Reusable packaging in Europe

Between facts and fiction – an informed opinion for Metal Packaging Europe

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Summary

Politicians and non-governmental organisations (NGO) are lobbying for the implementation of reusable packages for fast moving consumer goods (FMCG) to limit the impact of packaging waste on our environment. This opinion paper summarises the knowledge on reusable packaging in the public literature and the experience of incumbents with reusable packaging systems. The intention of this opinion paper is to offer insights under which conditions it can and cannot be implemented successfully with respect to the reduction of environmental impacts.

The overview of the scientific literature revealed that indeed reusable packaging systems are presented in many articles as possible solutions to limit the environmental impact of FMCG's. Most of these articles do, however, not describe actually reusable packaging systems that operate in reality, but rather describe what if scenario's with guesstimated parameters. These studies therefore, show that under ideal conditions reusable packaging systems are beneficial for the environment. Interviews with incumbents that operate a reusable packaging system, revealed an ambiguous relationship of FMCG producers to reusable packaging systems; existing systems based on glass packaging are cherished and maintained, but there is also hardly any incumbent that wants to extend or erect new reusable systems. This largely relates to the fact that existing reusable packaging systems are used where it makes sense. Furthermore, the operational costs of existing well-performing reuse systems are lower than of single use systems, but the initial investment costs to establish a reuse system are large, effectively limiting further market expansion.

Additionally, the interviews with the incumbents resulted in a long list of conditions that have to be met to make a reuse system successful and help not only to limit littering but also limit greenhouse gas emissions. This knowledge is, however, not available in the public literature. Therefore, the stakeholders have diverging opinions on reusable packaging. Some politicians and NGO's regard it as an effective and tangible method to act on the environmental impacts, whereas FMCG producers and retailers see multiple challenges that need to be dealt with and worry that the contrived societal benefits will not be achieved and substantial investments need to be done at no avail.

1 Introduction

This informed opinion is written for Metal Packaging Europe to review the public and industrial knowledge on reusable packaging systems.

Renewed interest in reusable packaging

Humanity is faced with multiple challenges at the onset of the twenty-first century, varying from climate change, global pollution with persistent chemicals & materials, loss of biodiversity, pandemics, famine to injustice. The United Nations responded in 2015 by setting seventeen sustainability development goals. Governments and enterprises seek tangible policies and measures to address these development goals. Two of these goals (12 and 13; responsible consumption and production, climate action) relate directly to our use of packages. Already in 1992, the European Union has sought to reduce the environmental impacts of packaging waste by demanding member states to set-up recycling systems for packaging waste and to attain recycling targets. Currently, there is growing evidence that these recycling target based policies have insufficiently limited the environmental impacts of packaging waste [1,2] and in some cases even worsened the impact (the export of plastic waste to countries without recycling infrastructure was formally registered as recycling but resulted in enhanced levels of plastic soup) [3]. As a result, several NGO's are currently demanding new policies with reduce and reuse targets, besides the conventional policies aimed at raising the recycling targets.

Research question and objective

Multiple governments and NGO's regard reusable consumer packages as a solution for the environmental impacts of single-use packaging. Some EU member states, like France, have already set targets for reusable packages [4], others are currently contemplating this. The scientific literature and the experiences of incumbents have shown that reusable consumer packaging systems can be successful. Indeed in some cases reductions in material use, environmental impacts and overall business costs have been established in comparison to alternative single-use systems, but only under specific conditions. This leads to the research question: under what conditions are business-to-consumers (B2C) reusable packaging systems successful and what are the risks when these conditions are not met? Metal Packaging Europe (MPE) has asked Wageningen Food & Biobased Research (WFBR) to write an informed opinion on this topic. All relevant materials are in scope; not only metal packages.

This report aims to collate all knowledge on reusable packaging systems in both academia and industry with the intention to present a realistic impression of the performance of the current reuse systems in Europe. Secondly this report also intends to list the success and failure factors for reusable B2C packaging systems, to allow for an informed analysis of the opportunities and threats that reusable B2C packaging systems experience. A wide scope of dimensions of sustainability will be considered in the analysis: LCA, littering potential, economic costs, stakeholder acceptance, supply chain actor relationships.

Scope

The scope of this text is limited to B2C reusable packages, since business-to-business (B2B) reuse systems are well-established and the benefits they offer to businesses are widely accepted. This is, however, not the case for B2C reusable packages.

There are four types of B2C reuse models [5], as showed in Figure 1:

1. **Refill at home:** users refill their reusable container at home (e.g., with refills delivered through a subscription service)
2. **Refill on the go:** users refill their reusable container away from home (e.g., at an in-store dispensing system)
3. **Return from home:** packaging is picked up from home by a pick-up service (e.g., by a logistics company)
4. **Return on the go:** users return the packaging at a store or drop-off point (e.g., in a deposit return machine)

Figure 1 B2C reuse landscape with four different business models [5]

In principle all four reuse business models are considered, but most information is available with respect to return on the go business model.

2 Methods

Literature review
A literature search with Scopus and Google Scholar resulted in forty four scientific articles, eleven national reports and two trade-journal publications on reusable packaging systems. These articles have been analysed based on their relevance on the topic, the type of reusable packaging system they describe and the type of data they contain (measured or estimated). Roughly half of the scientific publications deals with reuse models, calculating operational aspects such as optimal pool size and cost minimisation of logistics. Sixteen publications predict the reductions in environmental impacts that could potentially be obtained in comparison to single-use packages in various scenarios. Most of these scientific papers are based on scenarios with estimated parameters. In contrast, eight national reports and two scientific papers describe existing B2C reuse systems, report measured parameters from these systems and perform calculations based on these parameters. These publications describe reusable beverage packages (PET and glass bottles).

Interviews
Interviews were conducted by WFBR with incumbents in reusable packaging systems in different European countries. Contacts were gathered by both MPE and WFBR. A list of interviewed organizations can be found in Table 1 (anonymized).

Table 1 List of interviewed organizations.

Company / organization	Country	Product
Company 1	The Netherlands	Beer
Company 2	International	Beverages
Company 3	Germany	Beer and beverages
Company 4	The Netherlands	Research
Company 5	International	Beverages
Company 6	Poland	Retail
Company 7	Germany	Beverages
Company 8	International	Dairy
Company 9	France	Retail
Company 10	Germany	Beverages
Company 11	Germany	Research

3 Literature review

The literature found has been categorised according to the type of publication (scientific article, national report) and the subject (logistics, consumer acceptance, description of existing reuse systems, estimation of potential reductions in environmental impacts with reuse systems, design for reuse systems, food safety, miscellaneous) , see Table 2.

Table 2 Categorisation of the scientific literature that is publicly available on the topic of B2C reusable packaging.

