. 182) shows the development of the emissions per cycle over the number of cycles achieved for the reusable box and the number of shipments for the single-use box. In the example shown here, the reusable PP box closes the gap with the single-use carton once 81 cycles have been completed and produces fewer emissions than a single-use carton from the 82^{nd} cycle onwards. If an emission factor for primary material rather than for recycled cardboard is assumed for the production of the single-use carton, the reusable PP box reaches a comparable level with the single-use carton after 61 cycles.

For the single-use carton, the same emissions from production, transport and disposal are generated for each shipment. For the reusable PP box, on the other hand, the total amount of emissions is calculated over several cycles from the emissions that occur one-time during the production, transport and disposal of the packaging for the first shipment. The emissions for each further shipment of the box result exclusively from the transport and reprocessing processes under the assumption that no rejects occur and that the same box is reprocessed and reshipped repeatedly.

In order to examine the effects of the use of recycled plastic in the manufacture of the reusable PP box on total emissions, a further scenario was calculated. The use of recycled PP reduces the number of required cycles down to the break-even point of 32 cycles.

Comparison of the reusable shipping bag with single-use shipping packaging

For the comparison of the reusable shipping bag and single-use packagings, a reusable polypropylene film bag with a volume of 21 litres and a weight of 118 grams has been compared to a single-use carton with a volume of 21 litres and a weight of 180 grams and a single-use LDPE shipping bag weighing 30 grams as well as the same shipping bag made of 80 percent post-consumer recycling material (PCR) reflecting available single-use shipping bags which fulfil the *Blue Angel* ecolabel *(Blauer Engel)* requirements.

As shown in figure 6 (p. 182), compared to the carton, the reusable shipping bag performs better from the very first shipment. This is in particular due to the weight of the carton of 180 grams compared to the reusable shipping bag's weight of only 118 grams

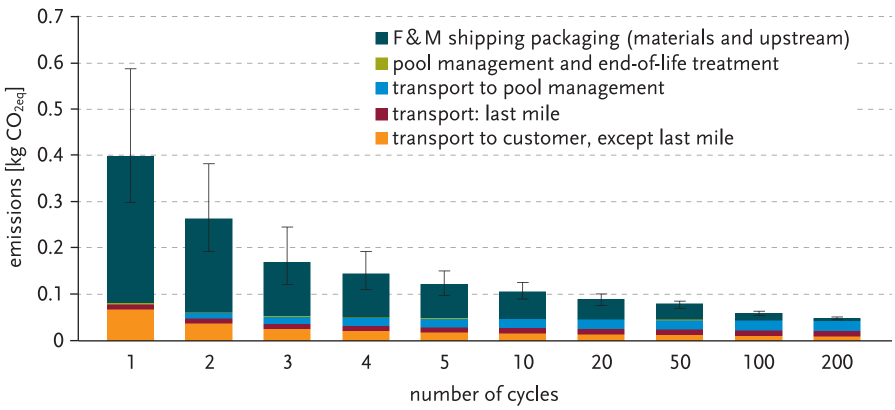

FIGURE 4: Emissions per cycle depending on the number of cycles achieved for a polypropylene (PP) shipping bag. The results vary with the emission factors used. F & M: fabrication and manufacturing.

and the associated higher production and transport emissions. 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.

reusable systems into question. Rather, it means that the reusable packaging system must be designed in a way ensuring a respective number of use cycles. A reusable shipping packaging system that does not achieve a sufficient number of cycles per packaging can mean additional environmental impacts compared to a single-use alternative. Also, for the consideration of real-life cases, primary data should be used wherever possible in order to obtain precise results.

Further improvements in the reusable system – as shown in particular by the example of the hard plastic box – lie in the choice of materials. For example, 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; however, the environmental performance of reusable systems can also be significantly improved through transport optimizations, particularly for packaging systems achieving cycle numbers in the higher two-digit range or even more.

So far, there is no reusable packaging system available for e-commerce that is less expensive than single-use options. In addition to the cost-effective design of return logistics and the use of possible incentive or deposit systems, different approaches to standardising and pooling reusable packaging should also be investigated.

