Recycling of multilayer composite packaging: the beverage carton

A report on the recycling rates of beverage cartons in Germany, Spain, Sweden and the UK

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Executive Summary

E.1.0 Background

In recent years, there has been a significant increase in consumer, media and policymaker focus on the 'end-of-life' outcomes of packaging. At EU level, this has led to recent legislation that has significantly increased mandatory targets for packaging and municipal waste recycling, substantially reformed the rules around extended producer responsibility (EPR), and introduced a new EU-wide calculation method for recycling.[1]

Some packaging formats are more straightforward to recycle than others. Formats involving the bonded layering of different materials or polymers have received particular attention as presenting challenges for recyclability, with the beverage carton being a good example of a relatively complex package involving multiple materials.

The aim of this report is to investigate the 'recyclability' of the beverage carton, as an example of a relatively complex multi-layer packaging format, using Germany, Spain, Sweden and the UK as case studies, based on the most up-to-date data available. According to the Alliance for Beverage Cartons and the Environment (ACE), 51% of all beverage cartons placed on the EU market in 2019 were recycled. One issue for beverage cartons – along with many packaging formats – is that while the 'placed on the market' weight (the denominator in the recycling rate calculation) is pure packaging, the 'recycled' weight (the numerator in the calculation) often includes other elements, such as food and drink remaining in items of packaging, or dirt and other contaminants "stuck" on or inside the package. This 'non-packaging' material, which is subsequently removed during the sorting and recycling process, can nonetheless represent a significant proportion of the mass of material counted as recycled packaging. Under the EU's new measurement method for recycling, all such process losses will have to be deducted from material counted within recycling figures.

E.2.0 Infrastructure and Technologies

While all four countries reviewed have networks of segregated 'carton only' bring collection sites, most beverage cartons are collected via co-mingled door-to-door collections. There are various combinations of packaging mixes seen in such collections, each posing different challenges to subsequent sorting and recycling performance. Whilst beverage cartons have a very distinctive infrared signal (as a result of the combination of paper and PE) that differs from most other cardboard or paper products, there are similarities with some laminated papers and take away coffee cups. Also, for facilities using mechanical sorting and eddy current separators to sort non-ferrous metals, the aluminium in some cartons causes them to be falsely identified as aluminium, and therefore not correctly separated in the sorting process.[2]

Based on beverage carton composition figures given by ACE and German NGO Deutsche Umwelthilfe (DUH), we have calculated an average beverage carton composition of 72.5% fibre board, 24% polymer and 3.5% aluminium.[3,4] Due to the composite nature of beverage cartons, they cannot be easily recycled by paper mills that recycle regular paper-based packaging. This is because these mills use a 2 to 4-minute soaking/pulping process, which is not sufficient to delaminate layers in beverage cartons to separate.

[1] These legislative changes have been introduced through the European Union's Circular Economy Package: ec.europa.eu/environment/waste/target_review.htm

[2] WRAP (2017) Collection of food and drink cartons at the kerbside, p.10

[3] ACE (2019) *WHAT ARE BEVERAGE CARTONS?*, accessed 4 December 2019, www.beveragecarton.eu/beverage-cartons/what-are-beverage-cartons

[4] Deutsche Umwelthilfe (2014) *Das Märchen vom umweltfreundlichen Getränkekarton*, November 2014

Therefore, beverage cartons must be processed at specialised paper mills. There are 20 such mills in Europe, and of those located in the four countries researched, all use the 'Single Separation' method, in which the paperboard fibres are separated from the aluminium and polyethylene layers using water and a washing machine-like drum in a process taking roughly 20 minutes. The processing capacities of the specialist mills – combined with their geographical coverage and process losses – is one of the factors impacting the recycling rate for beverage cartons in each country.

The polymer/aluminium fraction currently cannot be recycled in the countries researched and so is typically sent for incineration or co-incineration. Both Germany and Spain did at one time have recycling plants to separate the polymers and aluminium, but in both cases these plants closed after proving financially unviable. In Germany, beverage carton manufacturers planned to open a plant in 2020 to tackle this challenge. It is not clear, however, if this plant uses a different process to the former factories, and the extent to which its economic viability is safeguarded. At the time of writing, this plant was not yet operating.

E.3.0 Recycling Performance

New EU rules issued by the European Commission in April 2019[5] give clarity on how to undertake recycling rate calculations, providing one consistent methodology to be used by all Member States. Under the new rules, each separate material used in composite packaging must be assessed as "recycled" at its own calculation stage, with this typically being the point at which the material enters the actual recycling process where it is reprocessed into a new product, material or substance. For composite items such as beverage cartons, the rules require the recycling rate to be calculated based on the recycling rates for the materials making up the composite item.

According to the Alliance for Beverage Cartons and the Environment (ACE), 51% of all beverage cartons placed on the EU market in 2019 were recycled. 2018 recycling rates for the four case studies were also shared by ACE and can be seen in Table 1.1. ACE has acknowledged that its reported beverage carton recycling rates do not take the new recycling rate calculation methodology into account. It does not envisage this methodology being used until mid-2022, when countries are legally obligated to do so.[6]

Table 1.1 below presents the recycling rate estimates calculated in this study by applying the EU rules to the data collected through our research, along with country collection rates and ACE country-specific recycling rate

[5] COMMISSION IMPLEMENTING DECISION (EU) 2019/ 665 - of 17 April 2019 - amending Decision 2005/ 270/ EC establishing the formats relating to the database system pursuant to European Parliament and Council Directive 94/ 62/ EC on packaging and packaging waste - (notified under document C(2019) 2805)

[6] European Commission (2020) Reporting on Packaging Waste, ec.europa.eu/eurostat/documents/342366/351811/Legal+reference+reporting

	Germany	Spain	Sweden	UK
Collection rate[7]	87.4%[8]	51.2%[9]	40.1%[10]	48%[11]
ACE data - country recycling rate[12]	75%	80%	33%	36%
Eunomia - calculated recycling rate estimate	47.8%	21.4%	21.9%	29.5%

Table 1.1: Summary of Collection and Recycling Rate Estimates (2020)

As the table shows, when applying the new rules and estimated average loss rates for the recycling processes involved, the resultant recycling rates for each country are significantly lower than the recycling rates reported by ACE. Even the highest performing country on the new calculation method (Germany, at 47.8% recycling) does not achieve the 51% average beverage carton recycling rate for the EU quoted by ACE.Germany has a high collection rate (87.4%) but shows a significant loss of material between what is collected and what is recycled. For Spain, Sweden and the UK, all of which also show this loss of material in the sorting and recycling process, their initial relatively low collection rates mean that their recycling rate estimates are significantly lower.

E.4.0 Wider Environmental Impact

The findings in this report raise some important questions for a more holistic assessment of beverage cartons. Existing Life Cycle Assessments (LCAs) have so far supported the view that beverage cartons provide a relatively sustainable packaging solution. LCAs include a wide range of variables that need to be carefully considered, one being the recycling rate assumed in LCA calculations. The recycling rate estimates calculated here using the new EU methodology show a large variance to currently reported recycling rates. Furthermore, our estimates do not include the additional losses (e.g. those found in the pulping process), which further reduce the quantity of recycled material that actually makes it into a new product. As such, it may be that existing LCAs of beverage cartons reflect an over-statement of recycling benefits, inconsistent with the real situation.

In addition, beverage cartons cannot easily incorporate recycled fibre, due to their requirement for particularly long-length fibres. Fibre of the required quality can only be obtained (in Europe at least) from slow-growing conifers from far northern latitudes. This means that as well as not being able to achieve closed loop 'carton to carton' recycling, the fibre that is necessarily downcycled is likely to have a relatively high environmental impact in its production compared to the packaging board average.

In order to take these factors properly into account in accurately comparing products comprised of different materials, with different end-of-life fates, we will require models that reflect the whole life of those materials much more fully. Given the recycling challenges inherent in the beverage carton, it seems likely that taking more 'circular' LCA thinking to its logical conclusion by fully factoring in the whole useful life of its constituent materials could significantly influence beverage carton performance in LCAs.

[7] Material counted at the point of collection include materials such as product remnants, moisture and dirt and cannot therefore be compared on a like-for-like basis with the tonnage of cartons placed on market

[8] Calculated by Eunomia

[9] Calculated by Eunomia

[10] Institut für Energie- und Umweltforschung Heidelberg (ifeu) (2017) *Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for liquid food on the Nordic market*, April 2017

[11] WRAP (2017) Collection of food and drink cartons at the kerbside, p.7

[12] Personal correspondence with ACE, December 2019

E.5.0 Key Circularity Challenges

Although the renewable, biogenic raw material that makes up a large part of the beverage carton can make it an attractive option from an environmental perspective, the increasing focus on recyclability, recycled content and overall 'circularity' of single-use items presents a significant challenge for this packaging format. In particular, the potential circularity of the beverage carton is currently hampered by:

- High losses in collection and sorting systems due to relatively low separate collection rates and significant sorting losses;
- A lack of ability to use recycled content in the fibreboard body and plastic elements that come into direct contact with food or drink, leading to a reliance on virgin materials; and
- Significant losses of material in reprocessing due to the need for specialised material preparation and pulping infrastructure to optimise fibre recovery, as well as the challenges inherent in the package design regarding recovering the aluminium and plastic components as materials for recycling.

These issues and their potential solutions are elaborated upon below.

Effective Collection and Sorting Systems

To truly maximise collection rates, minimise sorting losses and maximise material quality, Deposit Refund Schemes (DRS) are likely to provide the most effective solution. DRS have proven to be a highly effective way of collecting beverage packaging, showing collection rates ranging between 80% and 99% for well-designed and implemented schemes. Unlike today's reported collection rates from regular door-to-door collections, these rates do not include moisture and contamination in the figures, as they are based on the number of items placed on the market rather than mass. However, implementing a carton DRS would require significant investment into adapted or new reverse vending machines, but seems the most feasible way to maximise capture of material for recycling.
Combining a consistent approach to calculation using the new measurement method set out by the EU with country-specific recycling targets for beverage cartons, such as those seen in Germany, would also create a driver for increased performance alongside the establishment of external data verification mechanisms.

Recycling Infrastructure and Technologies

Beverage cartons require additional pre-pulping material preparation and an extended pulping processing time to separate the aluminium and polymer layers from the fibres. Increased specialised mill capacity to process the increasing volumes of beverage cartons being collected and sorted is therefore required. The specialist mills also need to have the geographical coverage to ensure that transportation logistics are feasible and cost effective, so that sending material to be used for waste to energy is not seen as a more economically viable option. Germany provides an example of good practice here, as it has three specialist mills that together provide national coverage.

Design for Circularity

The fact that beverage cartons are primarily composed of renewable cellulose fibre from trees does not in itself ensure either their recyclability or sustainability. The need for long and strong fibres requires that the carton board in beverage cartons use a virgin fibre source. At the end-of-life of the beverage carton, once the fibres are reprocessed and thereby shortened, they are no longer suitable for beverage carton production and are used in applications such as corrugated cardboard boxes.

There is evidence that some manufacturers are taking steps to make beverage cartons more circular. While Tetra Pak's ambition is to "use renewable and/or recycled polymers for the plastic layer, or an alternative fibre or cellulose-based material",[13] potential for incorporating recycled content seems limited, not least because of legal constraints with the use of recycled plastics in food contact applications. Closed loop recycling, which Tetra Pak for example is striving to achieve, seems very challenging based on current manufacturing and recycling technologies, but if achievable could make a considerable difference to the circularity performance of the beverage carton.

[13] Ibid.

Contents

1.0 Introduction

In recent years, there has been a significant increase in consumer, media and policymaker focus on the 'end-of-life' outcomes of packaging. This has been driven by concerns about pollution caused by discarded single-use items (especially the pollution of the marine environment by waste plastics), as well as a growing recognition that efficient use of material resources presents an opportunity for climate change mitigation. At EU level, this has led to recent legislation that has significantly increased mandatory targets for packaging and municipal waste recycling, substantially reformed the rules around extended producer responsibility (EPR), and introduced a new EU-wide calculation method for recycling.[14]

In turn, this policy context has led to considerable attention being directed to the concept of 'recyclability'. All EU Member States will be required to introduce packaging EPR schemes that 'modulate' producer fees based on environmental criteria. This will economically incentivise eco-design, placing a strong emphasis on the extent to which a packaging format is considered to be recyclable.

Recyclability will ultimately be proven by the extent to which a material or packaging format is being recycled, with measurement of recycling shifting from the amount collected for recycling to the amount which is actually recycled. In its recently published Circular Economy Action Plan, the European Commission has gone further, committing to legislate to 'ensure that all packaging on the EU market is reusable or recyclable in an economically viable way by 2030', in effect heralding a ban on packaging that does not meet a minimum standard of recyclability.[15]

Although the terms 'recyclable' and 'recyclability' remain open to a degree of interpretation, they are likely to be more clearly defined in forthcoming revisions to the Packaging and Packaging Waste Directive.[16] However, it is clear that some packaging formats are more straightforward to recycle than others, due to factors such as the materials used and the complexity of design. Formats involving the bonded layering of different materials or polymers have received particular attention as presenting challenges for recyclability, with the beverage carton being a good example of a relatively complex package involving multiple materials.