Subject	Articles	Reports
Logistics	[6-17]	
Consumer acceptance	[18 - 22]	
Description of existing B2C reuse systems	[23, 24]	[25 - 32]
Estimation of potential reductions in environmental impacts	[33 - 46]	
Design for reuse	[47, 48]	
Food safety	[49 - 54]	
Miscellaneous	[55, 56]	[5,57,58]

The difference between the category "description of existing B2C reuse systems" and "estimation of potential reductions in environmental impacts" can be complex, since there are studies that combine elements of both. In case a B2C reuse system was described and at least two of the three critical parameters (amount of loops, average transport distances, average cleaning effort) were measured and reported, then it was categorised as "description". Articles that describe the potential environmental benefits of reuse systems, will typically conclude under which conditions the reusable packaging system is more favourable than the single-use packaging system. Typical results are figures with the amount of loops on the ordinate and the environmental impacts on the co-ordinate, which show a break-even point after a certain amount of loops between the reusable and single-use packaging system (in case all other parameters are fixed).Two examples of these figures are shown in Figure 2

A recent well-balanced article of Grisales et al. on 0.5 litre water bottles for the Italian hospitality sector describes very clearly the multiple parameters that influence the environmental impacts of both bottle systems: average transport distances, average amount of loops, the level of recycled content of the single-use PET bottle and the fuel type and fuel consumption of the transport vehicles. A reusable glass bottle can only be favourable over a single-use PET bottle under a list of strict conditions including more than 25 loops on average and an average transport distance (forward and return) that should not exceed 200 km, etc. [45].

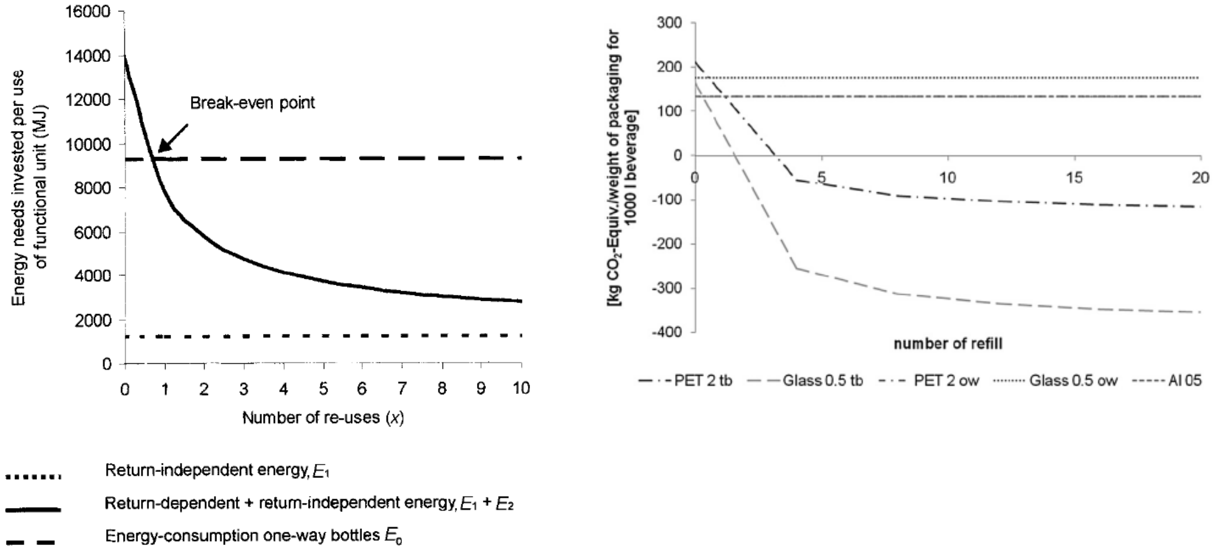

Figure 2 Studies that explore the potential environmental benefits of reusable packaging systems typically report break-even points. For instance the study of van Doorselaar and Fox from 1999 [33] and of Simon et al. from 2016 [36]

From Table 2 it is clear that the majority of the scientific literature deals with logistic optimisation (12 articles) and potential environmental gains (13 articles) and that existing B2C reuse systems are only described in 8 national reports and 2 scientific articles.

The five studies on the consumer acceptance describe the ambiguous relation of consumers with reuse systems. When consumers become familiar with reuse systems most are willing to participate, but simultaneously, most consumers prefer recycling as disposal method.

Of the six scientific articles on food-safety, five deal with bottles and cleaning procedures and one with vegetable crates cleaning and cross-contamination. The five publications about bottles and cleaning procedures are either from 1997 to 2004 and refer to these measurements. No recent articles have been published on the subject of food safety of reusable PET bottles.

Furthermore, the majority of the scientific articles and national reports focusses on the return-on-the-go business model, only seven articles and one report describe other business models [5, 22, 38, 40, 42, 44, 47, 48].

Overall, there is a lack of knowledge in the scientific literature on the following subjects:

- The current performance of existing B2C reuse systems, in relation to established and verified average amount of loops, average transport distances and cleaning efforts (use of water, heat, electricity and chemicals),
- A sharp definition under which conditions reusable B2C packaging systems are successful (with respect to different environmental performance indicators) and the consequences for both governmental policies and the range of packaged products that should / should not be targeted for reuse systems.

4 Interviews: general insights and industrial experience

4.1 Historic context

B2C reusable packaging systems used to be fairly well-established in the interbellum up to the early seventies of the last century in many European countries. The iconic milkman used reusable glass bottles, an early example of the return-from-home business model. Beer and mineral water was traded in reusable glass bottles and even some processed vegetables were traded in reusable glass jars. These are all examples of the return-on-the-go business model. The relatively high costs of glass packaging and the scarcity of glass resources back then were prime reasons to maintain these reuse systems. Some of these B2C reusable packaging systems survived up to today. However, many of them also vanished with the rise of supermarkets and convenience food products. In Table 3 an overview is given of the long-lasting reusable B2C packaging systems of which we are aware of.

Table 3 European B2C reusable packaging systems that are operational for decades and of which we are aware.

	Beer	**Wine**	**Beverages**	**Mineral water**	**Yoghurt**
Germany	Glass		Glass PET	Glass PET	Glass
France	Glass	Glass			
Italy				Glass	
Belgium	Glass		Glass		
Netherlands	Glass		Glass		
Denmark	Glass				

As can be seen in table 3, there are relatively many reusable B2C packaging systems with a return-on-the-go business model in Germany, which is partially related to their packaging law, the industry structure and the culture. The German packaging law of 2019 (Verpackungsgesetz) demands that 70% of the beverages are sold in reusable bottles. This demand is named “Mehrwegquote”. The autonomous market development, however, shows that increasing amounts of single-use bottles and not reusable bottles are used, see Figure 3, with the last public data from up to 2014.