Conclusion: the number of reuse cycles is decisive

In accordance with studies on reusable packaging systems outside the e-commerce sector, 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. Depending on the specific individual case, the accomplishable break-even point can be in the low single-digit range, as in the case of the reusable shipping bag examined here, but in other cases, it can be significantly higher, as in the case of the examined reusable PP box. If optimized single-use packaging is used – for example, LDPE shipping bags made from 80 percent PCR –, this also increases the environmental break-even point for reusable packaging. On the other hand, using PCR for the reusable bag as well would improve its environmental performance to a comparable extent, thus re-lowering the break-even point. Depending on the data basis used for emissions from packaging production and transport, the results may vary. Nevertheless, this does not call the environmental advantages of

From a more technical packaging perspective, realizing a respective number of use cycles is not a problem. The *RePack,* for example, is designed to last at least 20 cycles, which is well above the identified break-even points. The reusable hard plastic box *Memo Box* is designed to realize over 100 use cycles. Experiences made since the introduction of the *Memo Box* in 2009 show that in fact over 100 use cycles are realized.

Despite the technical feasibility of achieving certain numbers of use cycles for reusable packaging and the positive example of the *Memo Box,* in practice there are potential challenges. Most market players who gathered first-hand experiences in using reusable packaging in e-commerce identified the customer as the crucial point: returnable packaging systems can only be successful if the return from the customer to the packaging pool is successful. 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. It is therefore essential to design the system in a way that a high return rate is achieved. So far, only very limited experiences exist in how this can

>

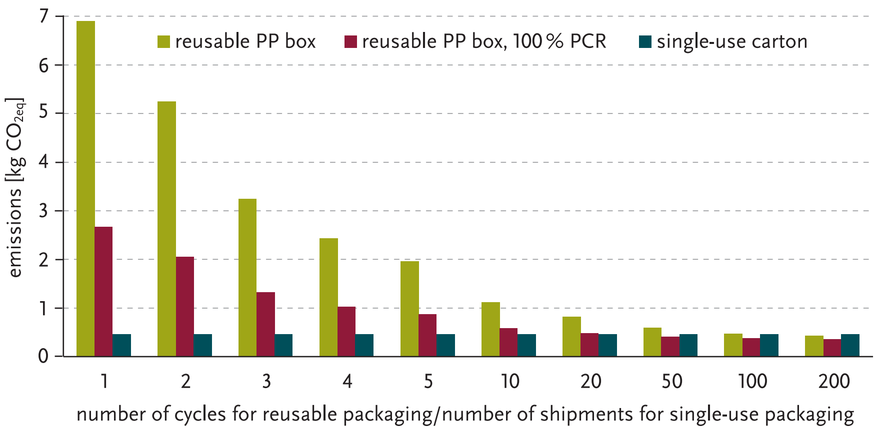

FIGURE 5: Comparison of the greenhouse gas emissions of a single-use carton with the emissions caused by a reusable polypropylene (PP) box and a reusable box made from 100 percent PCR (PP recyclate) per cycle at different achieved cycle numbers.