1.1 Scope

This report explores the issues specific to beverage carton recycling practices in the EU, using Germany, Spain, Sweden and the UK as case studies. It considers the potential for improvement in beverage carton recycling performance, drawing on current best practices and emerging recycling approaches and technologies. According to the Alliance for Beverage Cartons and the Environment (ACE), 51% of all beverage cartons placed on the market in the EU in 2019 were recycled. [17] However, the data behind this figure is unclear and therefore we seek

[14] These legislative changes have been introduced through the European Commission's Circular Economy Package: ec.europa.eu/environment/waste/target_review.htm

[15] European Commission (2020) Circular Economy Action Plan, ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf

[16] European Commission, Packaging and Packaging Waste Directive, ec.europa.eu/environment/waste/packaging/legis.htm

[17] ACE (2020) ACE ANNOUNCES INCREASED RECYCLING RATE FOR BEVERAGE CARTONS, www.beveragecarton.eu/news/ace-announces-increased-recycling-rate-for-beverage-cartons, accessed November 2020

to draw on the most credible available data, as well as new calculation rules issued by the European Commission, to provide updated estimations.

One issue for beverage cartons – along with many packaging formats – is that while the 'placed on the market' weight (the denominator in the recycling rate calculation) is pure packaging, the 'recycled' weight (the numerator in the calculation) often includes other elements, such as food and drink remaining in items of packaging, or dirt and other contaminants "stuck" on or inside the carton. This 'non-packaging' material, which is subsequently removed during the sorting and recycling process, can nonetheless represent a significant proportion of the mass of material counted as recycled packaging. Under the EU's new measurement method for recycling, all such process losses will have to be deducted.

Previous to this report, other organisations have attempted alternative calculations for 'real' recycling rates for beverage cartons that factor in the losses covered by the new EU calculation methodology, as well as further losses in the reprocessing steps that EU rules do not cover. It is therefore important to review the recycling rates of our four case study countries under the new calculation rules, to thoroughly assess what the likely recycling performance of beverage cartons in Europe will be in the future.

Our research sought to answer the following questions:

- What are the collection, sorting and recycling/treatment/disposal systems and routes for cartons in the EU, using Germany, Spain, Sweden and the UK as case studies?
- What are the coverages of different collection systems for cartons (i.e. what proportion of population is serviced by different systems)?
- What are the carton and material flows (qualitative and quantified where possible), including export?
- What factors affect recycling rates and what exactly are the declared rates measuring, taking into account:
    - collection rates versus recycling rates;
    - the new EU measurement method for recycling, taking account of material lost in materials recovery facilities (MRFs)/sorting and pre-treatment operations;
    - 'waste weights' including e.g. product residues compared with 'placed on market' empty, dry weights;
    - fibre yield in paper making; and
    - other losses in the recycling process.
- What are the key end markets for the processed carton materials, including the fate of the polyethylene (PE) and aluminium film fractions (e.g. waste to energy, downcycling)?
- What are the future plans and ultimate potentials for carton recycling rates and circularity, given limitations on the need for virgin fibre input?
- How do these findings relate to Life Cycle Assessments (LCAs) and the measurement of the wider environmental impact?

1.2 Method

We conducted a literature review of existing journals, websites and other online sources to identify data available for the four countries with respect to quantities of beverage cartons placed on the market, collected and recycled, and to identify the key stakeholders and companies involved in each country. We also used desk research to identify how each country's collection and recycling infrastructure operates, and to collate quantitative data from waste surveys and compositional analysis, as well as previous research conducted. This

was supplemented with telephone and e-mail consultations with processing mills, sorting centres, recyclers and trade associations to fill data gaps.

From this, it was possible to map out how beverage cartons are collected and processed in each country. Drawing upon average data, or assumptions based on the best available information where accurate data was not available, and using the new rules issued by the EU in April 2019, we were able to calculate recycling rate estimates for each country that reflect how recycling performance will be measured in future.

This report is a summary of the current state of the market, the future calculation methods for recycling rates, the assumptions we have made and the resulting estimated recycling rates calculated for Germany, Spain, Sweden and the UK.

2.0 Introduction to Beverage Cartons

'Beverage carton' is a generic term for a type of packaging made predominantly from fibreboard, laminated with layers of plastic and often aluminium to prevent leaking and provide aseptic and enhanced barrier properties. The beverage carton is a lightweight, strong, food safe package that offers extended shelf life for both ambient and chilled products and efficient storage and transportation, due to its simple, block shape.

The beverage carton began as a simple 'brick' design, but has since evolved to include additional features such as straws for on-the go-products, easy-to-pour spouts and closable/resealable openings. The medium is used extensively across Europe and is often seen as an environmentally friendly choice due to being made primarily from renewable wood fibre, mainly from Forest Stewardship Council (FSC) certified sources. There are three manufacturing market leaders in the EU:

- Tetra Pak (Lausanne / Switzerland; www.tetrapak.com);
- SIG Combibloc (Neuhausen / Switzerland; www.sig.biz); and
- Elopak (Spikkestad / Norway; www.elopak.com).

Together, these produce 95% of all beverage carton packaging used in the EU.[18]

Germany is one of the largest users of beverage cartons. Unlike other countries where beverage cartons are mainly used for juices, alternative milk products, long-life milk and sauces, in Germany fresh milk producers also mainly use beverage cartons to package their products.

Spain's consumption of beverage cartons is second highest in Europe after Germany. In Spain, beverage cartons are used for a range of products including beverages but also food items such as soups. Milk packaging is a particularly common use, as there is a reliance on long-life milk over fresh milk, perhaps due to the speed with which fresh milk deteriorates in the warm climate. It is estimated that on average four cartons are purchased each week per person.

While designed to be suitable for liquid material, beverage cartons originally became popular with food and drink producers because of their lower transport costs compared with other types of packaging, being lightweight and easily stackable. Increasingly, however, consumers are demanding products that have a low overall environmental impact, and while so far beverage cartons are often seen as a good solution environmentally, as a laminated multi-layer, multi-material package it presents challenges for recyclers that do not have to be overcome in the case of most other beverage packaging formats. Producer SIG Combibloc states that its products are 'designed for recyclability',[19] but that does not mean that beverage cartons are being successfully recycled to the degree that producers and consumers might hope.

Many sorting plants and recycling centres find beverage cartons challenging to recycle due to their composite nature, and there is some evidence that consumers can be unsure as to whether they should be classed as paper, cardboard or plastic packaging. This is not helped when, as in the UK, for example, different municipalities have different rules on what materials are accepted in door-to-door recycling collections and which can be mixed or must be kept separate.

[18] ACE (2019) *Our Industry*, www.beveragecarton.eu/en/beverage-cartons-3/our-industry, accessed 5 December 2019

[19] SIG Combibloc (2017) *SIGnals l3 Reasons why Carton Packs win every time*

2.1 Design and Composition

Design and composition of packaging set the basis for recycling performance. Easy to separate materials that can be subsequently reprocessed into new products are generally seen as an advantage in the content of 'design for recyclability'.

Beverage cartons are a composite packaging as shown in Figure 2.1.[20] The average beverage carton composition is detailed by ACE as:[21]

- Board = 75%;
- Polymer = 21%; and
- Aluminium = 4%.

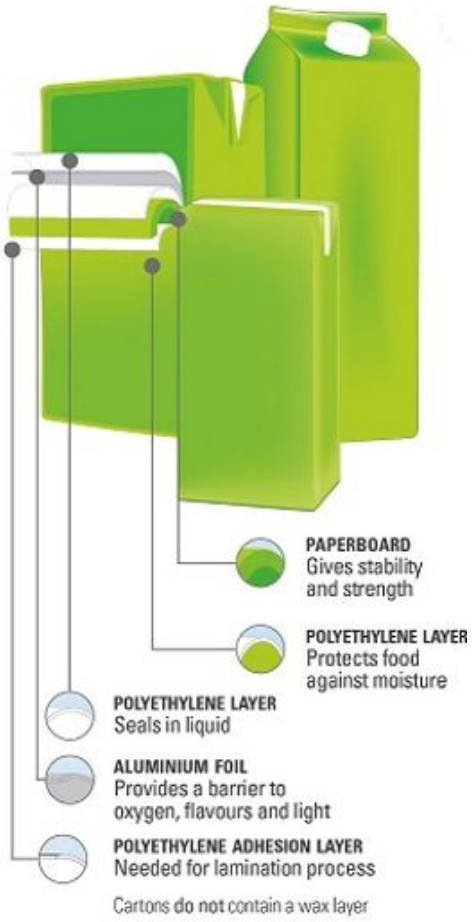

Figure 2.1: Composition of Beverage Cartons

[20] ACE UK, What is a beverage carton?, accessed 4 December 2019, www.ace-uk.co.uk/about-cartons/what-are-beverage-cartons

[21] ACE (2019) *WHAT ARE BEVERAGE CARTONS?*, accessed 4 December 2019, www.beveragecarton.eu/beverage-cartons/what-are-beverage-cartons

Deutsche Umwelthilfe (DUH) is a non-profit environmental and consumer protection association in Germany that has published a number of reports on beverage cartons. It provides a revised breakdown of beverage cartons comprising 70% board, 27% polymer and 3% aluminium in 2017. The variation to the ACE composition data is explained by an apparent consumer-driven change of design in beverage cartons, with consumer preference for easy pour spouts, more rigid bases and resealable enclosure leading to increased polymer content in beverage cartons.[22] DUH adds that the paper content of a carton can lie anywhere between 53%–80%. In practice, average composition is highly dependent on market profiles (including average pack size), and the average carton composition in Spain might be very different to that in Sweden, for example.

In absence of any detailed supporting data or calculations to back up either of these two claimed compositions, we have used the mean of the two data points as an average composition of beverage cartons across Europe, as shown in Table 2.1.

Material	ACE Composition	DUH Composition	Mean Composition
Fireboard	75%	70%	72.5%
Polymer	21%	27%	24%
Aluminium	4%	3%	3.5%

Table 2.1: Beverage Carton Composition

Beverage cartons use premium fibres mainly sourced from slow growing Nordic conifers, which provide fibres that are longer and therefore offer the higher engineering performance properties required for cartons relative to those used in other cardboard packaging. These exacting fibre standards mean that recycled fibres cannot be used in beverage cartons, meaning that closed-loop 'carton-to-carton' recycling is not currently an option, with cartons tending to be downcycled into lower value cardboard packaging.

[22] Deutsche Umwelthilfe (2014) *Das Märchen vom umweltfreundlichen Getränkekarton*, November 2014

3.0 Infrastructure and Technologies

Successful recycling of materials is also dependent on national waste infrastructure to capture and sort beverage cartons, as well as the processing technologies available.

3.1 Collection and Sorting Infrastructure

Spain, Sweden and the UK have considerable losses of material between the point at which quantities of packaging are placed on the market and the point at which they are collected – with further losses before material is ultimately recycled. Beverage cartons are too often being placed in residual waste bins (including packaging consumed on-the-go) or rejected as contamination in paper and cardboard collections. While a quarter of municipalities in the UK and some municipalities in Germany (i.e. in Bavaria), Sweden and Spain collect material via bring sites, these collections are, while generally good quality, capturing a low proportion of cartons in the overall waste stream. A more effective way of collecting beverage cartons therefore seems to be co-mingled with other packaging via door-to-door collections, which is the case to some extent in all four countries assessed in the case studies. In the UK, only 68% of municipalities accept beverage cartons in their door-to-door collections[23] and door-to-door collection of packaging is generally not well developed in Spain, with a much greater reliance on larger on-street communal bins.

For all four countries, within door-to-door collections, beverage cartons are mixed with other types of packaging. In Germany, Spain and some municipalities in the UK carton collections are not mixed with paper or cardboard. This reduces the likelihood of beverage cartons being sent to papermills that cannot process, and therefore reject, them. This is often the case in Spain, where beverage cartons are regularly (and wrongly) placed in the blue paper/cardboard bins rather than yellow packaging bins and then subsequently rejected later in the process (see Section A.2.1). This is a problem particularly at sorting facilities that do not have more sophisticated processing technology such as near infra-red (NIR) optical sorters. Also, for facilities using mechanical sorting and eddy current separators to sort non-ferrous metals, the polymer/aluminium fraction in some cartons causes them to be falsely identified, and not properly separated in the sorting process. This is because aseptic (aluminium lined) cartons can 'jump' into the aluminium stream when passed through an eddy current separator, where they become a contaminant.[24] In the UK beverage cartons are the 7th most common cause for contamination in door-to-door collections that do not list them as target materials (see Section A.4.1.1).

[23] ACE UK(2019), accessed November2019, www.ace-uk.co.uk/home

[24] WRAP (2017) Collection of food and drink cartons at the kerbside, p.10

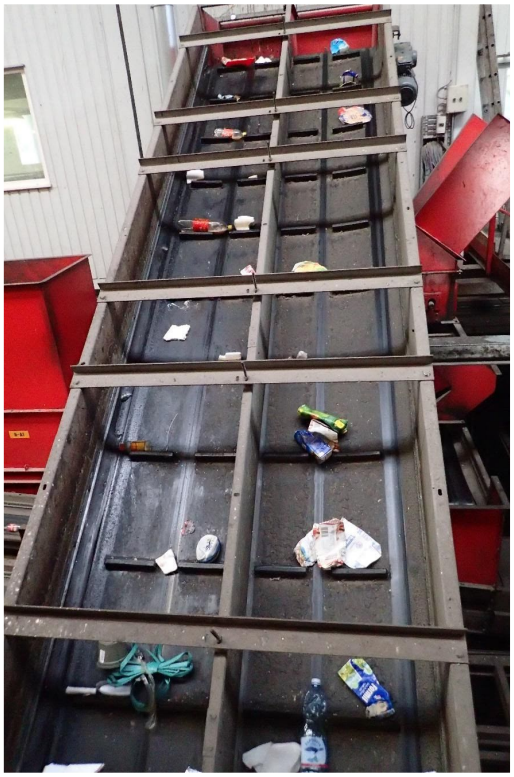

Figure 3.1: Sorting of Beverage Cartons

Figure 3.1 shows the sorting lines of household recycling collections, with the right-hand side of the line being for sorted beverage cartons and the left-hand side for all remaining materials. The image clearly shows other packaging, in this case a PET bottle, on the conveyor belt of the sorted beverage carton (right side). Further foreign material contaminants, such as Styrofoam and plastic film, are also commonly found in the beverage carton line.

