THE ALLIANCE FOR
BEVERAGE CARTONS
AND THE ENVIRONMENT

BEVERAGE CARTONS
DESIGN FOR RECYCLABILITY GUIDELINES

October
2022

Prepared by RISE Bioeconomy on behalf of ACE steering committee

CONTENTS

ACKNOWLEDGEMENTS

The Alliance for Beverage Cartons and the Environment (ACE) would like to thank the members of the working group responsible for generating these guidelines. The following companies and organisations were represented on the working group:

- **Billerud**
- **Elopak**
- **EXTR:ACT**
- **SIG Combibloc**
- **Stora Enso**
- **Tetra Pak**

In addition, ACE would like to thank the following stakeholders for reviewing and commenting on the draft document. Comments were gratefully received and where possible appropriate amendments have been incorporated into the final document:

- **4evergreen**
- **Cepi**
- **Ecoplasteam**
- **Institute cyclos-HTP**
- **Kadant Lamort**
- **Lamipak**
- **Plastigram**
- **Saperatec**

FOREWORD

ACE and its members - the beverage carton producers Tetra Pak, SIG Combibloc and Elopak, and their paper board suppliers, Stora Enso and Billerud – are truly committed to contribute to a low carbon circular economy. In 2021, through the ACE 2030 Roadmap[1], our members adopted an ambitious vision for 2030 and beyond to deliver the most sustainable packaging for resilient food supply systems, which is renewable, climate positive and circular. By 2030, the industry aims for example to only produce beverage cartons from renewable and/or recycled material, to increase the collection for recycling rate to 90% and the recycling rate of beverage cartons to 70%, while decarbonising the industry's value chain in line with the 1.5° C target.

Our industry also commits to develop and annually review a Design for Recycling Guideline that will provide producers of beverage cartons with technical guidance to:

- **Evaluate the recyclability of beverage cartons on the market today**
- **Provide guidance in the same format as the 4evergreen general guidance but specifically focused as to how recyclability of beverage cartons can be maximised.**

A high-level self-assessment of recyclability presented in the annex of this report demonstrates that beverage cartons are demonstrated to be recyclable and recycling of beverage cartons is already a reality today[2]. Recycling starts with collection. It is therefore critical to ensure that the needed infrastructure and legislative requirements are in place to ensure that all beverage cartons are collected separately from the general municipal waste stream.

Besides the needed infrastructure for collection, the design of beverage cartons can further improve their recyclability. There are still characteristics of carton structures and designs which may influence the recyclability of individual beverage cartons as measured by recyclability criteria and recycling processes.

These guidelines identify the design elements that can influence recyclability, discuss their relevance and identify, propose and recommend actions that could be taken by developers to maximise the recyclability of beverage carton materials and designs. They are based on expert judgement and consultation with targeted stakeholders including recyclers, waste collectors, equipment manufacturers.

Capabilities in sorting systems and reprocessing technologies are constantly changing. Existing technologies are evolving and new technologies are emerging which could revolutionise recycling value chains, especially emerging technologies for recycling of the residual of polyethylene and aluminium (PolyAl) fraction remaining after the fibre recovery process. Furthermore, the legal requirements and definitions of recycling are under constant review, particularly as policies relating to the Circular Economy Action Plan are finalised. The guidelines also highlight knowledge gaps where more information and/or testing regarding the influence of certain components on recyclability is required.

These guidelines will therefore be reviewed annually and updated where necessary to reflect the dynamic situation and to align with other emerging recyclability guidelines where relevant. Users of the guidelines are encouraged to check that they are accessing the most recent version.

The 4evergreen platform (a cross-industry alliance aimed at fostering synergies among companies promoting low-carbon and circular fibre-based packaging[3]) has produced guidelines for designing fibre-based packaging with circularity in mind (4evergreen, 2022)[4]. However, the current 4evergreen guidelines only address fibre-based packaging that is recycled in a standard recycling mill. Some fibre-based packaging solutions, such as beverage cartons, are recycled at specialised mills using enhanced recycling processes. This Guideline is therefore complementary to the 4evergreen Guideline.