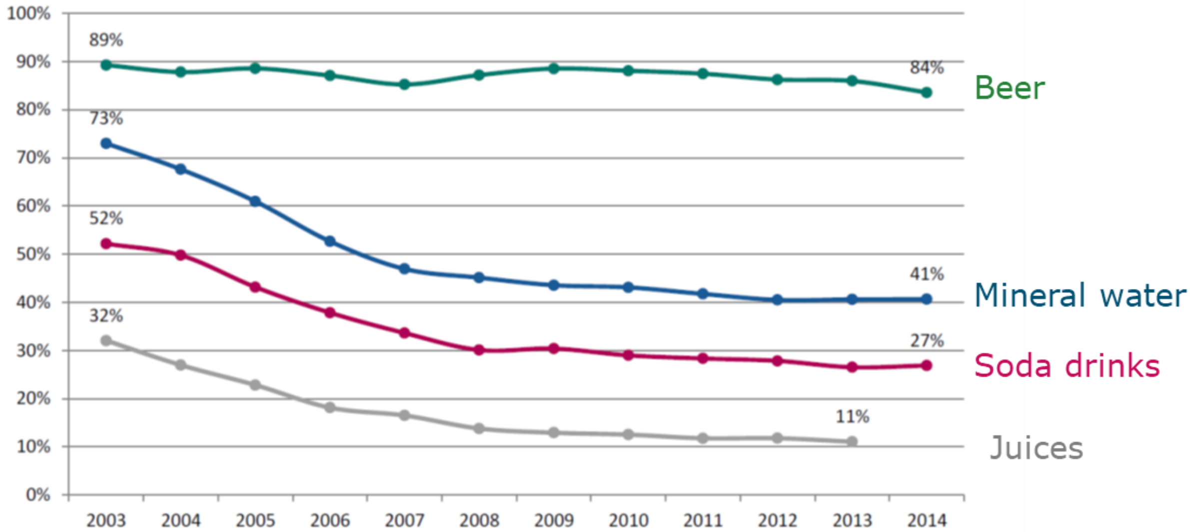

Figure 3 Development in the share of reusable glass and PET bottles in Germany in time for four markets [30]

Most German interviewees explain this rise in single-use beverage packages as a reflection of changing consumer habits, which increasingly demand convenience products and the rapid growth of out-of-home-consumption. But they also refer to the rise of discounter shops that only sell single-use bottles. Hence, in Germany we observe a clear conflict between a policy objective (Mehrwegquote) and reality in terms of consumer preferences and retail policies.

4.2 Industrial experience

The beer, mineral water, beverage and dairy industries that operate reusable packaging systems with glass bottles and jars are satisfied with their systems and intend to maintain these systems. One incumbent clarified its position, by stating that the operational costs for reusable glass beer bottles are lower than for single-use glass bottles. Another incumbent elaborated that having invested in a pool of glass bottles, crates and optical inspection & cleaning equipment they also need to safeguard their investment. Additionally it is widely recognised that these existing glass-based reuse systems are often successful in reducing the amount of packaging material used and the environmental impacts.

In reflection it should be noted that the reason for success of these glass-based reuse systems is that they fulfil all success factors (see chapter 5) when they are set up in a way that guarantees short transport distances and high refill rates, which often entails using standardized bottle formats in shared pool systems. High average amounts of loops are attained due to the deposit refund systems, the average transport distances are manageable, product residues can be cleaned from the packages with doable efforts. This, however, doesn’t imply that all newly conceived reuse systems will automatically also fulfil these criteria and become successful.

The German producers that sell mineral water and beverages in PET bottles have diverging opinions. Some companies are strongly in favour of reuse systems. Others companies state that they follow the market trends and if retailers and consumers want their product in a certain package, then they will produce it for them. The share of reusable PET bottles for mineral water and soda drinks has decreased substantially over the last decade, see Figure 3. These markets are now dominated by single-use PET bottles (80% single use bottles for non-carbonated water, 50% for carbonated water and 65% for soda drinks), which is partially explained by a change in consumer preferences for on-the-go consumption and partially by the rise of discounter retailers that only sell single-use PET bottles. All incumbents agree that the rise of branded PET reusable bottles has resulted in reduced average amounts of loops and longer loop times. One incumbent states that the reusable PET bottle system is still ecologically more favourable than the single-use system. Another incumbent states that the difference with the single-use system has become minimal, due to the raised levels of recycled content in the single-use bottles. Other aspects that the incumbents have differing opinions about are the food safety and the scuffing of the bottles. One company states that although the reusable PET bottles are thoroughly washed, there is still a small remaining risk of consumer-misuse that can insufficiently be mitigated by the cleaning operation. With respect to bottle scuffing, one incumbent states that this problem can be resolved with a modified design and still sufficient loops (~15) can be obtained to make the packaging system have less environmental impacts than any single-use PET bottle system.

An interviewed representative of a dairy industry that operates a reuse system with yoghurt jars in Germany is satisfied with this system and will actively maintain it. However, this company does not consider to expand this system to other countries and products. This company strategically re-evaluates alternative packaging systems, such as reuse systems, every few years. For the large and important market of fresh pasteurised milk, the last life cycle assessment has clearly shown that single-use beverage cartons are more favourable than reusable glass or PET bottles [32]. The prime reasons are the relatively low average amount of loops that is expected to be obtained of roughly 10, the centralised production facilities that will create large transport distances and the high cleaning efforts that are required to remove milk residues that are dried in on bottle walls.

4.3 Reflection of incumbents on the scientific literature

According to German incumbents the data that is publicly available on the largest B2C reuse systems (beer and mineral waters in Germany) are already outdated. The last public report with well-measured data is from 2013 [29]. More recent studies have been performed but have not been released publicly. According to German interviewees the following parameters have changed in the last years:

- The share of branded bottles has grown rapidly, which complicates the return logistics in multiple manners. A larger share of bottles is discarded at sorting centres, because their production location is too far away. The average loop time has increased, the average transport distances have risen and the average amount of loops has decreased, which makes the reuse systems less favourable.
- The energy use of modern inspection and cleaning equipment has been reduced making reuse systems with modern equipment slightly more favourable.
- The level of recycled content of single-use PET bottles has increased making single-use systems slightly more favourable.

Several incumbents stressed that especially the rise of the branded bottles has a profound negative effect on the performance of reuse systems. The effects of branding the reusable bottle were already visible in the Deloitte report of 2013 [29], but recent market data has shown that the share of branded bottles is rising rapidly in Germany [59], which will impact the performance of the reuse systems negatively. However, there are no public studies available in which the magnitude of this impact is clarified.
Also the Austrian national report from 2010 [26] and the French national reports from 2009 and 2018 are not very recent [25, 27]. This implies that the current literature doesn't offer a realistic and up-to-date impression of the current performance of the reuse systems in Europe.