Figure 3.2 below shows that manual separation of foreign material is required to ensure a pure sorting of beverage cartons. Figure 3.3 shows sorted bales of beverage cartons ready for processing in specialised mills.

Figure 3.2: Sorting of Beverage Cartons

Sweden operates a completely different collection system in which beverage cartons are collected and reprocessed together with other paper-based packaging. This means that cartons do not need to be separated out, as the entire collection is processed in one. While there is one specialised recycling facility (see section 3.2 for further details) in Fiskeby that has capacity to process all of Sweden's beverage cartons, it is not clear that all beverage cartons are sent there. In fact, as there are many other regular paper mills with cardboard recycling facilities, it can be assumed that at least some of the cartons will find their way to these due to mis-sorting. Whether they are then taken out and sent to Fiskeby or whether they are sent for alternative treatment such as waste to energy remains unclear.

In Spain, a government report estimates that it will be necessary to increase the net recycling of cartons to 110,000 tonnes. This will require a 300% increase in the selective collection of this material.[25]

[25] Ministerio de Agricultura, Alimentacion y Medio Ambiente (2015) *20151106PEMAR-2016_2022_apartado-13_pag96.pdf*, accessed 7 November 2019, www.aprr.eus/wp-content/uploads/2016/11/20151106PEMAR-2016_2022_apartado-13_pag96.pdf

Figure 3.3: Beverage Carton Bales

Germany's significantly better performance demonstrates that a widespread collection, sorting and recycling infrastructure of beverage cartons is a critically important part of increasing recycling rates. Germany has over 50 sorting centres spread across the country, ensuring comprehensive coverage of services and capacity to take what is being placed on the market. This is a sentiment mirrored by ACE, which is concentrating on identifying ways to increase collection rates across its membership.

3.2 Recycling Technologies

Due to the composite nature of beverage cartons, recycling them through traditional paper mills that process standard paper-based packaging products such as cardboard boxes, egg boxes and toilet roll centres proves inefficient. This is because these mills use a pulping process in which paper-based packaging is soaked for only two to four minutes. While this is sufficient time to separate fibres from the stickers and tape found on cardboard boxes, it is not sufficient time for the various laminated layers in beverage cartons to separate.
It should be noted that, technically, regular paper mills could process beverage cartons, but this would bring many challenges, one being that it would take nearly three times as long to process the cartons relative to a

specialised facility.[26] As this conventional pulping process happens in a large tank, wastewater needs to be regularly changed so as to not contaminate the paper fibres unnecessarily. Because of this complex and lengthy process, a high proportion of beverage carton material entering such mills tends to be rejected.

3.2.1 Specialist Recycling Processes

Specialised mills can use two different processes, single separation or full separation, as discussed below.

Single Separation
In this process, after separation from other waste streams, beverage cartons are baled and brought to the specialised recycling facility. They are normally delivered as a pure stream of beverage cartons and processed through a drum pulping system. In some countries, such as Sweden, beverage cartons remain combined with other paper-based packaging but go through the same specialised process using a drum pulping system. In this process, the cartons are washed intensively with water at ambient temperature for roughly 20 minutes, so that the paperboard fibres separate from the aluminium and polyethylene layers and dissolve into the water.

The paperboard fibre pulp is then put through a series of screening machines designed to filter out impurities such as glass, grit, and remaining polymer and aluminium. There are several available technologies for the removal of contaminants, but all can be categorised as either high-density and low-density cleaners and are used in conjunction. High density cleaners remove glass, grit, and stones, often in a centrifugal rotating system based on specific gravity. Low density cleaners then remove any remaining pieces of polymer and aluminium by passing the pulp mixture through a perforated screen. The fibre slurry is then thickened, and the water content reduced and passed on to a storage tank.

Full Separation
A full separation process uses the same initial techniques used in the single separation process, but with additional stages designed to separate the polymer fraction from the aluminium layers. There are two main processes used:

1) Pyrolysis/Gasification: The polymer/aluminium mixture is heated up to a temperature in excess of 400°C, with limited or no oxygen. The polymers are converted into gas and the energy recovered, while the aluminium fraction is recovered for material recycling.
2) Delamination/Solvent Separation: An organic solvent is used as a separation reagent and mixed with the polymer/aluminium fraction at a controlled temperature to maximise separation of the materials.

3.2.2 Recycling Infrastructure

There are just over 20 specialised mills in Europe that can process beverage cartons (as shown in Figure 3.4). Of the four countries researched, all use the single separation method, with the remaining polymer/aluminium fractions being incinerated for energy or co-incinerated by the cement industry, as is done in Germany. This

[26] FKN (2019), *Trennung von Verbunden ist kein Hexenwerk*, accessed 5 December 2019, getraenkekarton.de/recycling/technik/trennung-von-verbunden-ist-kein-hexenwerk

means that on average only 72.5% of a beverage carton, which is the fibreboard, can technically be recycled in these countries.
In the UK, beverage cartons are not shredded before pulping, while in Germany and Sweden they are, which speeds up the pulping process. The shredding stage may shorten average fibre length, and although fibres are subsequently recycled into cardboard products, where a long fibre length is not necessary, any shortening in average fibre length will impact on losses in future recycling cycles. However, the Fachverband Kartonverpackungen für flüssige Nahrungsmittel e.V (FKN), which is equivalent to ACE in Germany, confirmed in consultation that this impact is insignificant, as the shredded pieces are still approximately the size of the palm of a hand.[27] It is not known what practice is currently used in Spain as the paper mills that we contacted did not respond.

Some of the key factors impacting beverage carton recycling rates are whether mills have capacity to process the volumes of beverage cartons being collected and sorted, and whether they have the geographical coverage to ensure that transportation logistics are feasible and cost effective – and that therefore sending beverage cartons to be used for waste to energy is not seen as a more economically attractive.

Germany has three specialist mills that together provide full national coverage. Meanwhile, the UK and Sweden only have one specialist mill each; it was not possible to ascertain how many specialist mills Spain has, if indeed it has any. The availability of specialist processing mills with the capacity to process the tonnages being placed on the market (the UK plant's annual capacity, for example, is 25,000 tonnes while 60,000 tonnes of material is being placed on the market) combined with a better segregated waste stream coming from the collection stage of the supply chain, has a direct positive impact on the recycling rate of beverage cartons.

Figure 3.4: Recycling Mills in Europe (Source: ACE website. www.beveragecarton.eu/beverage-cartons/recycling/collection#.U1-_8_mSwrU Accessed 13th December 2019)

[27] Personal correspondence FKN, October 2019

3.2.3 Polymer/Aluminium Recycling

While the fibre content of beverage cartons can be recycled into other, albeit lower grade fibre products, the polymer/aluminium content is more challenging to recycle. Typically, this fraction is sent to waste to energy treatment. In Germany, at one time 40% of the polymer/aluminium components were being separated and recycled to produce plastic pellets. However, the facility which was doing so closed in 2014 after four years of operation, due to the process being financially unfeasible compared with other disposal routes. An additional plant in China, which has a capacity of 30,000 tonnes per year, was also used to process these rejects from Germany. Since China introduced import bans in 2018, however, Germany is no longer exporting its beverage carton polymer/aluminium rejects there. In Spain, the Stora Enso plant, which was separating the polymer and aluminium, also closed after four years of operation, in 2015.

A lack of solutions for this fraction impacts on the recycling rate for beverage cartons, as under the new recycling measurement method, the recycling rate of a composite packaging type is determined by the combined recycling rates of its component parts. In Germany, beverage carton manufacturers are planning to open a plant in 2020 to tackle this challenge (see Section A.1.1.3). It is not clear, however, if this plant uses a different process to the other factories, and whether its economic viability is therefore safeguarded. At the time of writing, this plant was not yet operating.

ACE is currently exploring new market routes across its members via its EXTR:ACT project. Options include using the composite fraction as a shiny additive in garden furniture, pens, and flowerpots, and making use of technology that can separate the polymer/aluminium fraction into sperate polymer and aluminium streams.

4.0 Recycling Performance

4.1 Policy

Germany's environment agency Umweltbundesamt (UBA) has set recycling targets of 75% specifically for beverage cartons, so there is both a driver and a defined way to measure recycling performance. Spain, Sweden and the UK do not have such specific targets for beverage cartons, and this is reflected in the low collection and recycling rates achieved by these countries. ACE believes that without a metric to show recycling performance, countries lack a reason or incentive to invest in the necessary collection and processing infrastructure.

At the time of writing, there are no known deposit return schemes in place for beverage cartons in Europe. In Germany, the environmental impact of beverage cartons has historically been classed under the former Packaging Ordinance (VerpackV) as "ecologically beneficial" and has therefore been exempt from deposit return schemes. This is due in part to its apparent high recycling performance, which is assessed at regular intervals.

4.2 Placed on the Market Data

The most recent data published by the Umweltbundesamt (UBA), Germany's environment agency, shows that the volume of beverage cartons placed on the German market reached 176,100 tonnes in 2017.[28] In the UK, roughly 60,000 tonnes of beverage cartons have been placed on the market annually in recent years.[29] Unlike in Germany, the milk packaging market in the UK is dominated by HDPE bottles, so the quantity of beverage cartons used per capita is significantly lower, with beverage cartons mostly used in juice applications. For Spain and Sweden, placed on the market data was made available to Eunomia through a confidential source. While this data was used for calculations of market-specific recycling rates within this report, the exact volumes cannot be published at this time.

4.3 Recycling Rates for Each Country

Under the EU Packaging Regulations,[30] obligated companies placing packaging on to the market need to make a calculated contribution towards national recycling targets, based on their outputs. Of the four countries assessed, only Germany has a recycling target specifically for beverage cartons.

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[28] Umweltbundesamt (Germany) (2019) *Aufkommen und Verwertung von Verpackungsabfällen in Deutschland im Jahr 2017*, 2019

[29] ACE UK (2014) *ACE UK Recycling Fact Sheet*, accessed 5 December 2019, www.cravendc.gov.uk/media/1048/6603_ace_uk_recycling_factsheet_low_res.pdf

[30] Directive 2004/12/EC of the European Parliament and of the Council of 11 February 2004 amending Directive 94/62/EC on packaging and packaging waste (OJ L 47/26 of 18.2.2004)

The overall EU beverage carton recycling rate for 2019 published on the ACE website is 51%.[31] There has been a 1% increase each year for the previous two years. ACE confirmed to us that this is an average recycling rate. ACE uses country specific data based on statistics it receives in reports made by waste management and packaging recovery organisations. In cases where such official data does not show specific details about beverage carton recycling, ACE uses industry assessments based on data collected from waste management companies and recyclers.[32] While some countries provide very accurate data due to EPR targets and requirements, for other countries recycling rates could be averages or estimates. This shows that the EU as whole is not currently following a consistent calculation methodology and that data accuracy poses a challenge.

The average 51% recycling rate reported by ACE[33] demonstrates that a substantial amount of this packaging is either not being collected (and is lost, such as in residual waste) or is lost in the sorting and recycling process and therefore being incinerated rather than recycled. Also, the reporting of data under current EU regulations does not require packaging to be listed by individual medium types, so data on beverage cartons can be absorbed into paper and cardboard numbers. This makes achieving transparency around actual numbers of beverage cartons placed on the market, as well as what is collected and recycled, a challenge. This is discussed later in the report.

ACE shared the individual country recycling rates for Germany, Spain, Sweden and the UK, as can be seen in Table 4.1. ACE has acknowledged that its reported beverage carton recycling rates do not take the new recycling rate calculation methodology into account (see Section 4.3.1), and it does not envisage this methodology being used until mid-2022, when countries are legally obligated to do so.[34]

4.3.1 Recycling Rate Calculation

New EU rules issued in April 2019[35] give clarity on how to undertake recycling rate calculations, providing one consistent methodology to be used by all Member States, ensuring that all recycling rates factor in the same elements and are calculated at the same point in the process. According to these rules, the point at which Member States should calculate recycling rates varies for each material type. For composite packaging, each material contained in the packaging should be calculated and reported separately, unless a material component makes up an insignificant (<5%) proportion of the overall packaging, in which case it can be included within the reporting of other material types. In the case of beverage cartons, we can therefore distinguish between the following material types and their points of calculation:[36]

- Paper: sorted paper that does not undergo further processing before entering a pulping operation.

[31] ACE (2020) ACE ANNOUNCES INCREASED RECYCLING RATE FOR BEVERAGE CARTONS, www.beveragecarton.eu/news/ace-announces-increased-recycling-rate-for-beverage-cartons, accessed November 2020

[32] Personal correspondence with ACE, December 2019

[33] Personal correspondence with ACE, November 2019

[34] European Commission (2020) Reporting on Packaging Waste, ec.europa.eu/eurostat/documents/342366/351811/Legal+reference+reporting

[35] COMMISSION IMPLEMENTING DECISION (EU) 2019/ 665 - of 17 April 2019 - amending Decision 2005/ 270/ EC establishing the formats relating to the database system pursuant to European Parliament and Council Directive 94/ 62/ EC on packaging and packaging waste - (notified under document C(2019) 2805)

[36] COMMISSION IMPLEMENTING DECISION (EU) 2019/ 665 - of 17 April 2019 - amending Decision 2005/ 270/ EC establishing the formats relating to the database system pursuant to European Parliament and Council Directive 94/ 62/ EC on packaging and packaging waste - (notified under document C(2019) 2805), p.21

- Plastics: plastics separated by polymer type that do not undergo further processing before entering pelletisation, extrusion, or moulding operations; or plastic flakes that do not undergo further processing before their use in a final product.
- Metals: sorted metals that do not undergo further processing before entering a metal smelter or furnace.