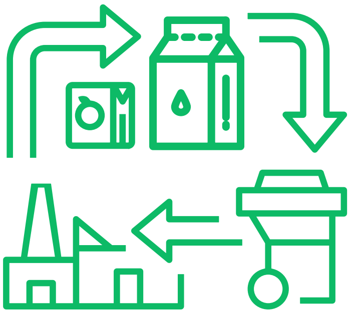
[1] www.beveragecarton.eu

[2] Beverage cartons are currently being recycled everywhere in Europe where this packaging is accepted alongside other packaging in a separate collection infrastructure

[3] 4evergreen is a cross-industry alliance, 4evergreen fosters synergies among companies promoting low-carbon and circular fibre-based packaging. By bringing together the entire value chain, 4evergreen enables cooperation with a comprehensive outlook on fibre-based packaging's life cycle

[4] The 4evergreen Circularity by Design Guideline can be downloaded: https://4evergreenforum.eu/wp-content/uploads/4evergreen-Circularity-by-Design-2.pdf

1. DEFINING **RECYCLABILITY**



"A packaging or packaging component is recyclable if its **successful post-consumer collection, sorting, and recycling is proven to work in practice and at scale.** Recyclable in practice and at scale means that there is an existing (collection, sorting and recycling) system in place that actually recycles the packaging (it is not just a theoretical possibility) **that covers significant and relevant geographical areas** as measured by population size."

Ellen McArthur Foundation

Other definitions of recyclability also include reference to the output material from recycling, requiring the recycled end products to "factually substitute material-identical virgin material in its post-use phase" (Institute cyclos-HTP, 2021).

Specifically referring to fibre-based packaging, the definition can be further refined as "The individual suitability of a paper-based packaging for its factual reprocessing in the post-use phase into new paper and board; factual means that separate collection (where relevant and followed by sorting) into EN 643 grades and final recycling takes place on an industrial scale." (Cepi, ACE, FEFCO, Citpa, 2020)

Thus, to be considered recyclable, collection and processing structures for the packaging format must be available at an industrial scale. This means that it must be possible that the packaging can be collected via the existing collection options and sorted in a qualified manner. Its reprocessability must enable recirculation of the material.

2. ABOUT BEVERAGE CARTONS

Beverage cartons are a multilayer packaging solution for non-carbonated beverages and liquid foods. Liquid packaging board provides strength whilst the other layers provide barriers to water vapour/moisture, oxygen and light to protect the contents and to ensure that the paperboard maintains its strength since it is negatively affected by water vapour/moisture.

The correct combination of materials ensures food safety, whilst preventing food waste by protecting the contents from deterioration and nutrient loss. **These barrier layers may consist of polymers or a combination of polymers and aluminium, depending on whether the product is kept refrigerated or if it is distributed and stored at room temperature.** Whatever the product, only the necessary quantities of each material are used in order to achieve food safety and package functionality. As with all packaging materials and solutions, the drive for a circular economy means that there is a requirement to ensure that current and future materials used for beverage cartons are compatible with enhanced recycling processes in specialised or dedicated paper mills, as well as promoted solutions for PolyAl.

2.1 Liquid packaging board

Liquid packaging board used by ACE members is manufactured from sustainably sourced bleached or unbleached virgin fibres[5]. The type of packaging board used depends on the product being packed, the regional market where it will be sold and the manufacturing conditions, but in order to achieve a good balance between performance and lightweighting, liquid packaging board often comprises a duplex or triplex material with a bleached or clay-coated outer layer of sulphate kraft and with a middle layer which contains CTMP (chemi-thermomechanical pulp) fibres.

Depending on the application, liquid packaging board may contain wet strength agents in the form of wet strength resins and/or neutral sizing agents. The primary function of wet strength resins is to improve the tensile properties of the liquid packaging board in wet state by crosslinking the cellulose fibres with covalent bonds that do not break upon wetting.