Two incumbents state that the food safety articles on reusable bottles from 1997 to 2004 [49- 52] do not provide a complete and up-to-date impression of the situation. Bottle misuse by consumers remains to be an issue that can potentially create liability issues and damage the brand. It is their opinion that single-use PET bottles with sufficient high recycled contents, nowadays have carbon footprints that approach those of reusable PET bottles and therefore it is no longer worth to take the liability risk.

It is the opinion of most interviewees that the scientific literature runs short on the following subjects:

- The current performance of existing B2C reuse systems, in relation to established and verified average amount of loops, average transport distances and cleaning efforts (use of water, heat, electricity and chemicals),
- The food safety aspects of reusable packages including the occurrence of incidental contamination,
- The barriers that FMCG (Fast Moving Consumer Goods) companies experience when they want to set up reusable packaging systems,
- The impact of the required large pool sizes to successfully operate reusable packaging systems are hardly ever taken in consideration in life cycle assessments [57].

5 Success and failure factors

Single-use and reusable packaging systems are fundamentally different organised. Reusable packaging systems in general require a much tighter co-ordination between the incumbents to succeed than single-use systems and also require a different infrastructure. This also implies that there is no quick-fix to convert a value chain based on single-use packages into a value chain based on reusable packages. For return-business models the most important differences relate to the reverse logistics that needs to be organised, the pool of packages that has to be acquired and maintained and the whole infrastructure that relates to packages that are returned. This means: collection points, a fleet of transport vehicles, sorting and reconditioning facilities. For food packages the latter translates in quality inspection and cleaning equipment that use energy, water and chemicals. For refill business models investments will be required in for instance refill stations. Therefore, the barriers to change an existing system are substantial and certainly do involve much more than just a change of packaging.
The general lessons from literature and the insights from interviewed incumbents resulted in a few general success and failure factors for B2C reusable packaging systems. Since the literature and interviews focus on the return-on-the-go business model, most gathered success and failure factors also relate to this model. Nevertheless, we will attempt to engage the other business models in the description of these factors.

Food safety
Food safety is predominantly a failure factor for the return business models involving food products. In the refill business case the consumers themselves are responsible for cleaning their packages, obviously depending on a proper design of the packaging. Within the return business models the food company is responsible for assuring food safety, irrespective of the amount of loops a food packaging has been used in. Only two materials (glass and stainless steel) can be thoroughly cleaned and will not cause migration issues. PET is a border-line case. PET cannot stand the high temperatures and levels of alkalinity used to clean glass and stainless steel, which raises the risk that the bottles are insufficiently cleaned. Furthermore, in PET molecular contaminants will absorb (for instance as a consequence of consumer misuse) which can only partially be removed in a conventional cleaning operation, hence raising potential food safety risks. This has three consequences. First of all, reusable packages need to be cleaned thoroughly to avoid food safety risks which entails in the use of large quantities of water, energy and chemicals. When comparisons are made with single-use packaging systems, often more water, energy and chemicals are required, especially when the packages are used for viscous food products. Secondly, there is always a residual food safety risk when using PET as packaging material, which has to be dealt with by the food company; not all food companies are willing to accept that residual risk and not all are able to manage it. Thirdly, when this food safety risk is not acceptable, only two possible materials (glass and stainless steel) remain which are relatively heavy. Due to the large weight of food safe reusable food packages, a high number of loops is required to break even (or approach) with light-weight single-use packages in terms of environmental impacts.

Standardisation
In return business models the use of a shared pool of standardised packages improves the performance of the reuse system greatly in multiple manners in case the participating companies are well-dispersed over the country and not all located in one region. First of all, more packages are returned to appropriate companies and less packages get lost or are discarded at remote sorting centres. This directly translates in reduced average transport distances per loop (and reduced fuel use), shorter loop-times, higher average amount of loops that are attained, and lower minimal pool sizes per producer. This boils down to lower costs and lower environmental impacts. Standardisation is, however, not self-evident. In most highly competitive markets, such as the food industries, there is a strong need for marketeers to differentiate. Hence, the German markets for mineral water and beer in glass bottles have witnessed a strong rise in "branded bottles" [59], which according to incumbents caused the average transport distances to rise and the average loop times to triple, transforming a successful reuse system in a less favourable system.
In refill-on-the-go business models the use of standardised packages becomes relevant when universal multi-brand filling machines are applied at retailers, requiring the refillable package to have fixed dimensions.

Minimal transport distances

Multiple LCA's have indicated that the maximum distance between producer and consumer should not exceed approximately 150 km (75 km forward and 75 km return) to keep the reuse system competitive. Hence a single factory with a cleaning operation would ideally have a service area of 17671 km^2. If we ignore geographical constraints such as mountains and rivers. If we want to keep the transports below the 150 km and hence maintain these maximum service areas, we will need many reconditioning facilities to serve complete European countries, roughly three for small countries such as the Netherlands and Denmark, 17 for Italy, 19 for Finland, 20 for Germany and 31 for France. With such high numbers of production facilities the average transport distances can be kept under the 150 km limit. But this analysis is just based on surface area's and not on consumption levels. Meaning that you might need 19 facilities to cover the whole of Finland, but you will have to settle for either a less economic & ecological optimal system with higher prices and more emissions, or you will have to combine several different packages to be served by the same reconditioning facility. The latter option might look attractive, but will require the standardisation of packages for multiple products from multiple producers to obtain an economy of scale (see below). This is not only complex from a technical point of view, but also from a legal point of view (in relation to anti-trust legislation).

Scale of operation

In return business models the scale of operation is important. On the one side the transport distance should not exceed 150 km. On the other hand, the cleaning operation is most efficient with high throughputs (>50000 bottles / packages per hour). Hence there is an optimum in scale size between transport costs and cleaning costs. In general, reuse systems perform best in densely populated regions. For larger countries this implies that the production needs to be decentralised, which raises the investment. This translates in reduced production efficiencies, higher production costs and ultimately increased prices.

With a very simple mathematical model (see annex 1), it can be proven that even under ideal conditions, these two conditions can only be met in densely populated countries (>500 persons/km^2) at average consumption levels exceeding 1 package per week per person. Only one European country has such an exceptional high population density and the rest has far lower values. This implies that it is hardly ever possible to reach the required scale of operation for a single packaged product. Only by standardisation of multiple different packages to a limited number of standardised packages, which can be cleaned and inspected by the same cleaning facility, the optimal scale of operation can be attained. Although this appears simple in written words, it will necessitate enormous changes in the real world; redesigning packages, setting up local cleaning facilities and local FMCG industries to fill these standardised packages locally. This would encompass an enormous societal change. Local, smaller scale FMCG industries are likely to be less efficient in production, which could result in higher energy use for production. Hence, the question is whether the economic and ecologic benefits of using standardised, reusable packages is nullified by the raised production costs.