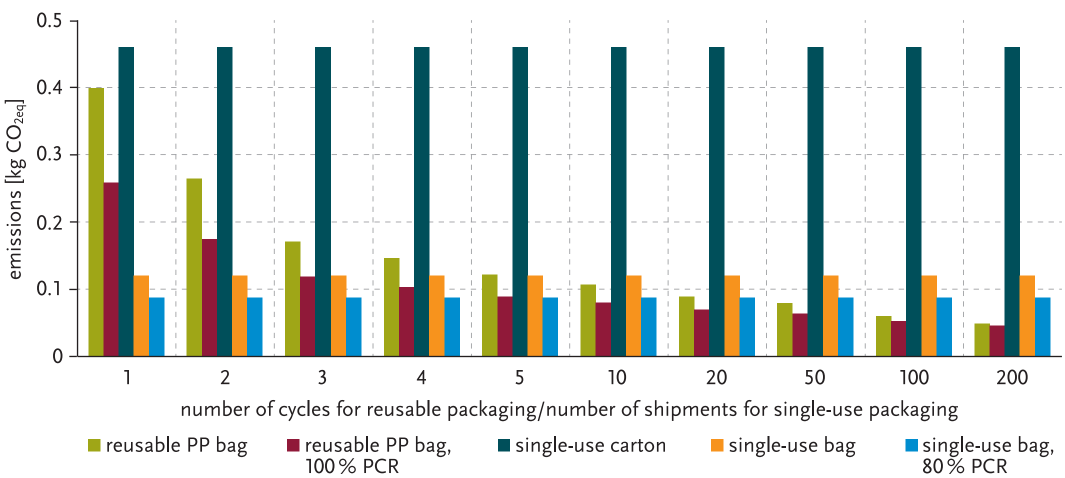

FIGURE 6: Comparison of greenhouse gas emissions per cycle for different packagings and different achieved cycle numbers. PP: polypropylene, PCR: post-consumer recyclate.

be done. The *Memo Box,* as one of the few real-life examples that can look back on a longer period of practical use, relies on a high deposit of 20 euros and actually achieves return rates close to 100 percent, corresponding to numbers of cycles between 60 and 130. However, such an approach is currently not considered to be feasible for the majority of online retailers in view of the competitive situation with high cost and price pressure. While using reusable packaging can have a positive marketing effect, so far, there is no reusable packaging system available which is not more costly than single-use alternatives, regardless of the achieved number of use cycles.

In addition to the cost-efficient design of return logistics and the use of possible incentive or deposit systems, there are further challenges for the players in e-commerce. Examples are the selection of the best-suitable packaging (required protective function, branding options, compatibility with standardised logistics processes, etc.) and the acceptance of possible additional costs (weighing up the costs and – potential marketing – benefits of a reusable packaging system).

While at least some actors in online trade have started to gather findings in this respect in pilot tests (see, e. g., Tchibo 2020), very specific questions arise for future research.

First of all, the cost-efficient design of return logistics is a key challenge that must be met if reusable systems are to be widely used in online retailing. In this context, different approaches to pooling reusable packaging should also be investigated. For a broad pooling of reusable packaging it must also be clarified to what extent branding of the packaging is necessary and desired and to what extent standardized packaging can be established for use by a large number of actors.

In order to achieve a high return rate of packaging, an in-depth analysis of stimulus systems and their effects as well as other possibilities for nudging is required. With regard to a supporting framing of reusable systems, possible legal measures and instruments need to be examined as well.

This work is part of the project *praxPACK* and has been funded by the German Ministry for Research and Education (BMBF; grant number 033R243A).

References

BEVH (Bundesverband E-Commerce und Versandhandel) (Hrsg.). 2019. *Interaktiver Handel in Deutschland: Ergebnisse 2018.* Berlin: BEVH.

BIEK (Bundesverband Paket und Expresslogistik). 2019. *Clever verpackt – effizient zugestellt: KEP-Studie 2019 – Analyse des Marktes in Deutschland.* Berlin: BIEK. www.biek.de/files/biek/downloads/papiere/BIEK_KEP-Studie_2019.pdf (accessed September 25, 2020).

Cooper, D. R., T. G. Gutowski. 2017. The environmental impacts of reuse: A review. *Journal of Industrial Ecology* 21/1: 38–56.

DCTI (Deutsches CleanTech Institut). 2015. *Klimafreundlich einkaufen. Eine vergleichende Betrachtung von Onlinehandel und stationärem Einzelhandel.* Bonn: DCTI. www.dcti.de/fileadmin/pdfs_dcti/DCTI_Studien/Studie_Klimafreundlich_Einkaufen_WEB.pdf (accessed September 25, 2020).

Edwards, J. B., A. C. McKinnon, S. L. Cullinane. 2010. Comparative analysis of the carbon footprints of conventional and online retailing. *International Journal of Physical Distribution and Logistics Management* 40/1–2: 103–123.

Edwards, J., A. McKinnon, S. Cullinane. 2011. Comparative carbon auditing of conventional and online retail supply chains: A review of methodological issues. *Supply Chain Management* 16/1: 57–63.