Non-aseptic beverage cartons contain fresh product and require refrigeration. To ensure carton integrity in some environments some liquid packaging board intended for non-aseptic beverage cartons contains wet strength agents. Cartons intended for retorted applications, where additional performance is required to withstand the retort process, may also contain wet strength. **Aseptic beverage cartons contain sterilised product and do not require refrigeration and therefore liquid packaging boards used for aseptic beverage cartons do not have significant quantities of wet strength.**

A distinction can be made between temporary and permanent wet-strength resins. Temporary wet-strength papers lose some of their wet-strength after a defined period of time in wet conditions. Temporary wet-strength papers and paper products using retention aids can be usually easily recycled. For temporary wet strength glyoxalpolyacrylamides (GPAM) are commonly used. Other polyacrylamides are commonly used as retention aids.

Permanent wet-strength papers retain wet strength properties over time. **This property makes wet-strength papers more difficult to recycle in standard conditions** and it is therefore recommended that these papers are recycled using enhanced recycling equipment. For permanent wet strength urea resins, melamine resins and polyamidoamine epichlorohydrin (PAAE or PEA) reasons are commonly used.

Sizing agents used include alkylketene dimers (AKD) and alkenylsuccinic anhydride (ASA) and rosin. Sizing agents are used to aid fibre retention during papermaking and to improve the absorption and wear characteristics of the finished paper by hydrophobizing the fibers.

[5] All fibres used in beverage cartons come from sustainably managed forests and are certified against a globally recognised certification system (FSC or PEFC)

2.2 Polymers used in the laminate

Typically, for both aseptic and non-aseptic beverage cartons, a low density polyethylene (LDPE) outer layer applied by extrusion coating provides a water vapour/moisture barrier for the board and enables the package flaps to be sealed. The LDPE outer layer is also important for the longitudinal seal, which may be achieved via a strip seal or via skiving. The presence of the outer LDPE layer also gives the beverage cartons a unique infrared fingerprint and therefore allows the beverage cartons to be sorted in automatic sorting lines using near infrared (NIR) technology.

Whilst the liquid packaging board provides the beverage cartons with shape and rigidity, other layers provide barriers to water vapour/moisture, oxygen and light to protect the contents. These other layers also allow the package to be sealed and can provide protection for the printed surface.

Whilst the majority of beverage cartons on the market are composed of liquid packaging board with layers of PE and/or aluminium foil, beverage cartons with alternative barrier layers are available for both aseptic and non-aseptic beverage cartons. Solutions already in the market include PA and EVOH barrier layers. These ACE Guidelines indicate the level of compatibility of those alternative polymers with the recycling processes for the dominant LDPE polymer.

2.3 Printing of beverage cartons

Different technologies are used for printing of beverage cartons. For some beverage cartons, ink is applied directly to the liquid packaging board, in which case the outer LDPE layer also protects the printing ink layer. For other beverage cartons, the laminated reel is printed and therefore the printing ink is applied to the outer side of the outer LDPE layer.

2.4 Polymers used for additional components

Beverage cartons may incorporate an easy opening device, and multi-serve beverage cartons often incorporate closures (screw caps or hinged lids) which prevent spillages, facilitate pouring and allow reclosure of the package. Such features are common on both aseptic and non-aseptic beverage cartons. From 2024 onwards, closures for beverage cartons in the European market must be designed so that they remain attached to the beverage carton after opening and disposal.

Opening and closure devices are predominantly manufactured from high density polyethylene (HDPE), low density polyethylene (LDPE) or polypropylene (PP), or a combination of them. Minor parts such as cutting rings are sometimes manufactured from other polymers. These parts of the beverage cartons, along with carton tops and necks from certain beverage cartons, are often (though not always) separated from the film fraction prior to the PolyAl recycling process by utilizing differences in material density and/or thickness in a wind-shifter. Thus, it is important to keep the amount of polymers that are not compatible with PO mixed recycling to a minimum.