High return rates

A successful B2C reuse system needs to attain a large amount of loops to out-perform single-use systems. The minimal amount of loops that need to be attained to out-compete single-use systems strongly varies with the systems that are compared, but often at least 10 loops need to be attained. This implies that the collection rate needs to be as high as possible and at least exceed 90%. For systems that are based on the return-on-the-go business model this necessitates a deposit refund system (DRS) to achieve such high collection rates. But DRS can only be accomplished with the co-operation of retailers. In countries with large retail stores this is feasible in case the amount of DRS objects remains manageable and the retailers are compensated for their facilitation and efforts. Although feasible, experiences of food industries of the last decade have learned that getting the retail co-operation is not self-evident, as retailers are businesses that seek to make profits and running DRS is not very profitable by nature. In countries with predominantly small corner shops, alternative DR collection systems (without retail involvement) might be more realistic. This implies creating drop-off points or separate return venues. There is very little experience with these systems and it is not known whether high collection rates can be attained this way.

Design
Reusable packages need to withstand multiple loops and are consequently designed to be stronger, this is true for all reuse business models. Therefore, reusable packages are heavier than their single-use counterparts. Furthermore, reusable packages that are returned are handled much more, but can be designed to cope with this and reduce scuffing marks, which will enable a higher amount of loops.
A relevant design topic to take into account for the comparison of single-use systems to reusable systems is the recycled content of single-use bottles.

Minimal losses
To gain the largest environmental benefits, it is obviously important that the reusable packaging is actually re-used for a maximal amount of time. For the return systems this implies that they need to attain a high amount of loops. Two types of loss prevail for reusable packaging in return systems: collection losses and quality inspection losses. The collection losses can be minimised by setting-up an effective collection scheme like DRS. To minimise inspection losses the packages should be cleaned efficiently (which is easier for aqueous products compared to more viscous products) and designed to withstand multiple loops. The scuffing of bottle walls makes the appearance of bottles less attractive and hence, marketeers tend to limit the amount of loops, to keep the bottles looking attractive. A well-designed reusable bottle can also help to minimise scuffing).
For reusable packaging in refill systems it is crucial that the civilian keeps on using the same reusable package and doesn't purchase a new reusable package every time or regularly hops over to another packaging system. This involves changing habits.

The critical success and failure factors for reusable packages in return systems are summarised in Table 4.

Table 4 The critical success and failure factors for reusable packages in a return system.

Critical factor	**Outcome**	**In favour of:**	
		Single-use	Reuse
Amount of loops in reusable packaging system	Lower	X	
	Higher		X
Transport distances	Low (often <200 km)		X
	High (often >200 km)	X	
Water, energy & chemical use for cleaning reusables	Lower		X
	Higher	X	
Fuel usage and type for transport vehicles	Lower / Electricity		X
	Higher / Diesel	X	
Products	More viscous	X	
	More aqueous		X
Marketing	Branded	X	
	Standardised		X
Breakage / damage rates in reusable packaging system	Lower		X
	Higher	X	
Weight ratio of reusable vs single-use packages	Lower		X
	Higher	X	
Required pool size to operate a reusable system	Lower		X
	Higher	X	
Recycled content single-use packaging	Low		X
	High	X	

For refill-at-home reuse systems long-lasting participation and low weights of the single-use refill packages are vital success factors.
For refill-on-the-go reuse systems also the long-lasting participation of civilians is paramount, which implies that the consumers need to change their habits, clean emptied packages and return them to the filling station. Furthermore, in case this filling station is placed in a retail outlet, the floor area of the filling machine

is often a limiting factor. Automatic filling machines tend to be large, which implies that the retailer has to choose which product it will present in refillable packages and for which there won't be enough space. Finally the refilling on a shop floor should be simple, time-efficient and not result in additional cleaning efforts due to spillage.

6 Generalised performance of reusable packaging systems

The scientific literature and opinions of industrial incumbents agree that reusable packaging systems can have environmental and economic benefits in comparison to single-use packaging systems when a list of conditions (success factors) are met. Both scientists and industrial incumbents disagree amongst each other whether these conditions are met for the various existing reuse systems. For a few reuse systems (especially glass beer bottles) there is wide consensus that these are beneficial, for other systems there is more debate. The industries mostly focus on the economic impacts and the emission of greenhouse gases. Whereas most scientists have limited interest in the economic consequences and assess multiple environmental impacts (greenhouse gas emissions, littering potential, circularity indicators). On top of that both stakeholders have different information positions. This combination of different assessment criteria and different information positions results in different conclusions by both groups of stakeholders. In this section we will summarise this knowledge.

Economic impact
Setting up a reusable packaging system usually implies large investments. Dependent on the business model and the execution form, these investments range from a pool of reusable packages, quality-inspection and cleaning equipment, to dedicated filling equipment, transport vehicles, packaging machines etc. So, overall setting up a reusable packaging system is costly and these investments are only done in case the company is confident that they will be rewarding.
On the other side, well-managed and well-organised reuse systems such as the pooled glass beer bottle systems have lower operational costs than the single-use packaging systems. So, the business case for a reuse system can indeed be positive when it is well managed and executed. For the beer bottle cases this implies that the breweries, retailers and other outlets all agree to the use of standardised (pooled) bottles. This is vital to keep the losses and transport distances minimal.
This wide consensus on the use of pooled packages is, however, not self-evident as recent history in Germany has shown. The share of pooled reusable beer bottles has dropped from 85% in 2012 to 51% projected for 2022 [59]. With the beer market shrinking every year with roughly one percent, breweries try to maintain their market volume. Marketing and the use of branded bottles form an important aspects of this competition. Since there are no laws or regulations that restrict or forbid the use of branded bottles, their share grows annually. This in turn makes the business case for the reusable glass beer bottles less and less attractive in comparison to single-use glass bottles.

Greenhouse gas emissions
The greenhouse gas emissions or the carbon footprint are often a dominant motivator for stakeholders to pledge in favour or against reuse systems. These footprints are calculated with various life cycle assessment tools that - depending on their quality - take more or less parameters and aspects into account. These calculations are delicate and changes in crucial parameters can toggle the result, see the critical success and failure factors for reusable packages in Table 4. Also pre-set assumptions like "the production will occur at the current production sites" will influence the outcomes of these analyses to a great extent. Another critical factor that is often overlooked is the required pool size to operate a reusable packaging system, which implies that the amount of material needed to fulfil the functional unit are in most cases systematically underestimated [57]. It is fairly common for industrial incumbents and scientists to use arguments based on carbon footprints to reaffirm their business decisions or opinions; it is unfortunately far less common for incumbents to conclude that given the large uncertainty in the results there is no preferred solution.

A typical trend of the kg CO_2 equivalents vs. the amount of loops of a reusable package is shown in Figure 4.