EPA (United States Environmental Protection Agency). 2015. *Waste reduction model WARM.* www.epa.gov/warm/versions-waste-reduction-model-warm (accessed September 25, 2020).

EY (Ernst & Young), WI (Wuppertal Institut für Klima, Umwelt, Energie). 2020. *Zwischenbilanz COVID-19: Umweltpolitik und Digitalisierung.* www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Digitalisierung/zwischenbilanz_covid19_bf.pdf (accessed September 25, 2020).

Franklin Associates. 2017. *Comparative life cycle assessment of reusable plastic containers and display and non-display ready corrugated containers used for fresh produce applications.* https://cdn0.scrvt.com/f152d078e18222739495b38742ac2b85/cc5a5d129eb3c63b/829b9801e469/IFCO-RPC-Life-Cycle-Assessment_Feb2017_Executive-Summary.pdf (accessed September 25, 2020).

Franklin Associates. 2018. *Life cycle impacts for postconsumer recycled resins: PET, HDPE, and PP.* https://plasticsrecycling.org/images/apr/2018-APR-Recycled-Resin-Report.pdf (accessed September 25, 2020).

Gombiner, J. 2011. Carbon footprinting the internet. *Consilience* 5/1: 119–124.

HDE (Handelsverband Deutschland). 2019. *Online Monitor 2019. Berlin: HDE.* https://einzelhandel.de/publikationen-hde/12177-online-monitor-2019 (accessed September 25, 2020).

Hischier, R. 2018. Car vs. Packaging: A first, simple (environmental) sustainability assessment of our changing shopping behaviour. *Sustainability* 10/9: 3061.

Jepsen, D., L. Spengler, A. Reihlen, A. Vollmer. 2016. *Themenbereich B: Methoden. Themenblock 1: Ökodesign-Prinzipien. B1.1 Langlebigkeit.* Berlin: UBA, BMU. https://www.ecodesignkit.de/fileadmin/user_upload/Dateien/PDFs_Themenpapiere/EcodesignKit_B1_1_Langlebigkeit.pdf (accessed September 27, 2020).

Jepsen, D., T. Zimmermann, L. Rödig. 2019. *Eco Design von Kunststoff-Verpackungen. Der Management-Leitfaden des Runden Tisches.* Bad Homburg: IK Industrievereinigung Kunststoffverpackungen.

Kahlenborn, W., B. Keppner, C. Uhle, S. Richter, T. Jetzke. 2018. *Die Zukunft im Blick: Konsum 4.0: Wie Digitalisierung den Konsum verändert. Trendbericht zur Abschätzung der Umweltwirkungen.* Dessau-Roßlau: Umweltbundesamt.

KBA (Kraftfahrt-Bundesamt). 2018. *Verkehr deutscher Lastkraftfahrzeuge (VD): Gesamtverkehr.* Flensburg: KBA.

Keith, J. 2010. *Methodology for assessing the climate change impacts of packaging optimisation under the Courtauld Commitment Phase 2. Final report.* Banburry, Oxon: Waste and Resource Action Programme.

Mangiaracina, R., G. Marchet, S. Perotti, A. Tumino. 2015. A review of the environmental implications of B2C e-commerce: A logistics perspective. *International Journal of Physical Distribution and Logistics Management* 45/6: 565–591.

McKinsey. 2020. *The great consumer shift: Ten charts that show how US shopping behavior is changing.* www.mckinsey.com/business-functions/marketing-and-sales/our-insights/the-great-consumer-shift-ten-charts-that-show-how-us-shopping-behavior-is-changing# (accessed September 26, 2020).

Mottschall, M. 2015. *Online shoppen oder beim lokalen Händler?* www.oeko.de/aktuelles/2015/online-shoppen-oder-beim-lokalen-haendler (accessed January 16, 2020).

Oláh, J., N. Kitukutha, H. Haddad, M. Pakurár, D. Máté, J. Popp. 2019. Achieving sustainable e-commerce in environmental, social and economic dimensions by taking possible trade-offs. *Sustainability* 11/1: 89.