For single-serve beverage cartons targeting the on-the-go market, drinking straws are often attached to the outer face of the beverage carton. In the past, these straws were made from plastic (usually PP), but from July 2021 plastic straws may no longer be placed on the market within the European Union. The industry has moved to timely develop and adopt fully recyclable paper straws for beverage cartons, including paper U-bend straws.

2.5 Alternative polymers

Currently, the majority of PE used as barrier layers and for closures is fossil-based PE. However, bio-based PE is also used by some manufacturers. Bio-based PE is functionally equivalent to fossil-based PE but is derived from biological matter (e.g. sugarcane or tall oil) rather than fossil fuels. Bio-based PE has the same properties as fossil PE and behaves in the same way in recycling processes. Other bio-based polymers are also being explored as solutions for closures, drinking straws and barrier layers.

It is important that beverage carton designers and manufacturers are considering recyclability in the early stage of the design process and at the same time are able to continue to innovate and to investigate alternative materials and solutions which may offer improved functionality and reduced environmental impact. The impact on recyclability needs to be assessed during the innovation process. At the same time, it is essential that recycling processes are developed that are capable and robust enough to handle the materials commonly used in beverage cartons, including sorting quality/impurity challenges of sorted bales of used beverage cartons.

2.6 Typical beverage carton structures

Aseptic beverage cartons, which contain sterilised product, are typically composed of layers of liquid packaging board, low density polyethylene (LDPE) and aluminium. Examples are presented in Figure 1. Non-aseptic beverage cartons, contain fresh product and require refrigeration. Non-aseptic beverage cartons do not require the additional aluminium foil layer. Examples are presented in Figure 2.

For aseptic beverage cartons, the structure typically has the inner side of the liquid packaging board coated with LDPE to tie it to the aluminium foil. Aluminium foil thickness varies depending on required barrier properties but is very thin (measured in µm) , constituting around 4-5% of the total weight of the carton. The aluminium foil provides an odour, light, and gas barrier. Adhesion of the aluminium foil to the innermost plastic layer is usually achieved through the use of an LDPE layer containing a low percentage of an adhesive co-polymer like EAA (poly(ethylene-co-acrylic acid) or EMAA (poly(ethylene-co-methacrylic acid)) (Robertson, 2021). These co-polymers have rheological properties similar to those of LDPE.