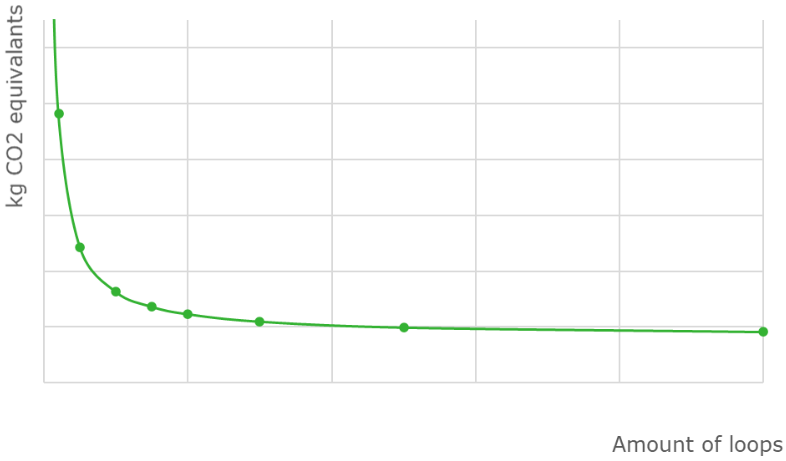

Figure 4 A typical trend of CO_2 equivalents (kg) vs. the amount of loops

Littering potential

Plastic waste still leaks into the environment via littering and illegal trading of plastic waste. A large part is related to Asian countries that rely on uncontrolled landfilling to manage their waste. But also countries with highly developed waste management industries and intricate collection schemes contribute to the formation of litter and plastic soup [3]. Although the latter share might be limited, any plastic product that ends up in nature will degrade over time in billions of particles with unknown environmental impacts [60]. This has led to growing concerns with mostly scientists, NGO's and governments. The environmental impact of this litter and the resulting microplastics cannot be calculated, yet [61], but the chance that an item will be littered can crudely be estimated with littering potential indicators [62]. Reusable packages are likely to have lower littering potential, since they are used multiple times. Therefore, it has been suggested that the littering potential of reusable packages will get lower with increasing amount of loops. Hence, reusable packages often have a lower littering potential than single-use packages and this is an important argument in favour of reusable packages for NGO's and governments. However, in the case the collection of single-use packages is extremely well managed with a well-executed DRS, as is the case for German aluminium cans with collection rates of 99.3% and littering rates of 0.03% [64], then reusable packages cannot surpass such low littering rates. Under these circumstances this argument is no longer valid and lower littering rates cannot be achieved by demanding reusable packages.

Material circularity indicator

Multiple circularity performance indicators have been suggested, ranging from relatively simple indicators that express whether packages can be recycled, to much more elaborate indicators that take losses, reuse, life span and quality in consideration. One of these more elaborate circularity indicators is the so-called "material circularity indicator" of the Ellen MacArthur Foundation [63]. Reuse is in general positively awarded in this indicator and the more loops that are made, the higher (more positive) the indicator value will be. Especially governments find these indicators valuable as they seek tangible indicators to measure the progress towards a more circular economy.

This indicator takes into consideration parameters also accounted for in a classical LCA, such as the recycled content in the package, the recycling efficiencies when the packaging is recycled and the average amount of loops the reusable package makes. Therefore, in the classical comparison of a single-use package versus a reusable package (assuming a similar package design), the reusable package gets awarded a higher MCI than the single-use package when the return rate is high (e.g. at least 90%) and the number of loops is high e.g. (at least 10). When the single use package has a higher level of recycled content or recycling rate or the reusable package system has a low return rate or number of loops, the single-use package gets awarded a higher MCI than the reusable package and the tipping point will be at a much higher amount of loops. The precise details of the packages (feedstock, recycled content, recycling rates, life span and amount of loops) will determine the precise amount of loops where the tipping point is situated. The MCI, however, doesn't consider transport distances and investments, as it is not an LCA- or carbon emission related indicator.

Figure 5 shows a typical (exponential) trend of the Material Circularity indicator vs. the amount of loops for reusable packages.

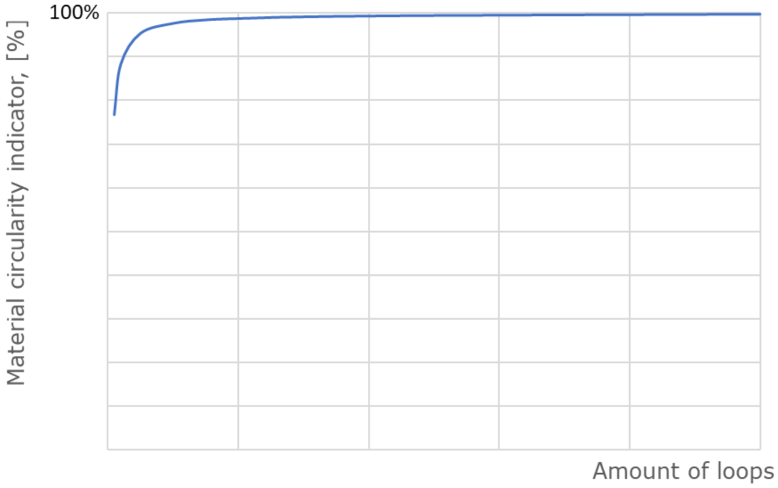

Figure 5 A typical trend of the Material Circularity indicator (%) vs. the amount of loops

7 Stakeholder perspectives and expectations

The perspectives and expectations of stakeholders with respect to reusable packages differs greatly. For several relevant groups of stakeholders their opinions and perspectives are further explained. Again most stakeholders have experience with the return-on-the-go business model and hence most opinions and perspectives relate to this model.

Scientists aim to publish articles which are often cited and hence are popular with their peers. Furthermore, they need to acquire new grants and are hence constantly looking for new funding opportunities. Since the discovery of plastic soup, all subjects related to the management of plastic waste are increasingly popular research topics. Also the amount of publications on reuse have risen sharply in the last ten years. As discussed previously most publications are scenario studies, since real measured data is lacking of existing reuse systems and laborious (and hence costly) to measure in a reliable manner.

Environmental pressure groups regard reusable packaging as one of the few options to minimise the environmental impacts of plastic packaging effectively. They refer to the waste hierarchy and reuse is the second best option, just below reduce. Moreover, these groups consider multiple environmental impacts simultaneously, so not only the emission of greenhouse gases, but also the global pollution with persistent chemicals and materials and the loss of biodiversity. It is their hope and expectation that the implementation of reusable packaging systems can reduce the amount of packaging materials used and consequently reduce littering, which in turn should positively affect biodiversity as well. Environmental pressure groups feel that their positive perspective on reuse systems is backed by scientific literature, which shows that environmental impacts can be lowered substantially. In their opinion, environmental impacts such as littering potential and circularity are as important as greenhouse gas emissions and since the first two improve with most reuse systems and the third varies, their overall opinion is in favour of reuse systems.