Otto Group. 2019. *Geschäftsbericht 2018/2019: Hallo Mensch. Wie wir die digitale Zukunft gemeinsam gestalten können.* Hamburg: Otto Group.

Plastics Europe. 2005. *Eco-profiles.* www.plasticseurope.org/en/resources/eco-profiles (accessed September 25, 2020).

Pro Carton. 2019. *The Carbon footprint of carton packaging 2019: Executive summary.* www.procarton.com/wp-content/uploads/2019/10/Carbon-Footprint-Report-2019-Exec-Summary-English-1.pdf (accessed September 26, 2020).

Raugei, M., P. Fullana Palmer, R. Puig Vidal, A. Torres. 2009. Single-use vs reusable transport packaging: A comparative life cycle analysis. *Packaging Technology and Science* 22/8: 443–450.

Reitz, A. 2020. *Versandverpackungen. Bestandsaufnahme von Mengen und Materialdaten. Werkstattpapier, Projekt praxPACK.* www.praxpack.de/fileadmin/user_upload/materialien/praxPACK_Werkstattpapier_Bestandsaufnahme_Versandverpackungen_Mengen.pdf (accessed September 26, 2020).

Tchibo. 2016. *Nachhaltigkeitsbilanz 2015.* Hamburg: Tchibo.

Tchibo. 2020. *Teststart mit Mehrwegversandtaschen bei Tchibo, Otto und Avocadostore.* www.tchibo.com/servlet/content/1326894/-/pid=310330/starteseite-deutsch/presse/presseinformationenpraxpack.html (accessed August 19, 2020).

Umweltbundesamt. 2015. *ProBas – Prozessorientierte Basisdaten für Umweltmanagementsysteme.* www.probas.umweltbundesamt.de/php/index.php (accessed January 21, 2020).

Umweltbundesamt. 2019a. *Emissionskennzahlen Datenbasis 2017: Emissionsfaktoren bezogen auf Personen-/Tonnenkilometer.* Wien.

Umweltbundesamt. 2019b. *Entwicklung der spezifischen Kohlendioxid-Emissionen des deutschen Strommix in den Jahren 1990–2018.* Dessau-Roßlau: Umweltbundesamt. www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-04-10_cc_10-2019_strommix_2019.pdf (accessed September 26, 2020).

van Loon, P., L. Deketele, J. Dewaele, A. McKinnon, C. Rutherford. 2015. A comparative analysis of carbon emissions from online retailing of fast moving consumer goods. *Journal of Cleaner Production* 106: 478–486.

Weber, C. L., C. T. Hendrickson, H. S. Matthews, A. Nagengast, R. Nealer, P. Jaramillo. 2008. Life cycle comparison of traditional retail and e-commerce logistics for electronic products: A case study of buy.com. In: *2009 IEEE International Symposium on Sustainable Systems and Technology.* Phoenix, AZ, May 18–20. DOI: 10.1109/ISSST.2009.5156681.

Wiese, A. 2013. *Sustainability in retailing: Environmental effects of transport processes, shopping trips and related consumer behaviour.* PhD diss., Universität Göttingen.

Wood, G., M. Sturges of Edge. 2010. *Single trip or reusable packaging: Considering the right choice for the environment.* Banburry, Oxon: Waste and Resource Action Programme.

Zalando. 2019. *Geschäftsbericht 2018.* https://corporate.zalando.com/de/investor-relations/publikationen/geschaeftsbericht-2018 (accessed September 26, 2020).

Till Zimmermann
PhD in engineering from the University of Bremen, Germany. Senior researcher at Ökopol Institute for Environmental Strategies in Hamburg, Germany. Leader of various projects in the field of circular economy. Research interests: circular economy and industrial ecology.

Rebecca Bliklen
MSc in environmental science and technology (Technischer Umweltschutz) from Technische Universität Berlin, Germany. Researcher at Ökopol Institute for Environmental Strategies in Hamburg, Germany, until January 2020. Since February 2020 consultant for international waste management at BlackForest Solutions GmbH in Berlin. Research interests: circular economy and waste engineering.