For aluminium, the guidance clarifies that "aluminium recycled after separation from incineration bottom ash shall be reported separately and shall not be included in the row for reporting aluminium."[37]

ACE has acknowledged that the beverage carton recycling rates it reports do not take the new recycling rate calculation methodology into account. It does not envisage this methodology being used until mid-2022,[38] when countries are legally obligated to do so. ACE has created a project team called EXTR:ACT, which will look to support it in verifying data reporting.

Research conducted across the sample countries has demonstrated that the point at which a 'recycling rate' is calculated can vary, given that some municipalities, plants or mills might quote a percentage based on a range of metrics including the amount sorted, amount collected, amount taken into the processing plant, etc. However, the amount lost during processing, as well as additional weight gained due to product residue or excessive moisture will have an impact on measured tonnages.

4.3.2 Calculating New Recycling Rate Estimates

Based on data collected in desk research, supplemented with data gathered in telephone interviews and e-mail consultations with stakeholders in each country, we used the new rules issued by the EU to calculate recycling rate estimates for Germany, Spain, Sweden and the UK.

We further drew on a fully mapped out beverage carton collection and processing flowchart, created by DUH, which shows percentage losses identified at each stage.[39] Our research builds on this diagram, using the same process stages and applying country-specific losses where known.

Gathering data on the actual tonnages collected, the loss rates experienced during further treatment, and on how the infrastructure for collection and recycling operates across the four countries proved challenging. For each country we have found and applied key data for our own calculations, and where verified country specific data has not been available, the German percentages have been applied for loss rates and moisture and contamination, due to these being validated data, in some cases from multiple sources.

It should be noted, however, that this approach needs to be treated with caution, as the beverage carton specific information, such as the design and use of cartons, for beverages or sauces for example, dictate the average composition and possible losses due to contamination by moisture, dirt and other materials in each country. Therefore, as the range of products packaged in cartons, as well as their representative share of the carton

[37] Ibid.

[38] Personal correspondence with ACE, November 2019

[39] Deutsche Umwelthilfe (2019) *Recycling von Getränkekartons in Deutschland 2016*, September 2019

packaging market, is not the same from country to country, applying German percentages across the board runs the risk of misrepresentation. Nevertheless, doing so was the most accurate method available.

Some of the key data points we used in our calculations were:

- Placed on the market data (country specific sales data);
- Cartons collected for recycling (as opposed to cartons collected in residual waste);
- Sorting rejects (cartons lost or not suitable for recycling, including contamination); and
- Contamination in or on the cartons:
    - Foreign materials (e.g. foils, straws, pieces of glass); and
    - Moisture and dirt (e.g. leftover beverage or sauces that remain in the carton as well as any dust or debris sticking to this).

The specific data used is detailed in the assumptions for each calculation, which are provided in the Appendices (Sections A.2.0 to A.4.0).

Table 4.1 below presents the recycling rate estimates we calculated by applying the EU measurement rules to the data collected through our research, along with country collection rates and ACE country recycling rates. These rates reflect how recycling performance will be measured in future.

	Germany	Spain	Sweden	UK
Collection rate[40]	87.4%[41]	51.2%[42]	40.1%[43]	48%[44]
ACE data - country recycling rate	75%	80%	33%	36%
Eunomia - calculated recycling rate estimate	47.8%	21.4%	21.9%	29.5%

Table 4.1: Summary of Collection Rates and Recycling Rate Estimates (2020

As the table shows, when applying the new rules and average loss rates for the plants, most rates are significantly lower than ACE's average rate for the EU of 51%.

Germany has the highest recycling rate but there is still a significant loss of material between what is collected (85.3%) and what is recycled. Germany has a 15% loss rate due to moisture and contamination found in collected cartons, likely due to the fact that consumers are only required to present the packaging 'spoon clean', as opposed to being rinsed as is required in the UK.

For Spain, Sweden and the UK, all of which also experience a loss of material, their initial low collection rates mean that their recycling rate estimates are significantly lower.

[40] Includes foreign materials, dirt and moisture and does not depict the actual tonnage of cartons placed on market

[41] Calculated by Eunomia

[42] Calculated by Eunomia

[43] Institut für Energie- und Umweltforschung Heidelberg (ifeu) (2017) *Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for liquid food on the Nordic market*, April 2017

[44] WRAP (2017) Collection of food and drink cartons at the kerbside, p.7

5.0 Wider Environmental Impacts

Although a detailed consideration of wider environmental costs and benefits associated with beverage cartons is outside the scope of this report, the findings raise some important issues for a more holistic assessment of this packaging format.

Life Cycle Assessment (LCA) is a tool used to provide a systematic framework to identify, quantify, interpret and evaluate the environmental impacts of a product, function or service in an orderly way. It is often used as a method of comparison between existing products or services or with a new design proposal. Several organisations have carried out LCAs comparing beverage cartons to other beverage packaging such as PET and glass single or multi-use bottles.

In most widely cited, published studies, beverage cartons perform well in comparison with other packaging formats. For example, in the LCA published on the ACE web site, they are shown to have the lowest impact for greenhouse gas emissions when compared with other types of packaging, such as PET, HDPE and glass bottles, metal cans and stand-up pouches, for juice and fresh milk (when compared with single-use packs), largely due to the renewable, biogenic origin of the paperboard element of the carton. Against a multi-use glass bottle, however, beverage cartons do not perform as well.[45]

The Institute for Energy and Environmental Research (ifeu) in Germany has carried out several LCAs for beverage cartons which have arrived at broadly consistent conclusions. Notable ones are a comparative LCA of Tetra Pak® carton packages and alternative packaging systems for liquid food on the Nordic market published in 2017 and an LCA comparison of composite beverage cartons with PET non-returnable and reusable glass bottles in the juice / nectar, long-life milk and fresh milk beverage segments on behalf of FKN and published in 2018.[46]

General LCA guidance shows that there are many parameters that will influence the outcome of an LCA, and although carbon footprint is often a significant focus, the LCA methodology also considers a range of other environmental impacts such as on water, land and air pollution. Performance of an item depends on the system boundaries in which it is being compared – e.g. in terms of geography, substrate and whether a packaging type is used once or multiple times, such as refillable glass milk bottles. This is demonstrated by a German LCA commissioned by FKN. This study stated that beverage cartons perform better than reuse bottles, but was subsequently criticised by DUH for using inaccurate recycling rates for the beverage cartons and longer than average transport distances for reusable bottles.

The Europeans Commission's Product Environmental Footprint (PEF) guidance issued in May 2018 requires the use a Circular Footprint Formula that seeks to take into account the 'downcycling' of a material at the end of a product's life and includes an allocation for a proportion of material being incinerated.[47] This suggests a direction of travel in LCA methodology towards seeking to more fully reflect the whole useful life of the materials that make up a product, including future recycling and use cycles.

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[45] von Falkenstein, E., Wellenreuther, F., and Detzel, A. (2010) LCA studies comparing beverage cartons and alternative packaging: can overall conclusions be drawn?, *The International Journal of Life Cycle Assessment*, Vol.15, No.9, pp.938–945

[46] Institut für Energie- und Umweltforschung Heidelberg (ifeu) (2018) *FKN Ökobilanz 2018*, Report for Heidelberg, December 2018

[47] *European Commission, PEFCR Guidance document, - Guidance for the development of Product Environmental Footprint Category Rules (PEFCRs), version 6.3, December 2017*, eplca.jrc.ec.europa.eu/permalink/PEFCR_guidance_v6.3-2.pdf

Regarding the historic treatment of the beverage carton in LCAs in the context of emerging thinking on environmental appraisal of products, there are two issues of interest to highlight:

- **Recycling**: comparative LCA calculations use the various recycling rates of different packaging types in comparing them, although the recycling data used in the LCA is not always provided. The approach taken to calculating recycling rates can have a significant impact on the outcome, for example as a result of the new recycling rate calculation introduced in the EU in April 2019. While the recycling rate estimates calculated in this study follow the EU calculation model, they do not factor in further losses that occur in the recycling process, such as fibre losses in the pulping stage. It is only when a recycled material makes it into a new product that we begin to obtain environmental benefit to offset the impacts of the collection, sorting and recycling processes. Therefore, it is really this material yield into new products that should be considered in evaluating the environmental costs and benefits of different end of life fates of different products and materials.
  This can be challenging in an LCA when considering the circularity of a product which undergoes multiple loops, with each loop being subject to further material losses. However, it seems clear that to accurately compare products comprised of different materials with different end of life fates, we will need to build models that reflect the whole life of those materials much more fully. Given the recycling challenges inherent in the beverage carton, it seems likely that taking 'circular LCA' thinking to its logical conclusion could significantly influence beverage carton performance in LCAs.
- **Fibre sources and biogenic carbon**: most LCAs assume that wood pulp derived fibre is carbon neutral as its carbon content is biogenic in origin. While trees harvested for beverage carton production in Europe will be replaced, there will be a time lag in the extent of carbon sequestration between an aged tree and a newly planted seedling. Often, the solution is to plant more trees than are being harvested but matching the sequestration of carbon of the felled mature tree using this approach is still subject to a significant time lag.

The fibre pulp used to produce beverage cartons in Europe currently originates from virgin material derived from slow growing conifers from northern latitudes that can provide the particularly long, high quality fibres required. This gives rise to several related issues when considering the environmental impact of the raw materials used in the beverage carton. Firstly, in a 'climate emergency' context there is increasing focus on the role that emissions from biogenic sources of carbon may have on climate change, given the time lags between emitting the biogenic carbon into the atmosphere (for example through waste incineration) and the sequestration of an offsetting quantity of CO_2 through the planting of new biomass. This issue is amplified where the mature tree felled is relatively old and large and has therefore sequestered a relatively high quantity of CO_2 in its lifetime, as this increases the likely time lag in offsetting the emitted carbon.

As well as relying on relatively slow-grown sources of pulp, the beverage carton cannot use recycled fibre, so it is not able to benefit directly from the avoidance of primary pulp use through use of recycled content, which may become more important as circularity is more fully factored into LCAs. As these considerations of biogenic carbon emissions are likely to receive increased focus in the context of the drive towards a net-zero carbon European economy, they may raise particular issues for beverage cartons.

In the context of the drive towards a circular economy, the recycling challenges facing the carton and the increasing focus on the impact of non-fossil sources of carbon emissions suggest that it may be appropriate to revisit beverage carton LCAs to ensure that as objective a comparison as possible is being made with other packaging types.

6.0 Key Circularity Challenges

Although the renewable, biogenic raw material that makes up a large part of the beverage carton can make it an attractive option from an environmental perspective, the increasing focus on recyclability, recycled content and overall 'circularity' of single-use items presents a significant challenge for this packaging format. In particular, the potential circularity of the beverage carton is currently hampered by:

- High losses in collection and sorting systems due to relatively low separate collection rates and high sorting losses;
- A lack of ability to use recycled content in the fibreboard body and plastic elements that come into direct contact with food or drink, leading to a reliance on virgin materials; and
- Significant losses of material in reprocessing due to the need for specialised material preparation and pulping infrastructure to optimise fibre recovery, as well as the challenges inherent in the package design regarding recovering the aluminium and plastic components as materials for recycling.

Even in top-performing countries such as Germany, these factors combine to result in high losses of material in the waste management system and, in the context of the EU's new measurement method for recycling, consequent low recycling rates relative to other beverage packaging formats. The further losses of material in the recycling process, resulting from a combination of packaging design and limitations in recycling infrastructure, mean that the environmental benefits obtained in terms of reutilisation of high-value material are limited. The lack of uptake of recycled material in beverage cartons further undermines circularity by inhibiting potential for closed loop recycling. These issues and their potential solutions are elaborated upon below.

6.1 Effective Collection and Sorting Systems

To improve recycling rates, having in place nationwide collection infrastructure capable of capturing higher percentages of beverage cartons is an essential starting point. Failing to capture material at the collection stage is a particularly acute issue for products or materials that are prone to subsequent losses later in the recycling process.

Reported collection rates in each of the countries analysed in this study show that many beverage cartons placed on the market are not captured in targeted collection systems. Even the highest collection rate of nearly 85% seen in Germany still includes moisture and contamination, with the rate of 'pure' carton material collected being lower.

In mixed collection systems, particularly when paper is part of the target material as is the case in some UK municipalities, then beverage cartons may be lost into paper or cardboard streams and a significant proportion rejected at a later stage by conventional board mills. Indeed, in any system where cartons are co-mingled with other materials at the point of collection, losses will occur during the sorting process. Although cartons can be sorted with a high degree of accuracy due to their distinctive infrared signal, generating high-purity bales of cartons inevitably leads to losses of cartons. As a general rule, the more materials that are co-mingled and the higher the quality specification of the outputs, the higher the losses of target material will be. As such, collecting cartons in simpler material mixtures, or in combinations that are relatively easy to sort from one another due to

material composition, size and shape, are likely to reduce sorting losses relative to, for example, collecting cartons co-mingled with all other packaging or with all dry recyclables.

To truly maximise collection rates, minimise sorting losses and maximise material quality, Deposit Refund Schemes (DRS) are likely to provide the most effective solution. DRS have proven to be a highly effective way of collecting beverage packaging, showing collection rates ranging between 80% and 99% for well-designed and implemented schemes. Unlike today's reported collection rates from regular door-to-door collections, these rates do not include moisture and contamination in the figures, as they are based on the number of items placed on the market rather than mass. As the collection of cartons would be separate from any other material, the need for sorting and consequent sorting losses would be eliminated. This would require significant investment into adapted or new reverse vending machines, but seems the most feasible way to maximise capture of material for recycling.