Consumers / civilians have an ambiguous relationship towards reusable packaging. Consumer scientists report that there is a group of consumers that is highly interested in reusable packaging systems and willing to start using them. But simultaneously there is also another group of consumers that finds reuse a hassle or even regard it unhygienic. Retailers and entrepreneurs confirm the diverse opinion and behaviour of consumers towards reuse systems. On the one side, once civilians get used to reuse and change their habits they will participate. For instance, it is common knowledge that beer drinkers do not have the highest “environmental awareness”, but still they do participate in reuse systems. However, if consumption patterns change to more convenience & on-the-go consumption and single-use alternatives are present, reuse can be replaced by single use quickly, as we have also seen in Germany with PET bottles.

Retailers also hold diverse opinions with respect to reuse systems. First of all, they will try to serve consumers the best possible way, to make them regular returning customers. This implies that in case reuse is the norm within a society, they will offer that. They will not initiate and try to force a reuse system on their customers, due to the competitive nature of their business. They are in general inclined to offer reuse systems as an option for interested customers. But reuse via retail (return on the go business model) implies that empty packages are returned via the retail organisation and hence space in the shops and transport vehicles should be reserved for this. Within the retail, business floor space is money and hence the use of floor space for returned packages will in general be considered as a loss of earning capacity. Furthermore, in case packages cannot be reclosed and product residues cannot be contained, they will regard it as a potential safety risk / hygiene issue. This explains that retailers haven’t been enthusiastic when national laws forced them to operate deposit-refund systems. Retailers in countries with DRS are at ease with maintaining the system as it is, but in general do not want to expand it with more packages, since they worry that one additional packaging type will lead to another and so on.
Several European retailers are experimenting with refill-on-the-go models for nuts, detergents, etc. Some of these refill stations can take up a lot of floor space which is still manageable in hyper-markets but not in smaller stores. Moreover hygiene can be a challenge in this type of systems. Tests with nut refill stations in

regular supermarkets were not very successful. According to representatives of retail organisations the ratio between newly purchased packages and refilled packages was not favourable and these stations created additional cleaning efforts in a few supermarkets.
The European retail landscape is heterogeneous and in Eastern-European countries like Poland most shops are corner shops and floor space is extremely limited, which implies that these retailers find it impossible to facilitate reuse systems. In urban centres in Western-Europe with large hypermarkets and environmental conscious customers, several retailers are testing expanded reuse systems such as LOOP (by Carrefour). These retailers find it challenging to convince FMCG industries to participate in reuse systems and to pack in reusable packages for these venues.
Furthermore, in urban centres in Western-Europe, small relatively new retailers, alternative outlets and delivery services with an ecological profile embrace reusable packaging to differentiate themselves from ordinary retailers. This is a heterogenous group with refill and return business models, from farmer shops to delivery services with cargo bikes.

Food industries or FMCG industries are in general reluctant to large changes that involve investment in new packaging machines and pools of packages. Since these investments often involve large amounts of capital and long order periods (1-2 years is common), once a successful reusable packaging system is in place, they would like to maintain it. But setting-up new reusable packaging systems can only be executed in case it is planned well ahead of time. The large enterprises will typically not favour reusable packaging systems, since it will require them to decentralise production to keep transport costs and carbon dioxide emissions low. Almost all FMCG industries have sustainability goals of which the reduction of greenhouse gases is often central. Remarkably, this focus on greenhouse gas emission reduction will make these companies incredulous towards reusable packaging systems, since they know from experience that it will be difficult to meet the critical success factors in reality within the constraints of their business model. Furthermore, targets towards recyclability, reusability, litter prevention or circularity are institutionalised to a lesser extent by businesses than targets with respect to climate change. Hence, the advantages that reuse systems offer with respect to these indicators are often not taken in consideration by companies.
The middle-size enterprises which serve local regions will generally regard reusable packaging systems as a positive option and a competitive advantage over large enterprises. Whereas small enterprises will usually be wary of the large investments that are required with reusable packaging systems. Most of the food industries are in highly competitive markets, that in some cases are slowly shrinking over the years (beer, canned foods, dried foods, etc.). For these markets branding of the products is an important tool for marketeers to keep or expand their market share. When branding is not confined to the labels, but also involves embossed bottles and specific brand-designs, reuse systems with these bottles will become less effective. For these food industries branding is more important than an efficient reuse system.
However also the FMCG industry is heterogeneous and there are also companies that want to differentiate themselves from competitors by using alternative outlets of which reusable packages and/or refill systems are elements. So, currently we are witnessing the development of various alternative FMCG companies with different reuse business models.

Governments and politicians will strive to regulate societal problems, including packaging waste. Packaging waste is very heterogeneous, making it difficult for politicians to address it successfully. Hence the focus of most packaging waste policies was on reaching recycling targets (from 1992 on). When single-use PET bottles were introduced for beverages (around 2003) and replaced either glass bottles or reusable PET bottles, the amount of plastic packaging waste grew. This led to a policy focus on first PET bottles and later also metal cans in Germany, the Netherlands, Nordic countries. These single-use packages had to be collected via DRS. Most other packages were only obliged to fulfil the "essential requirements", but inspections by the authorities were rare, so effectively these packages were hardly regulated. When the environmental issue of plastic soup reached the public opinion (around 2015) some governments decided to ban specific plastic objects such as carriage bags, single-use items as drinking straws, cutlery, balloon sticks and Q-tips. But it remains difficult for governments to get a grip on the large and diverse market for plastic packages and related articles. Some politicians are now campaigning for virgin taxes, or recycled content policies as a much simpler approach. In contrast, the French government has decided that in 2025 all supermarkets with a floor space in excess of 300 m^2 need to offer 10% of the articles in reusable packages. Whereas the FMCG industry is still focussing on reducing the carbon footprint, most politicians start to shift their focus towards reducing packaging itself to prevent littering.

8 Conclusion and future outlook for reusable packaging

In theory all single-use packages can be replaced by reusable packages. However, it would have an enormous impact on our daily lives, FMCG industries, retail industry, transport industry and financial industry. Furthermore, in case these reusable packaging systems are implemented in an ill-conceived manner, the negative consequences will outweigh the contrived benefits greatly. The contrived societal benefits are the reduced use of packaging materials and the associated environmental impacts (global warming, plastic littering, circularity, etc.). Some of these benefits (littering prevention, circularity) will be easily achieved with reusable packaging systems. This is, however, not self-evident for the reduction of greenhouse gases. This benefit will only be attained in case a long list of conditions has been met; sufficient amount of loops need to be attained, meaning that consumers need to return / refill empty packages, these need to cleaned efficiently and the transport distances between producer and consumer typically needs to be below 150-200 km, which can imply that the value chain needs to be redesigned to decentralised production.