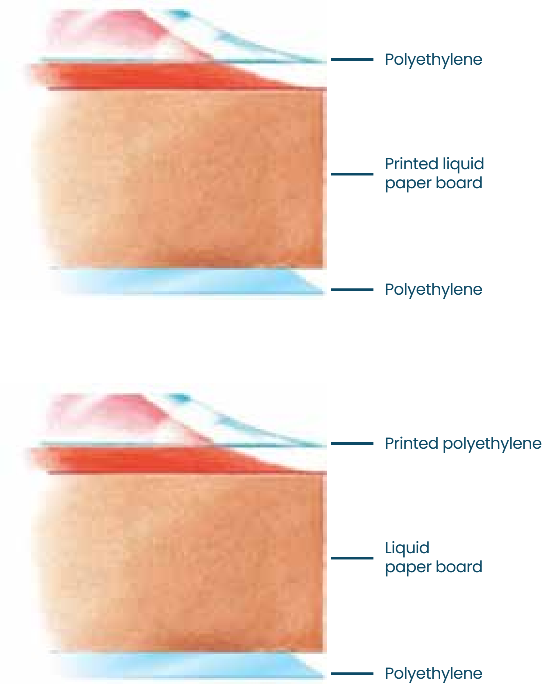


Figure 2: Typical structure of non-aseptic beverage cartons

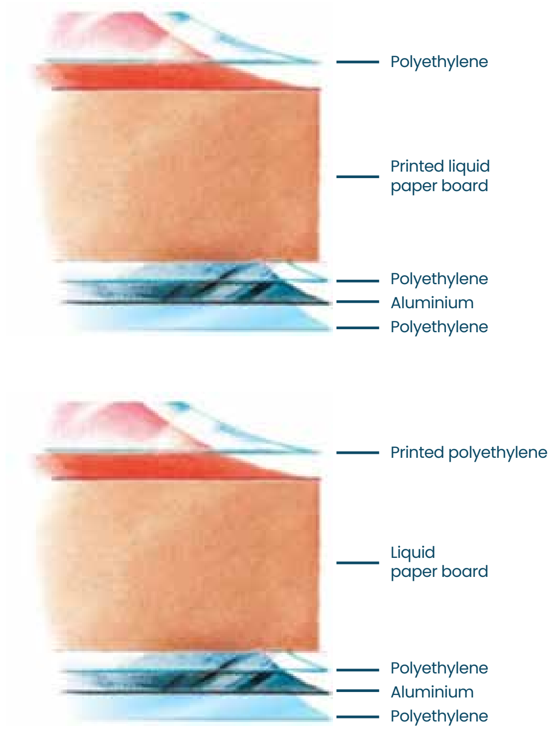


Figure 1: Typical structure of aseptic beverage cartons

For both aseptic and non-aseptic beverage cartons, an inner layer of LDPE is applied to enable heat sealing of the carton and to further protect the board from the contents of the carton.

Carton material may be supplied as roll-fed or as preformed blanks. Roll-fed carton material requires a longitudinal seal strip to be applied internally to prevent contact between the edge of the aluminium and/or the edge of the liquid packaging board and the product. Depending on the oxygen sensitivity of the product, the strip is composed of a core layer of polyethylene terephthalate (PET), polyamide (PA) or ethylene vinyl alcohol copolymer (EVOH), coated with LDPE or LLDPE (Robertson, 2021). This sealing strip is not required for preformed carton blanks. Instead, the longitudinal seam of preformed carton blanks is made via skiving, folding (180°) and sealing the overlap (inner LDPE layer on folded inner LDPE layer).

3. ABOUT USED BEVERAGE CARTON RECYCLING

51%

A high level of recyclability is indicated by the fact that used beverage cartons (UBCs) are already extensively collected and recycled in Europe. Within the EU28, in excess of 450,000 tonnes of material was reprocessed in 2019. This represents a recycling rate of 51%[4] of all beverage cartons sold in Europe (Alliance for Beverage Cartons and the Environment, 2020)[5], with some countries such as Belgium and Germany achieving rates of over 70%.

3.1 Collection

Collection is a precondition to the recycling of any material. Collection of packaging materials, separately from household waste, significantly increases the volume of materials available for recycling, which in turn creates a more predictable, **high-quality waste stream as well as a strong incentive for investment and innovation within the sorting and recycling industry.**

Strategies for collection of beverage cartons vary between Member States. Generally, used beverage cartons are collected with other light-weight packaging or with other paper-based packaging.

Systems and infrastructure for collecting these material streams already exist in most EU Member States. With a few exceptions[6], it is not necessary to create new collection systems or infrastructure to increase the collection of beverage cartons ready for recycling.

3.2 Sorting

In some countries, used beverage cartons are collected as part of the light-weight packaging stream and they are then sorted out separately. When collected as part of the overall paper-based packaging stream, beverage cartons sorting is recommended, otherwise used beverage cartons in an unsorted paper-based packaging stream would enter the standard mill recycling process and would not be recycled as efficiently as in a specialized mill.

When designed following the recommendations in this document, beverage cartons are easily sorted from the other materials that they are collected alongside in these mixed material streams using existing automated optical sorting technologies that are widely installed at material sorting plants. **The structure of beverage cartons provides unique spectral properties which allow their identification and automated separation at commercial speeds and with high yield and purity.** The presence of the outer PE layer plays a key role in the identification and optical sorting of beverage cartons by means of NIR sensors.