As demonstrated in this report, recycling rates are closely linked to collection rates and therefore country specific recycling targets, such as those seen in Germany, would help ensure that more focus is given to ensuring an effective collection system. Combining a consistent approach to calculation using the new measurement method set out by the EU with country-specific recycling targets for beverage cartons would create a driver for increased performance and the establishment of external data verification mechanisms. All of this would provide greater clarity on the sources of the data that countries are providing to ACE. ACE is exploring ways to review and validate the data it is sent, and is itself calling for country specific targets with external verification.

6.2 Recycling Infrastructure and Technologies

Specialist mills are needed to process cartons prior to pulping and to facilitate the longer pulping process residence times required to break down beverage cartons into their material components and dissolve the fibres, allowing reprocessing into alternative products. There are just over 20 of these specialised mills in Europe, with varying levels of capacity. While our case study shows that the three specialised mills in Germany provide adequate coverage and capacity to process beverage cartons in this particular market, our other case studies demonstrate that this is not the case for all European countries.

If these types of mills are not present in a market, are difficult to reach or do not provide the required capacity, many beverage cartons that could otherwise be recycled (or partially recycled at least) end up being rejected and sent to waste to energy plants. It is crucial when deciding on plant locations to also consider the overall scale of beverage carton processing in one single market, as well as across several markets where countries are small (e.g. Luxembourg). As with any capital-intensive facility, specialist mills will require economies of scale to ensure long-term economic viability.

As discussed in section 3.2.3, the polymer/aluminium fraction in cartons is currently not recycled, but processed in incineration and co-incineration facilities. Specialist plants that can separate and recycle the two materials were once operating in Germany and Spain, but both closed after only a few years due to lack of economic viability. A new plant by the FKN owned subsidiary Palurec GmbH is currently under construction in Germany and was scheduled to open in 2020; however, no recent literature was found to confirm the state of this facility. It is not yet clear what technologies would be used by Palurec and how economic viability will be safeguarded, although it is notable that it is financially backed by the three largest beverage carton producers in Europe.

While chemical recycling technologies are far from commercially mature, they have the potential to address some limitations found in mechanical recycling. These technologies involves a high-temperature processes that in some cases show promise in processing complex waste plastics, such as the polymer/aluminium fraction found in composite packaging like beverage cartons, for conversion into raw materials such as pyrolysis oil or synthesis gas, which can substitute primary hydrocarbons in both energy and other chemical products, including plastics. They are, however, energy intensive and high cost processes relative to conventional mechanical recycling and considerable further development of the technology and market needs to occur such technologies are shown to be financially and environmentally feasible at scale.

6.3 Improved Eco Design

The fact that beverage cartons are primarily composed of fibre content from trees (a renewable source) does not alone ensure either their recyclability or sustainability. The need for long and strong fibres requires that the cartonboard in beverage cartons use a virgin fibre source. At the end-of-life of the beverage carton, once the fibres are reprocessed and thereby shortened, the only possible applications for them are cardboard applications, such as pizza boxes.

There is evidence that some manufacturers are taking steps to make beverage cartons more circular. Tetra Pak, for example, has set out aspirations for creating the ideal packaging of the future, with measures including:[48,49]

- Increasing the share of renewable materials, by removing or replacing fossil-based plastic with plant-based alternatives;
- Increasing the use of recycled polymers and paper; and
- Developing design features that reduce the likelihood and/or impact of littering, such as paper straws (though these are likely still wrapped in plastic film), non-detachable alternatives to conventional straws, and tethered caps.

While Tetra Pak's ambition is to "use renewable and/or recycled polymers for the plastic layer, or an alternative fibre or cellulose-based material",[50] this does not solve issues with the lack of end-of-life reprocessing technologies. Furthermore, there are legal constraints for the use of recycled materials in food contact packaging, as Tetra Pak recognises. There are also plans to replace the aluminium barrier, though details have not yet been revealed.

Fuller circularity, based on closed loop recycling, which Tetra Pak is striving to achieve, however, needs to consider materials being returned into the product packaging rather than being recycled into another product. So far there is little evidence to show that this is possible based on current recycling technologies.

[48] TetraPak, Sustainable Packaging, www.tetrapak.com/sustainability/customer-focus/sustainable-packages, accessed 26.09.2020

[49] beveragedaily.com *Tetra Pak: 'The ideal package of the future is made solely from renewable or recycled materials, is 100% recyclable, and supports a low-carbon circular economy'*, accessed 28 October 2020, www.beveragedaily.com/Article/2020/09/02/Tetra-Pak-aspires-to-the-ideal-beverage-pack-of-the-future

[50] Ibid.

APPENDICES

A.1.0 Appendix 1 – Germany Case Study

A.1.1 Country Waste Infrastructure

Due to the significance of beverage cartons in Germany, the industry has its own trade association called Fachverband Kartonverpackungen für flüssige Nahrungsmittel e.V. (FKN). FKN's members are the three main manufacturers Tetra Pak, SIG and Elopak. ReCarton GmbH is a wholly owned subsidiary of FKN and was founded in 1991 with the introduction of the packaging EPR "Duales System" in Germany. As a so-called "guarantor", the task initially consisted of developing a market for this new wastepaper fraction and ensuring that all beverage cartons were recycled in accordance with the provisions of the Packaging Ordinance. This required substantial investment in the early years. Since the introduction of competition for packaging EPR providers in 2003, ReCarton has been a service provider of the dual system companies. It concludes agreements with paper mills, appoints transport agencies to pick up the material from the sorting plants and records material flow volumes to report exactly how many beverage cartons were used in which plants to the ministries of the environment.[51]

A.1.1.1 Collection

Germany's collection systems are largely shaped by Packaging EPR introduced in 1991. In most of Germany, beverage cartons are collected door-to-door together with other packaging, except glass, paper and cardboard, in a separate bin or bag, often just referred to as yellow bin/bag. Bavaria shows a different collection landscape.

Some municipalities here operate a bring system in which packaging is separately collected in defined recycling centres, making up less than 10% of Germany's total collections according to FKN[52]. This means that the consumer must separate the packaging waste at home and bring the individual items (e.g. beverage cartons) to their local recycling centre. While this offers a high quality of recyclate, the barriers of the bring system are higher cost and lower volumes than from door-to-door collections, which means that recycling targets set by the German environment agency Umweltbundesamt (UBA) may not be met. Therefore, more and more collection systems from door-to-door are being rolled out nationwide to supplement existing bring systems.

Beverage cartons do not need to be washed. They merely need to be "spoon clean". While this has no big impact for beverage cartons containing milk or juices, cartons containing yoghurt or sauces or similar will weigh heavier.

[51] FKN *ReCarton*, accessed 12 November 2019, getraenkekarton.de/ueber-uns/recarton/wertstoffgewinnung-aus-getraenkekartons

[52] Personal correspondence with FKN, October 2019

A.1.1.2 Sorting

The packaging waste collected in yellow bins and bags is then transported to a sorting station. It is unclear whether the separately collected beverage cartons in Bavaria's municipalities are sent directly to a paper mill or enter the sorting station first. According to FKN, Germany's total sorting capacity is 200,000 tonnes per annum, processed in approximately 50 facilities. ALBA Group Europe (www.alba.info), has the majority of Germany's market share, owning around 5 or 6 of the largest facilities. There is a general downward trend in sorting facilities with smaller providers closing under financial pressures resulting from investment needs in new technology.

A.1.1.3 Reprocessing

Germany has three facilities that can process beverage cartons for recycling. They are located in different parts of the country and cover all of Germany's beverage carton reprocessing. Each of these facilities is equipped with a specialist drum for processing the cartons which is three times faster than traditional pulping in paper mills. They are:

- Raubling Papier GMBH, processing approximately 1/3 of the total collected beverage cartons in Germany (raubling.heinzelpaper.com);
- Delkeskamp (www.delkeskamp.de) ; and
- N + R Getränkekarton Recycling GmbH, a joint venture between ReCarton GmbH and paper mill Niederauer Mühle (niederauer-muehle.de).

None of the above organisations were available for comment at the time of writing.

Before the cartons enter the pulping process, they are shredded into pieces roughly the size of the palm of a hand. The fibre pulp is then used to make new carton packaging applications such as pizza cartons and corrugated board, i.e. into products that do not require specifically long fibre lengths.

In Germany, the plastic and aluminium residues are currently used in waste incineration plants or cement factories. Compared to material recycling, this disposal route is low on the waste hierarchy and seen as disadvantageous from an environmental point of view. Though having a high calorific value, plastics films and closures made of LDPE, HDPE and PP merely become a replacement for fossil fuels. The aluminium content turns into aluminium-oxide in the burning process in cement factories and replaces bauxite to improve the setting properties of the cement. Aluminium is produced from bauxite, which is an energy consuming process, and is therefore considered to be of higher grade or value. Replacing the lower grade bauxite with aluminium in the cement making process means that this energy becomes redundant and is essentially wasted.[53] In the absence of facilities that can separate the polymer/aluminium composite, however, having a process in place to use the aluminium is therefore still better than landfilling it.

FKN believes that rising raw material prices make the option for material recycling feasible.[54] It was also stated, however, that APK AG in Merseburg, Germany carried out separation of the plastics and aluminium compounds using innovative technology. This resulted in material recovery of 40%. The plant only operated for four years

[53] Deutsche Umwelthilfe (2014) *Das Märchen vom umweltfreundlichen Getränkekarton*, November 2014

[54] FKN *Trennung von Verbunden ist kein Hexenwerk*, getraenkekarton.de/recycling/technik/trennung-von-verbunden-ist-kein-hexenwerk

between 2010 and 2014, halting this specialised recovery process due to cost. A representative of FKN explained that due to the high volumes of waste generated globally, prices for disposal are rising, including the cost to send recycling rejects from the beverage recycling process to cement factories, which is priced at over €100/tonne at the moment. This makes this route of disposal not economically feasible and therefore alternatives need to be considered. Therefore, FKN founded Palurec GmbH in 2018. The €8 million recycling plant, which is meant to start operation in 2020, will recover plastic and aluminium from beverage carton packaging, i.e. from rejects of the specialist pulping process. Materials will be recovered from aluminium and LDPE foils as well as HDPE closures. The recycling operation, with an annual capacity of 18,000 tonnes, is conducted on segregation units, "which have already proved their capability during many years in service and which are able to mechanically/physically separate such inhomogeneous material mixtures," Michael Brandl, former Managing Director of Palurec.[55]

A.1.1.4 Calculating the Recycling Rate Estimate

Since 2019, German law set a packaging recycling target of 75% specifically for beverage cartons. It replaces the 60% target that was initially set for general composite materials. From 2022, Germany's target for beverage carton recycling will increase to 80%.[56]

The UBA publishes the recycling rate each year. In their 2018 report on the Emergence and Recycling of Packaging waste in Germany in 2016, a rate of 77.6% is quoted.[57] This rate, however, is based on the weight of returned beverage cartons, which in Germany includes considerable amounts of food and drink residues as cartons only need to be returned "spoon clean" and not rinsed as is necessary in the UK, for example. The returned cartons also contain foreign materials such as foils, straws and other pieces of residue which have found their way inside or onto the carton either deliberately (e.g. someone sticking the straw into an on-the-go beverage carton) or accidentally (resulting from collections with other materials).

The use of this rate in previous life cycle assessments (LCA) was heavily criticised by DUH which led the organisation to produce their own calculation correcting the overall recycling rate down to just under 36% in both 2014 and 2016. DUH's recycling rate calculations for 2016 considers the following assumptions:

1) Sorting rejects of 11.2%;
2) Contamination of collected cartons with approximately 12.5% foreign materials and 17% dirt and moisture, which means a total of just under 30% needs to be removed from the weight of collected cartons to show pure cartons;
3) A carton composition of 70% paper, 27% polymer and 3% aluminium;
4) A third of the polymer/aluminium fraction of cartons being exported and recycled in China, which was halted in 2018; and
5) A loss rate of approximately 20% in paper recycling.[58]

[55] PlastEurope.com (2019) *Beverage Carton Recycling*, accessed 12 November 2019, www.plasteurope.com/news/BEVERAGE_CARTON_RECYCLING_t242958

[56] Umweltbundesamt (Germany) (2019) *Verpackungen*, accessed 5 December 2019, www.umweltbundesamt.de/themen/abfall-ressourcen/produktverantwortung-in-der-abfallwirtschaft/verpackungen#textpart-2

[57] Umweltbundesamt (Germany) (2019) *Aufkommen und Verwertung von Verpackungsabfällen in Deutschland im Jahr 2017*, 2019

[58] Deutsche Umwelthilfe (DUH) (2019) Recycling von Getränkekartons in Deutschland 2016

The latter was reviewed in a communication between FKN and Papiertechnische Stiftung (PTS) in 2014[59] and deemed as incorrect. It was, however, left open as to whether this loss rate does not apply at all or whether it was simply too high. The average loss rate within paper and cardboard recycling ranges between 11% and 27%.[60] The use of longer fibres in the original production of beverage cartons will likely put the fibre losses within the pulping process on the lower end of this; we are using the median of 19% to allow for the total life cycle of the fibres, which are being downcycled into regular cardboard applications. This does not affect the calculation of the recycling rate estimate, as these losses only come into the picture during the pulping process. It needs to be recognised, however, that further losses take place and not all of the cardboard materials of a beverage carton are recycled into new products as such.