Most enterprises favour centralised production facilities to keep production costs low. They will only convert to reuse systems in case there is a strong societal pressure and/or legislative need to do so. Centralised production in combination with single-use packages can offer the lowest carbon foot prints. But single-use packages with or without collection and recycling systems will always result in some level of littering and leakage of packages into the natural environment (unless for beverage packaging near 100% collection rates are achieved through deposit return systems like e.g. in Germany). Most large businesses will favour to safeguard their investments in large centralised production facilities, to finance collection and recycling schemes for packaging waste (EPR), to stress the low product costs and low carbon foot prints of their products.
Some small existing enterprises will consider reuse systems a costly advantage in the competition with large enterprises. Also newly erected businesses can choose for reusable packaging systems in case this will render them a clear competitive advantage. They will actively promote that their packaged products cause the least environmental impacts, which is likely to be true with respect to littering and can also be true for carbon foot prints when all critical success factors are met.

Since the plastic soup and global littering problem is likely to worsen further in the coming decades due to the lack of waste management infrastructure in many parts of the world, also the pressure on politicians is expected to increase to act on the issue. European NGO's and politicians that want to act on environmental issues are likely to favour reusable packaging systems as a simple and tangible method to reduce littering and climate change. That these environmental benefits can only be attained under specific conditions, which are not-self-evidently met, is of lesser political concern. The act of demanding reuse systems and / or implementing laws alone will already appeal to their public and electorate.

Predicting whether reuse systems will truly break through, to which extent and when, is notoriously difficult to do. Besides the well-established bottle reuse systems, currently, innovative small players also bring products in reusable packages to the market. Although these new players are still small, they also show a large annual growth. Nevertheless, the barriers for implementing reusable packaging systems are in general substantial (requiring large investments, the alignment of multiple stakeholders and the active participation of civilians) which would suggest that mass-adoption is unlikely in the coming years. But establishing dominance in specific niche markets and regions (urban centres) is a realistic scenario. The political pressure to act on global pollution is mounting and could result in reuse-obligating laws. There is no authority currently planning and orchestrating the design and implementation of reusable packaging systems that would make sense from an economic, ecologic and societal point of view. And therefore, the future of reusable packaging in Europe in unclear and relies on political choices of governments and companies.

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Annex 1 Mathematical model for an optimal reuse system

As discussed in chapter 5, reuse systems operate optimally when roughly 50000 packages can be cleaned per hour at a reconditioning facility and when the average transport distances can be kept below 150 km (75 km forward and 75 km return). These numbers can be used to calculate the required consumption level within a hypothetical service area with a radius of 75 km. This service area would be 17671 km^2 and 350 million packages per year will need to returned from that area, if we assume a 20% downtime. This equals an annual required consumption level of 19829 packages/km^2.year. This required optimal consumption level (ROCL) can be reached by either having a densely populated country or very high average consumption levels per person. In mathematical terms we have a reciprocal function.

$$ROCL = PD \times ACL$$

Symbol	Meaning	Unit
ROCL	Required optimal consumption level	Packages/km^2.year
PD	Population density	Persons/km^2
ACL	Average consumption level	Packages/person.year

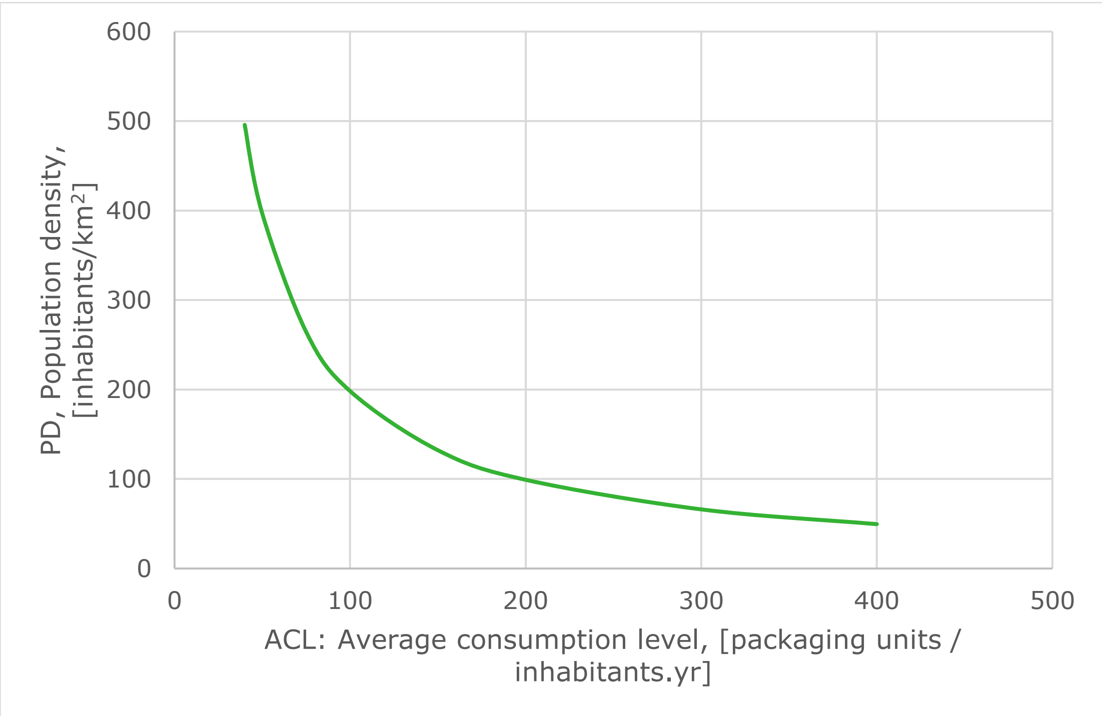

Figure 6 Relation between population density and average consumption level to attain the required optimal consumption level

This means that in sparsely populated countries like Finland (18 inhabitants/km^2), such a reuse system cannot operate efficiently, because not a single food product will have such enormous high average consumption levels. But even for a densely populated country such as the Netherlands (508 inhabitants./km^2), still the average consumption levels need to exceed 48 packages / inhabitant.year, so roughly 1 package/person.week. Only a limited amount of food products will attain that consumption level. The consequence is that either we have to settle for non-optimal economic conditions, which will imply that products will become more expensive to accommodate these inefficiencies or that multiple products have to be bundled in one packaging type to attain the required level of consumption.

From the same mathematical perspective also the amount of required reconditioning facilities can be calculated in order to keep the average transport distances below 150 km. This would imply that we would need only 3 facilities in Denmark and in the Netherlands, 17 in Italy, 19 in Finland, 20 in Germany and 31 in France. But this calculation is just done to keep the average transport distances below 150 km and does not take the optimum cleaning capacity in consideration. Meaning that for the larger European countries that would require a larger number of recondition facilities either these facilities cannot operate economically, or that we have to settle for a less optimal system with higher prices, or that we will have to combine the packages of multiple products to be cleaned by the same facility.

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