[6] Using the calculation method as defined before the adoption of the Implementing Act (EU) 2019/665

[7] Data includes information from the United Kingdom, which at that time was still an EU Member State

[8] Currently some Members States have systems that do not function in some markets as well as in other ones, and higher collection rates need to be achieved. However, legislative improvements (separate targets, performance of extended producer responsibility systems), infrastructure optimisation and consumer education need to be addressed on an EU Member State by Member State level

3.3 Recovery and recycling of the fibres

Recycling of beverage cartons begins with the recovery of the paper fibres, which constitute approximately 75% of the total weight of the carton. The fibres are recovered from used beverage cartons at pulp and papermills with dedicated processing equipment. The process is summarised in Figure 3.

Eighteen to twenty reprocessing facilities exist across Europe (Figure 4) which specifically target beverage cartons as a valuable recovered fibre stream, with a further four reprocessing facilities in the pipeline. Currently, all UBC collected and sorted for recycling can be recycled by the existing mills and the capacities will increase in line with growing collection and sorting of UBC.

These facilities use proprietary or patented technologies using water and agitation at specific process conditions to separate the paper fibres from the plastic and aluminium. Typically, this is accomplished using a drum pulper or a specialised hydrapulper, large cylindrical vessels with impellers (rotors) **at the bottom which break apart the paper fibres and produce a dilute slurry of fibres that can be further processed within a papermill. Also, some new technologies for recovering the fibre are under construction.**

Fibre recovery can be performed either as a batch process or as a continuous process. Contact between the water and the paper layer occurs in the pulper, and the layers separate due to the hydraulic forces inside the pulper. It is a mechanical process typically not using chemicals. Pulpers are generally equipped with screens to remove unwanted material such as baling wires and larger plastic pieces (big bags, sacks, etc). Closures and caps are also separated out from the slurry. This residual material stream of caps and closures (the hard fraction) and foil (lamination films and aluminium), obtained after pulping and fibre separation, is known as the PolyAl fraction.

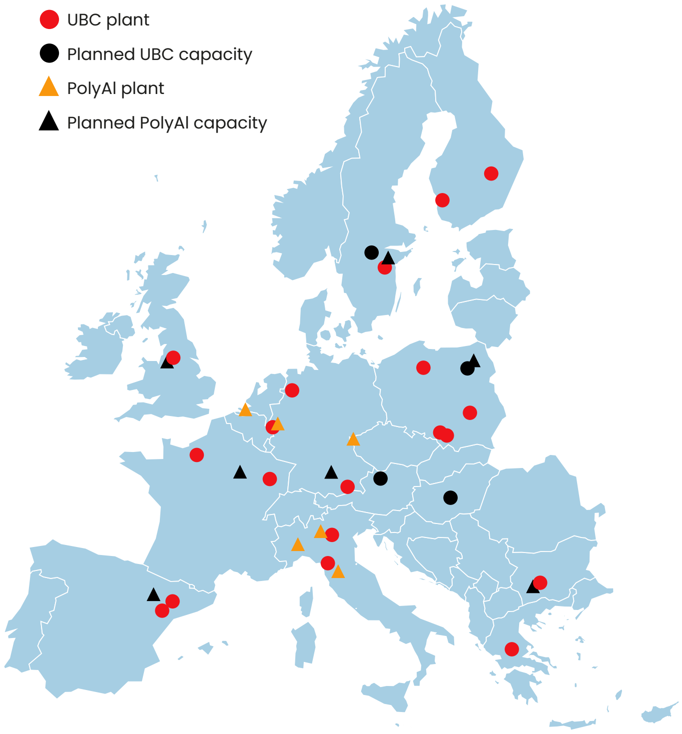


Figure 4 UBC and PolyAl recycling facilities in the European Union and UK, 2022 (Source: EXTR:ACT)