The loss rate of 11.2% at the sorting stage referenced by DUH is laid out in ifeu's most recent lifecycle assessment of beverage cartons.[61] This rate sees a slight increase from the previously referenced 10% reject rate. Our calculation includes the most recent rate of 11.2%.

While it is acknowledged that some of the polymer/aluminium fraction were previously recycled in Germany and China, this is no longer the case, as confirmed in consultation with FKN.[62] The polymer/aluminium fraction is indeed currently sent for incineration due to the high calorific value of the polymer. The aluminium is recovered from the process and added to cement production. This might change in future, as discussed in Section A.1.1.3. As detailed in Section 4.3.1, although the aluminium is technically recycled, as we have found no evidence that the aluminium is separated from incineration bottom ash, it may not be counted into the recycling rate.

The beverage carton composition has been corrected by us as discussed in section 4.3.1.

In their latest LCA on beverage cartons in Germany (2018), ifeu has adjusted UBA's recycling rate to a rate of 64.7%[63] by including losses for foreign materials and moisture at a rate of 15%. This is much lower than the nearly 30% used by DUH, but is the same percentage reported by the UBA in 2011.[64] This loss rate data is the most recent and is being used by two different organisations, one of which is the German Environment Agency (UBA) and so was used in our calculations instead of DUH's percentage which seems very high and could not be verified due to confidentiality reasons.
The most recently published, placed on the market figures by the UBA are from 2017 and stand at 176,100 tonnes.[65] In the same report, it is also confirmed that 136,700 tonnes of material are sent for recycling (i.e. collected excluding sorting rejects but including contamination such as moisture, dirt and foreign materials).[66]

Adding all these assumptions into our calculations and using the EU guidance on calculating the recycling rate estimate (see section 4.0) provides a new recycling rate of 47.8%. When looking at the losses occurring in the pulping process but adding the recycled aluminium which is omitted from the EU guidance, only 41.1% of the cartons are indeed recycled into new products.

[59] Papiertechnische Stiftung (2014) *Ihre Anfrage per Email am 25.09.2014*

[60] Van Ewijk, Stegemann and Ekins, (2017). *Global Life Cycle Paper Flows, Recycling Metrics, and Material Efficiency*, Journal of Industrial Ecology, 22(4), pp.686-693.

[61] Institut für Energie- und Umweltforschung Heidelberg (ifeu) (2018) *FKN Ökobilanz 2018*, Report for Heidelberg, December 2018

[62] Personal correspondence with FKN, October 2019

[63] Institut für Energie- und Umweltforschung Heidelberg (ifeu) (2018) *FKN Ökobilanz 2018*, Report for Heidelberg, December 2018

[64] Umweltbundesamtes (2011) *Planspiel zur Fortentwicklung der Verpackungsverordnung*, August 2011

[65] Umweltbundesamt (Germany) (2019) *Aufkommen und Verwertung von Verpackungsabfällen in Deutschland im Jahr 2017*, 2019

[66] Umweltbundesamt (Germany) (2019) *Aufkommen und Verwertung von Verpackungsabfällen in Deutschland im Jahr 2017*, 2019

The loss rates of 15% for moisture and foreign materials (from ifeu) and 19% for fibre loss at pulping stage, as detailed above, have been applied to calculations for Sweden and Spain, and the latter in the UK, in the absence of country specific data.

The following Sankey diagram (Figure A - 1) shows the material flows for beverage cartons in Germany including losses within the lifecycle, which forms the basis for the calculation of the recycling rate estimate.

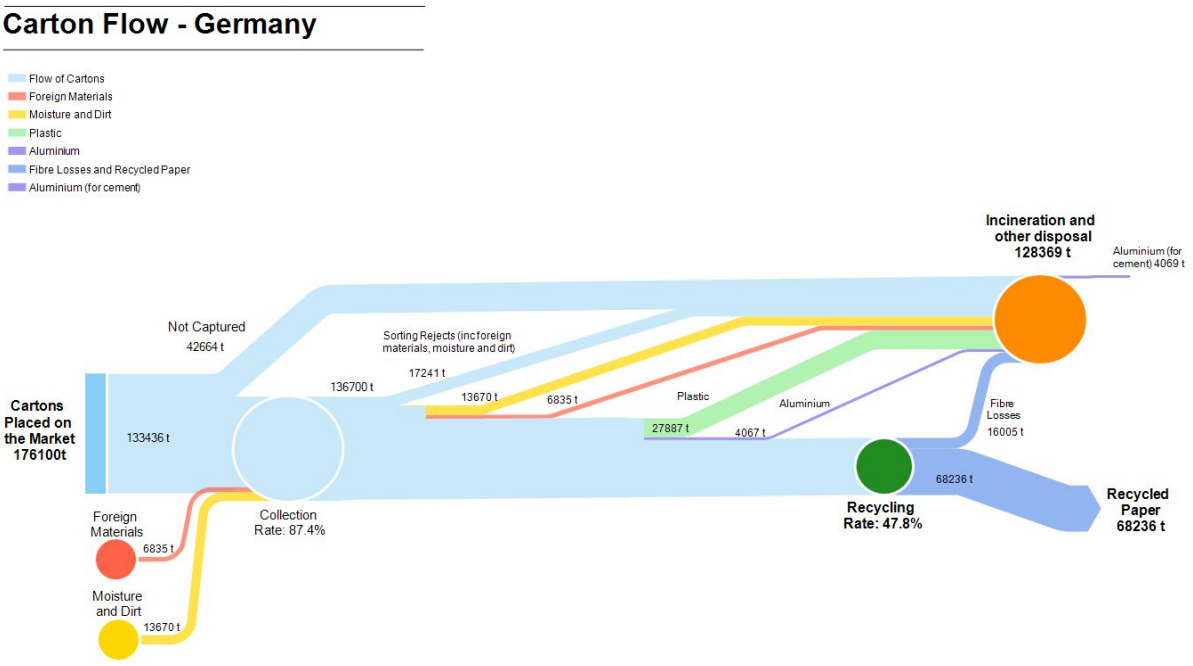

Figure A-1: Beverage Carton Material Flows, Germany

Table A - 1 shows the recycling rates for Germany calculated so far as well as the recycling rate estimate calculated in this report.

Packaging Level	UBA[67] (2018)	ifeu[68] (2019)	DUH[69] (2019)	ACE[70] (2019)	Eunomia (2020)
Whole pack	77.6%	64.7%	35.8%	75%	47.8%
Board			30.3%		47.8%
Polymer			4.9%		0%[71]
Aluminium			0.6%		0%[72]

Table A - 1: Recycling Rates, Germany

Data for beverage cartons placed on the market was published by UBA in 2019. As the volumes captured and sent to recycling includes foreign materials and moisture, they cannot be calculated as a percentage of cartons placed on the market. It also needs to be noted that UBA's recycling rate includes recycling abroad at 3.5%. In consultation with FKN it was confirmed that this indeed happens. As it is a minimal amount, we have assumed

[67] Umweltbundesamt (Germany) (2019) *Aufkommen und Verwertung von Verpackungsabfällen in Deutschland im Jahr 2017*, 2019

[68] Institut für Energie- und Umweltforschung Heidelberg (ifeu) (2018) *FKN Ökobilanz 2018*, Report for Heidelberg, December 2018

[69] *Deutsche Umwelthilfe (DUH) (2019) Recycling von Getränkekartons in Deutschland* 2016

[70] Personal correspondence with ACE, December 2019

[71] Personal correspondence with FKN confirming incineration of polymer/aluminium fraction

[72] While aluminium is recycled into new products, due to there being no clear separation from incineration bottom ash it is exempt from the recycling rate estimate.

that the recycling in a different EU country would have the same result as the recycling in Germany and therefore included the total volume in material flows within Germany.

There is a potential to increase the overall recycling rate by up to 18% once the new specialist recycling facility Palurec starts operations in 2020, provided the entire polymer/aluminium fraction is used for material recycling.

A.2.0 Appendix 2 – Spain Case Study

A.2.1 Country Waste Infrastructure

It is important to note that in Spanish beverage cartons are commonly referred to as 'briks'. In Spanish 'carton' is the word for cardboard, so talking of cartons can lead to confusion.

A.2.1.1 Collection

Packaging waste is overseen by the ECOEMBES, an organisation founded in 1996 to coordinate the recovery and recycling of packaging waste. Ecoembes signed agreements with the regional municipalities to facilitate the selective collection and treatment of packaging waste, including beverage cartons.

The majority of households in Spain have access to a selective collection for packaging waste, mostly via the large coloured containers on the street. Increasingly there is also a door to door collection of separated waste. Best practice is that the beverage cartons are disposed of in the yellow containers, and blue bins are provided for paper/cardboard waste (see Figure A - 1). However, consumers typically consider beverage cartons as being paper and so are often put in the blue bin instead.

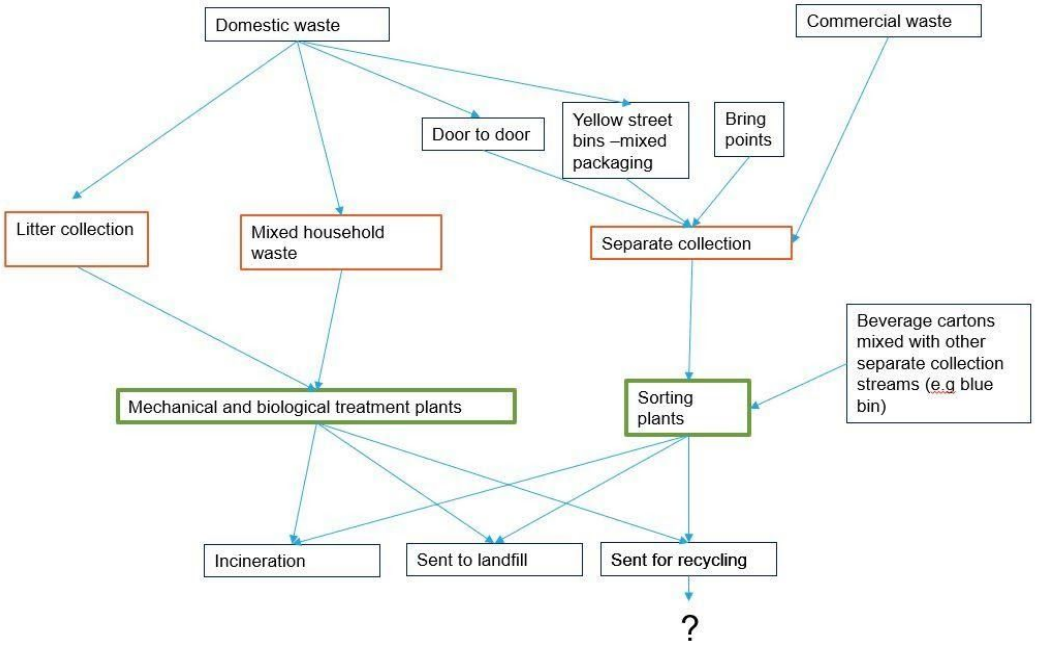

Figure A -2 Management of packing waste in Spain (Source: Eunomia own diagram adapted from Grafico 18 PEMAR 2016-22)

Current figures show that there are 383,974 yellow containers for the separate collection of lightweight packaging with each citizen adding 15.7 kg waste per year.

A.2.1.2 Sorting

All selectively collected waste goes to the waste sorting centres 'clasificacion de envases' of which there are 92 in Spain. Beverage cartons that are not disposed of correctly will be taken, along with mixed household waste and litter sweepings, to the waste treatment plants, some of which can extract beverage cartons. In all there are 185 plants that separate and report on the weight of beverage cartons.

The Ministerio para la Transicion Ecologica, in its annual report, shows figures for the quantities of 'compuestos' - mixed materials packaging - that are balled up ready to leave the sorting centres.[73] In 2016 this totalled 69,424 tonnes.[74]

Ecoembes do not report data on beverage cartons, as a category of its own. It appears that any beverage cartons sent for recycling are actually counted together with the paper and cardboard sent for recycling. This makes sense as the factories potentially processing beverage cartons are paper mills, who are also taking the paper and card waste.

Figures from Ecoembes show the quantities of paper and card that are sorted from the mixed packaging collection stream, this is likely to predominantly be beverage cartons, though it could include paper and card that was wrongly deposited in the yellow containers. This was 55,732 tonnes in 2018, which is lower than the 2016 figure reported by Miteco.

Overall, mixed packaging waste - 'envases mezclados' – is reported as 706,338 tonnes in 2018.[75] The PEMAR Waste Management Plan reports that 'briks' comprise 9.6% of light packaging waste collected, [76] which indicates a total collected quantity of 67,808 tonnes, a figure very similar to that reported by Ministerio para la Transicion Ecologica.

Comparing the weight of material collected with confidential information placed on the market data available to us reveals that around 50% of beverage cartons placed on the market are lost during the collection and sorting stage and remain in with mixed waste, going to either landfill or incineration.

[73] The term 'compuestos' means composite packaging and the PEMAR report indicated that it is primarily referring to 'briks'. Clarification was sought by email with the Ministry on the possible contents of the 'compuestos' category. Their reply stated that Compuestos corresponds to LER 15 01 05 and could include other compound materials but since it all comes via the selective collection route of the yellow bins, the only compound packaging material that is meant to be put in these are the beverage cartons.

[74] Ministerio para la Transicion Ecologica (2016) Memoria Anual de Generacion y Gestion de Residuos de Competencia Municipal 2016.pdf

[75] KPMG Audit of Ecoembes data 2019

[76] Ministerio de Agricultura, Alimentacion y Medio Ambiente (2015) *20151106PEMAR-2016_2022_apartado-13_pag96.pdf*, accessed 7 November 2019, www.aprr.eus/wp-content/uploads/2016/11/20151106PEMAR-2016_2022_apartado-13_pag96.pdf

A.2.1.3 Reprocessing

Of the material collected, it is then necessary to see how much is sent for reprocessing. There is reason to believe that some material is sorted and baled but not sent for reprocessing. Ten waste treatment and sorting plants were contacted, with a focus on those that the data shows bale up over 2,000 tonnes of 'briks' annually. None of them would explain where the material is sent to, though one waste sorting station indicated that some of their waste goes to an incineration plant. Another said that it is coordinated through Ecoembes so they do not have access to the information. This lack of willingness to communicate on the part of the paper mills and the waste treatment centres means that, although the data suggests that around 50,000 tonnes of beverage cartons are being sent for reprocessing, it is unclear where these are being processed.

The best data to give an estimate of what may actually be sent for reprocessing is the 'net recycling' figures for 'briks' in the national Waste Management Plan (Plan Estatal Marco De Gestión De Residuos (PEMAR) 2016-2022) report. This is 47,086 tonnes using 2012 data.

Of the material that is sent for reprocessing, currently in Spain there is no capacity for the recycling of the polyethylene and aluminium components of beverage cartons.

Prior to 2018 this material was exported to China for processing, a practice no longer possible. Domestic processing of these components took place at a facility near Barcelona called Stora Enso between 2011 and 2015. In 2011 the plant was upgraded with a pyrolysis plant that was capable of separating the plastic and aluminium components of a beverage carton from each other and had capacity for 30,000 tonnes of beverage cartons.[77] Despite an investment of 8 million Euros, 4 years later this plant closed down, reportedly because of lack of profitability.

The paper board component of beverage cartons is still a useful material to paper mills, even when the plastic and aluminium components are simply rejected. However, three of the five largest paper mill companies in Spain responded to this research by saying that they do not take 'briks'; one plant manager said that any 'briks' that do come are contaminants of the paper waste stream and are discarded as such. The other two paper mills have refused to comment as to whether they receive beverage cartons or process them in any way.

A.2.1.4 Calculating the Recycling Rate estimate

As detailed above, Spanish Government data available online shows figures for the quantities of 'compuestos' - mixed materials packaging- that are balled up ready to leave the sorting centres. [78] Another Government report indicates 'net recycling' figures for 'briks'. [79] Using the data that Ecoembes make available leads to a third estimation of the quantity of beverage cartons sent for recycling. See Table A - 2:

[77] packaging enfasis (2011) *Inauguran planta de reciclaje de tetrabricks*, accessed 21 November 2019, www.packaging.enfasis.com/notas/20346-inauguran-planta-reciclaje-tetrabricks

[78] Ministerio de Agricultura, Alimentacion y Medio Ambiente (2015) *20151106PEMAR-2016_2022_apartado-13_pag96.pdf*, accessed 7 November 2019, www.aprr.eus/wp-content/uploads/2016/11/20151106PEMAR-2016_2022_apartado-13_pag96.pdf

[79] Ministerio para la Transicion Ecologica (2016) Memoria Anual de Generacion y Gestion de Residuos de Competencia Municipal 2016.pdf

Source and date of data	Tonnes of beverage cartons sent for recycling
PEMAR, 2012 'net recycling'	47,086
MITECO, 2016 balled 'briks' at sorting plants	69,424
Ecoembes, 2018 (assumed 'briks' as is paper and card collected through mixed packaging stream)	55,732

Table A – 2: Comparing data on beverage cartons sent for recycling

The differences between these figures are difficult to ascertain. The higher 2016 figure cannot be simply the result of increased collection in comparison to the 2012 figure as the Ecoembes figure is lower again and is from 2017. The best interpretation of this data is that the 2016 figure, coming from a detailed analysis of waste sorting centre data, can be viewed as a 'gross recycling' figure while the other two are 'net recycling' figures, showing the quantity of material actually going to be reprocessed.

For the purposes of this recycling calculation, it is therefore taken that the figure for beverage cartons baled up at the sorting stations is the MITECO figure of 69,424, and the figure for material reaching the reprocessors is taken to be the PEMAR figure of 47,086. The difference between these suggests that there is quite a high weight of beverage carton material that is sorted but not reprocessed. One waste sorting station indicated that some of their waste goes to an incineration plant. This loss seems to be as high as 30%.

Where Spanish specific data was not available, German data was deemed suitably equivalent. The percentage loss rate applied for foreign materials (5%), and moisture and dirt (10%) was applied as per ifeu's data for Germany, because a large share of the beverage carton use in Spain is for soups and food products, which leave a larger residue in the carton than a beverage.

The plastic and aluminium components are not currently recycled in Spain and the loss rate of 19% was applied for a further loss of material during the fibre reprocessing stage. As discussed above, this does not impact the recycling rate estimate calculation, but needs to be considered when assessing the resource efficiency.

The recycling rate estimate achieved in Spain is 21.4%. Considering resource efficiency, however, the rate falls to 17.3% once losses in the pulping process are taken into account.

In the Sankey diagram shown in Figure A – 3, we present the material flows for beverage cartons in Spain. The volumes placed on the market shown in the diagram is for indicative purposes only and does not reflect the true data, which was not available for public use at the time of writing this report

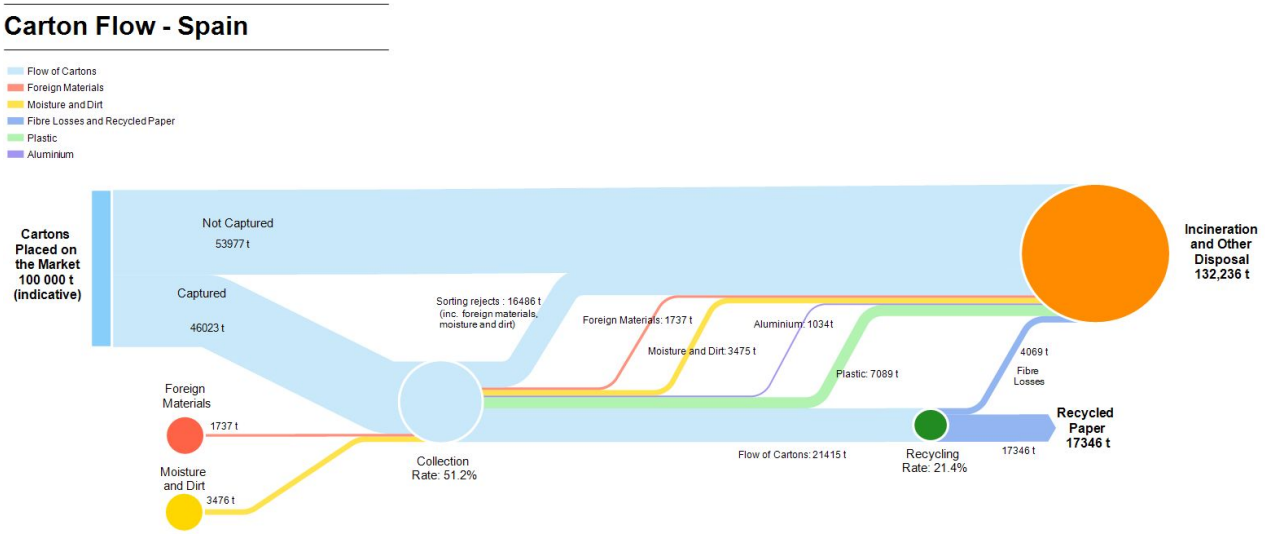

Figure A - 3: Beverage Carton Material Flows, Spain

Table A - 3 shows the recycling rates published by Ecoembes and ACE as well as the recycling rate estimate calculated under the assumptions outlined above.

Packaging Level	Ecoembes[80](2017))	ACE[81] (2019)	Eunomia 2020
Whole pack	77.7%	80%	21.4%
Board	0%	0%	21.4%
Polymer	0%	0%	0%
Aluminium	0%	0%	0%

Table A - 3: Recycling Rates, Spain

This recycling rate is even likely to be on the high side, assuming that these 47,086 tonnes reported are actually being taken to paper mills. The challenge to obtain data on this stage of the process questions whether more of the material is going straight to incineration or landfill rather than being processed.

[80] There are no actual official recycling rates for beverage cartons, though the Ecoembes rate of 77.7% is claimed to be for 'cardboard packaging for drinks' - 'envases de cartón para bebidas'

[81] Personal correspondence with ACE, December 2019

A.3.0 Appendix 3 – Sweden Case Study

A.3.1 Country Waste Infrastructure

A.3.1.1 Collection

Similar to Germany, Sweden also has an EPR for packaging waste in place and the collections are organised by producer responsibility organisations (PRO) such as Förpacknings- och Tidningsinsamlingen AB (FTI). Most cartons are collected together with other paper packaging in bring banks or recycling centres, though door-to-door collections are in place in some regions. Other paper waste, such as newspapers, magazines and letters, are collected and processed separately.

A.3.1.2 Grading and Reprocessing

The combined paper packaging recyclate gets sent for processing at paper mills across the country, according to FTI. Swedish Environment Protection Agency (Swedish EPA), Naturvårdsverket, however, states that the only plant in Sweden that processes beverage cartons is located in Fiskeby. This is confirmed by Fiskeby Board AB itself on their website, stating it is "the only mill in Scandinavia that accepts used plastic coated carton board such as milk or juice packaging".[82] When questioned, FTI maintained that there are other paper mills in Sweden that have the same specialised beverage carton recycling process as Fiskeby. We could therefore not establish which statement is correct and whether all collected beverage cartons are processed in a specialised recycling process or whether some, i.e. those not sent to Fiskeby, are rejected and enter an alternative waste stream. The following processing details are based on information about Fiskeby's recycling process found online. No representative of Fiskeby was available to comment.

Once the paper packaging waste arrives at Fiskeby's paper mill, it is graded. It remains unclear if the grading process separates beverage cartons from all other paper waste or whether it remains co-mingled with other types of cartons, laminated or not. Given that neither FTI nor the Swedish EPA were able to confirm collection and recycling rates for beverage cartons only, it is assumed that beverage cartons are not sorted into a separate grade itself in the grading process.

Each grade is shredded before entering the pulping process. The size of the shredding is not confirmed. The fibre pulp is processed into cardboard applications, while rejects (e.g. polymer and aluminium foils, caps, etc.) are used to generate energy. Fiskeby Board AB produces approximately 30% of its own electricity requirements from waste/rejects.

[82] Fiskeby *Manufacturing with sustainability in mind*, www.fiskeby.com/sustainability/production/?lang=en

A.3.1.3 Calculating the Recycling Rate Estimate

There is no evidence of a beverage carton specific recycling rate in Sweden. This is likely due to beverage cartons not being collected or processed separately, but together with other cardboard and paper packaging.
Due to the lack of separation, the transparency of the recycling stream for beverage cartons in Sweden is not clear. Neither the Swedish EPA nor FTI were able to confirm collection or recycling rates for beverage cartons. In its LCA commissioned by Tetra Pak for the Nordic market, ifeu calculates a recycling rate of 36.1%, 24.9% for fibres and 11.2% for polymer/aluminium compounds, which they have indicated as being used for energy supply in the recycling plant. This therefore cannot be classified as true recycling and the recycling rate therefore should be 24.9%. Ifeu also noted that their published graph is simplified and does not include scrap rates within the recycling process.[83] ACE confirmed a recycling rate for Sweden of 33%, but it is unclear how this was derived.

In absence of specific data relating to the processes in Sweden, in our calculation we are applying the ifeu loss rates for moisture and dirt (10%) and foreign materials contamination (5%), and the fibre loss rate of 19% at pulping stages. There will, however, be differences based on local particularities such as average carton compositions and how cartons need to be presented (e.g. washed or "spoon clean").

It is important to note the low collection rate assumed in ifeu's LCA. They apply a collection rate of just over 40%.[84] While this is data based on Tetra Pak packaging alone, we assume this applies to all beverage cartons in absence of any more accurate data.

The recycling rate estimate for Sweden calculated on this basis is 21.9%. If losses in the pulping process were considered, the rate reduces to 17.8%.

Figure A - 4 shows the material flows of beverage cartons in Sweden. Similarly to Spain, the placed on market data in this diagram is for illustrative purposes only, and it is assumed that the actual placed on the market data is far less than this, due to the significantly smaller population found in Sweden.

[83] Institut für Energie- und Umweltforschung Heidelberg (ifeu) (2017) *Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for liquid food on the Nordic market*, April 2017

[84] Institut für Energie- und Umweltforschung Heidelberg (ifeu) (2017) *Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for liquid food on the Nordic market*, April 2017

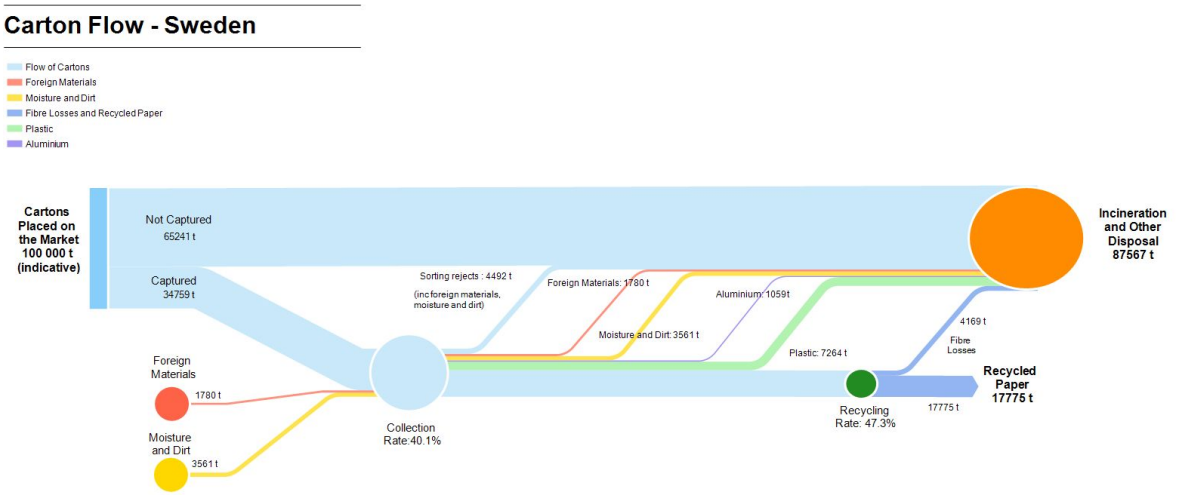

Figure A - 4: Beverage Carton Material Flows, Sweden

In Table A - 4, recycling rates that have so far been published by ifeu and ACE have been listed together with the recycling rate estimate calculated based on the assumptions discussed above.

Packaging Level	ifeu[85] (2017)	ACE[86] (2019)	Eunomia (2020)
Whole pack	36.1%	33%	21.9%
Board	24.9%	33%	21.9%
Polymer	11.2%[87]	0%	0%
Aluminium		0%	0%

Table A - 4: Recycling Rates, Sweden

[85] Institut für Energie- und Umweltforschung Heidelberg (ifeu) (2017) *Comparative Life Cycle Assessment of Tetra Pak® carton packages and alternative packaging systems for liquid food on the Nordic market*, April 2017 – Study on Tetra Pak only

[86] Personal correspondence with ACE, December 2019

[87] ifeu: Used for energy supply in recycling plant

A.4.0 Appendix 4 – UK Case Study

A.4.1 Country Waste Infrastructure

A.4.1.1 Collection

There is no unified collection scheme for packaging in the UK, with each municipality operating its own system. The majority of municipalities (68%)[88] offer a door-to-door collection service for residents using one of the following options:

- Beverage cartons separately collected;
- Co-mingled with other containers (plastic bottles, metal cans, glass bottles);
- Co-mingled with other containers, cardboard and other materials;
- Co-mingled with other cardboard or fibre grades.

Only a very small minority of municipalities (6%) do not offer any sort of recycling service for beverage cartons. The remaining 26% of municipalities run a series of bring-back sites, where residents can bring their used beverage cartons back to be deposited along with paper cups.[89]

Due to the many different types of collection services offered in the UK, beverage cartons may be placed in door-to-door collections for municipalities that do not accept them, causing contamination of other recyclates and incurring additional sorting and disposal costs for an MRF. According to WRAP, beverage cartons are the 7th most common cause for contamination in door-to-door collections (15% of householders put it for recycling when they are not accepted locally).[90]

A.4.1.2 Sorting

As a result of the wide variety of collection methods, there are also several different sorting processes for beverage cartons. Firstly, and most simply, if beverage cartons are separately collected via door-to-door collection, no further sorting will be required at an MRF. If the cartons are mixed with other containers at collection, MRFs need to employ techniques ranging from simple options, such as manual sorting or magnetic separation, to more technologically complex equipment like optical separation units. These options can separate beverage cartons into a pure stream for recycling; however, optical sorting is only deemed cost effective in larger MRFs.

[88] ACE UK(2019), accessed November2019, www.ace-uk.co.uk/home

[89] ACE UK(2019), accessed November2019, www.ace-uk.co.uk/home

[90] WRAP, Icaro Consulting (2019) *Britain Does, Recycling Tracking Survey 2019*, www.wrap.org.uk/sites/files/wrap/Recycling%20Tracker%20Report%202019_.pdf

In order to avoid confusion for residents, beverage cartons are commonly collected mixed with other paper grades or with fully co-mingled materials, reducing collection costs in comparison to separately collecting in a dedicated compartment.[91] However, if this is the case, it is unlikely that these cartons will be separated into a pure beverage carton stream and, as will be discussed below, it is unlikely these will be recycled in the UK, and there is limited information on the end destinations of 'mixed paper' exports.

A.4.1.3. Reprocessing

In the UK there is one dedicated beverage carton recycling plant, opened in 2013 and operated by the Alliance for Beverage Cartons and the Environment (ACE) UK, the beverage carton industry body in the UK, in partnership with Sonoco Alcore, a manufacturer of paper coreboards. Members of ACE UK include Tetra Pak, Elopak, and Sig Combibloc, who are the leading manufacturers of beverage cartons in the UK. ACE UK sources its input materials from municipalities and MRFs and provides a subsidy on the material delivered to the facility, resulting in revenue of roughly £55 per tonne for beverage cartons delivered.[92]

The ACE UK plant uses the 'single separation' method as described in Section 3.2.1.1. The plant has a capacity of 25,000 tonnes, accepting either cartons from bring sites that have been segregated at source or any that have come from MRFs with the capacity to sort them out from other containers. However, in consultation with ACE UK, it was stated that the plant is only running at a third of capacity, currently accepting roughly 8,300 tonnes annually. ACE UK works with municipalities to minimise the contamination levels of the material they receive, and set maximum tolerated limits of 2% liquid contamination and 5% other fibre-based products.[93] When asked about the low levels of cartons being processed at the Sonoco site, an ACE representative commented that the problem is that the UK's current infrastructure for sorting cartons is not capable of separating them from co-mingled materials so most are lost. There is no incentive to collect or sort this material and so, without a separate collection of beverage cartons, the capacity will not be filled, let alone justify their plans to build a second processing plant.[94]

There are several other paper mills in the UK operated by companies such as DS Smith, Smurfit Kappa and SAICA Natur UK – none of which use equipment dedicated to pure beverage carton recycling. From phone interviews with members of staff at these companies it was understood that these mills would treat beverage cartons as a contaminant, if received mixed with cardboard, and any beverage cartons would be filtered out and not reprocessed. Either a manual picker would remove any cartons before material enters the pulper or, if cartons do enter the pulper, these can be removed via a ragger device consisting of a spinning rope to remove spinning contaminants that do not pulp within the 2-4 minutes of the soaking process. These contaminants would usually then be sent to either incineration or landfill.

[91] WRAP (2017) *Collection of food and drink cartons at the kerbside*, p.23

[92] WRAP (2017) *Collection of food and drink cartons at the kerbside*, p.23

[93] ACE UK (2014) *Recycling Beverage Cartons in the UK Mill*, accessed 5 December 2019, www.ace-uk.co.uk/images/uploads/Beverage_Carton_ops_doc_and_baling_spec_Feb_2014.pdf

[94] Personal correspondence with ACE, January 2020

A.4.1.4 End markets

The ACE UK mill converts the paper fibre into coreboard which is used by Sonoco Alcore and converted into tubes and cores, such as gravy granules and hot chocolate containers. The polymer/aluminium fraction of the packaging is currently recovered via waste to energy, and is not recycled, although ACE UK confirmed when interviewed that they are planning to have a solution in place by Q2 2020, which will separate and recover the polymer and aluminium elements.[95]

There is limited information on the exports of beverage cartons from the UK. WRAP suggests a capture rate of 48% for beverage cartons in Wales.[96] This figure is based on just over 68% of Welsh municipalities offering door-to-door collection.[97] With this being very close to the UK's door-to-door collection scenario, we will therefore assume that this capture rate may apply nationwide, which equates to just under 29,000 tonnes of beverage cartons. As roughly 8,300 tonnes are being reprocessed at the ACE UK plant, this implies that the remainder are exported for recycling abroad. ACE UK confirmed that there are no export streams of pure beverage cartons in the UK. However, it is likely that they are being exported as 'mixed paper' grade packaging, and sourced from MRFs who are not able to sort beverage cartons from other paper grade packaging.

A.4.1.5 Calculating the Recycling Rate Estimate

There are no specific recycling targets for beverage cartons in the UK, who only report recycling rates for paper, plastic, glass, aluminium, steel and wood. Beverage carton recycling targets were alluded to in a 2011 report from the 'Advisory Committee on Packaging', which suggested that 50% would be a reasonable target for beverage carton recycling, although this has not been introduced,[98] and no more recent evidence could be found. While ACE UK and Tetra Pak do not disclose the national recycling rate in the UK, they have said that it is "certainly higher than the global average" of 25%, though no evidence for this claim could be found.[99]

Eunomia's UK calculation makes several assumptions for calculating the recycling rate estimate in the UK:

- A collection rate of 48%, as discussed further in Section A.4.1.4;
- In absence of any other data, we have assumed that there is a rate of 11.2% of sorting rejects, as used in our calculation for Germany;
- A moisture and contamination rate of 4.5%, based on guidance given by ACE UK to their suppliers, allowing a maximum of 2% food contamination and 2.5% foreign materials[100];

[95] Personal correspondence with ACE, January 2020

[96] WRAP (2017) *Collection of food and drink cartons at the kerbside*, p.7

[97] WRAP (2017) *Collection of food and drink cartons at the kerbside*, p.7

[98] Defra (2011) *Advisory Committee on packaging Annual Report 2010/2011*, accessed 5 December 2019, assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69398/acp-report2010-11.pdf

[99] foodmanufacture.co.uk *UK drinks carton recycling is still low*, accessed 5 December 2019, www.foodmanufacture.co.uk/Article/2017/12/04/UK-drinks-carton-recycling-is-still-low

[100] ACE UK (2014) *Recycling Beverage Cartons in the UK Mill*, accessed 5 December 2019, www.ace-uk.co.uk/images/uploads/Beverage_Carton_ops_doc_and_baling_spec_Feb_2014.pdf

- For beverage cartons processed in the UK, ACE UK confirmed that the polymer/aluminium fraction of the beverage cartons are currently not recycled. As the polymer/aluminium is approximately 28% of the mass of a beverage carton, a further 28% loss rate is seen here; and
- While not impacting the recycling rate estimate, a rate of 19% process losses is allowed in paper recycling.

While the UK recycling plant is running at a third of capacity (8,333 tonnes), it is assumed that the remainder is exported to an unknown location. It was confirmed by FKN that there are currently no beverage carton imports into Germany. The point at which the cartons are exported, however, is not providing any variances between the countries as the real factors influencing the differences in rates are linked to the collection rate and contamination of cartons which stays the same for UK generated cartons, regardless of where they are recycled in the end.

The recycling rate estimate for beverage cartons fully processed in the UK (approx. 8,333 tonnes) is just under 10%. With an export of approximately 17,500 tonnes, a combined recycling rate estimate for the UK of 29.5% is achieved, which is assumed to be the same even if all cartons were processed in the UK. It is unclear why the UK chooses to export cartons, instead of processing them in the UK plant which would have capacity for these. When considering the losses of 19% in the pulping process, only 23.9% of the cartons are indeed recycled into new products.

The Sankey diagram in Figure A - 5 depicts the material flows found for beverage cartons in the UK. It is important to note that we have assumed that the beverage cartons that are exported are sent to other parts of Europe. This is not confirmed, and it is possible that, at least to some part, they may be sent to countries like India or Indonesia, after import restrictions have been put in place in China in 2018.

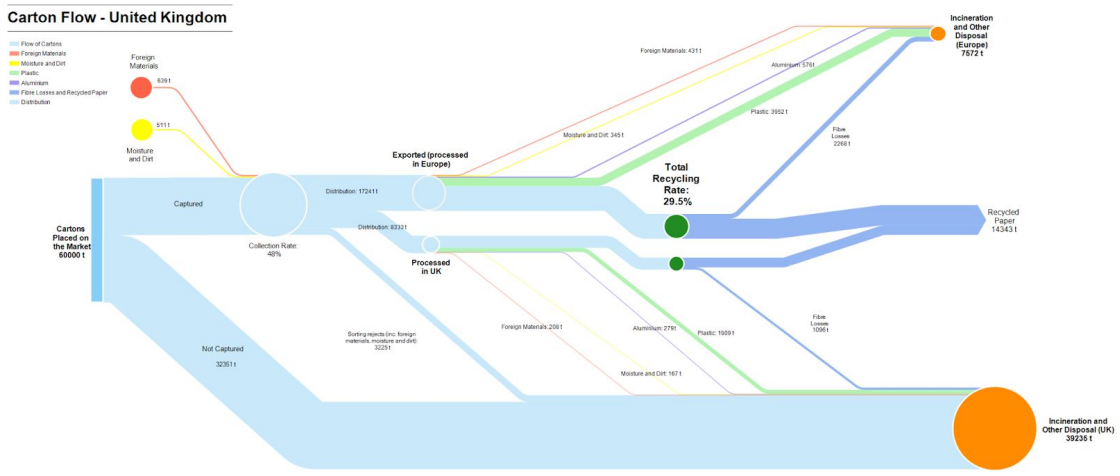

Figure A - 5: Beverage Carton Material Flows, UK

Table A - 5 shows the recycling rates provided by ACE in comparison to the recycling rate estimate calculated based on the assumptions outlined in this report. As the export destination for part of the beverage cartons have not been disclosed during the course of this research, these rates have been based on export to another EU country in order to be counted as recycling under the new EU guidelines,

Packaging Level	ACE[101] (2019)	Eunomia (2020)
Whole pack	36%	29.5%
Board	36%	29.5%
Polymer	0	0%
Aluminium	0	0%

Table A – 5: Recycling Rates, U

[101] Personal correspondence with ACE, December 2019

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Zero Waste Europe is the European network of communities, local leaders, businesses, experts, and change agents working towards the same vision: phasing out waste from our society. We empower communities to redesign their relationship with resources, to adopt smarter lifestyles and sustainable consumption patterns, and to think circular.

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