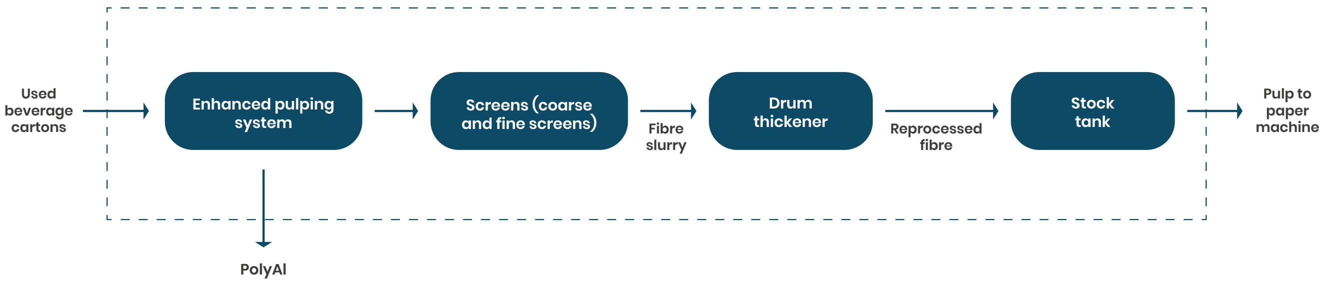


Figure 3 Typical processes in a UBC recycling mill

Washing drums can also be used to further clean the PolyAl, to recover additional fibres and to eliminate fibre contamination for the PolyAl recycler.

The main difference between the repulping process to recover fibre from used beverage cartons compared to the repulping process to recover fibre from other paper fractions such as old corrugated cardboard (OCC), newspapers and magazines, etc, is the dwell time required in the pulper. A considerably longer repulping regime is required for recovering fibre from used beverage cartons. Additionally, the capacity to remove and process the PolyAl fraction is better in an enhanced process compared to the standard recycling mill.

Once recovered, the high-quality, strong, once-used fibres from beverage cartons are a highly desirable as a source of recovered fibre. They are used for a number of different applications, including production of different paper grades (e.g., test liner, kraft paper) and packaging products (e.g., corrugated boxes, paper bags, tissue paper).

3.4 Recycling of the PolyAl fraction

A number of technologies are currently applied in order to recycle the PolyAl fraction. Mechanical recycling preserves the molecular structure of the polymer after being mechanically pre-treated it (e.g. shredding, washing, cleaning and drying) and remelted it into granulate. This is opposed to chemical recycling, in which polymer chains are split and the resulting output provides products such as fuel or chemical pre-cursors. Currently, all commercial technologies for recycling of the PolyAl fraction are basically mechanical[9]. Chemical recycling technologies are emerging and may be available in the future but are not considered in this assessment yet.

After the paper fibres have been removed by pulping, a residual of polymer and aluminum (PolyAl) remains, with a moisture content of approximately 20-40%. The PolyAl fraction contains predominantly polyolefins (mostly polyethylene with some polypropylene), with around 20% aluminum particles of different shapes and sizes, plus a small amount of residual fibres. A pre-cleaning step may be undertaken at the paper mill or at the PolyAl recycling facility, which further reduces the residual fibre content and any other contamination.

As illustrated in Figure 5, the available mechanical recycling technologies can be broadly grouped as processes where the plastic and aluminium foil layers are reprocessed together as a composite material, and processes where the plastic and aluminium foil layers are first separated before mechanical recycling of each fraction. In both cases, it is common practice to separate the foil fraction (LDPE and aluminium barrier layers) from the hard plastic fraction (caps, closures, etc), which is then processed separately into flakes as a mixed polyolefin stream. However, A general rule for all processes is that the less residual fibre in the PolyAl stream the better the quality of the output material from the recycling process.

Some PolyAl recycling processes do reprocess the combined rigid and foil polymer and aluminium fractions together to produce a composite material which is compatible with extrusion or injection moulding processes. However, these composite materials are currently not subsequently recyclable and are therefore not considered in these guidelines, which encourage circularity of the product and material in its subsequent lives as well as its first life.

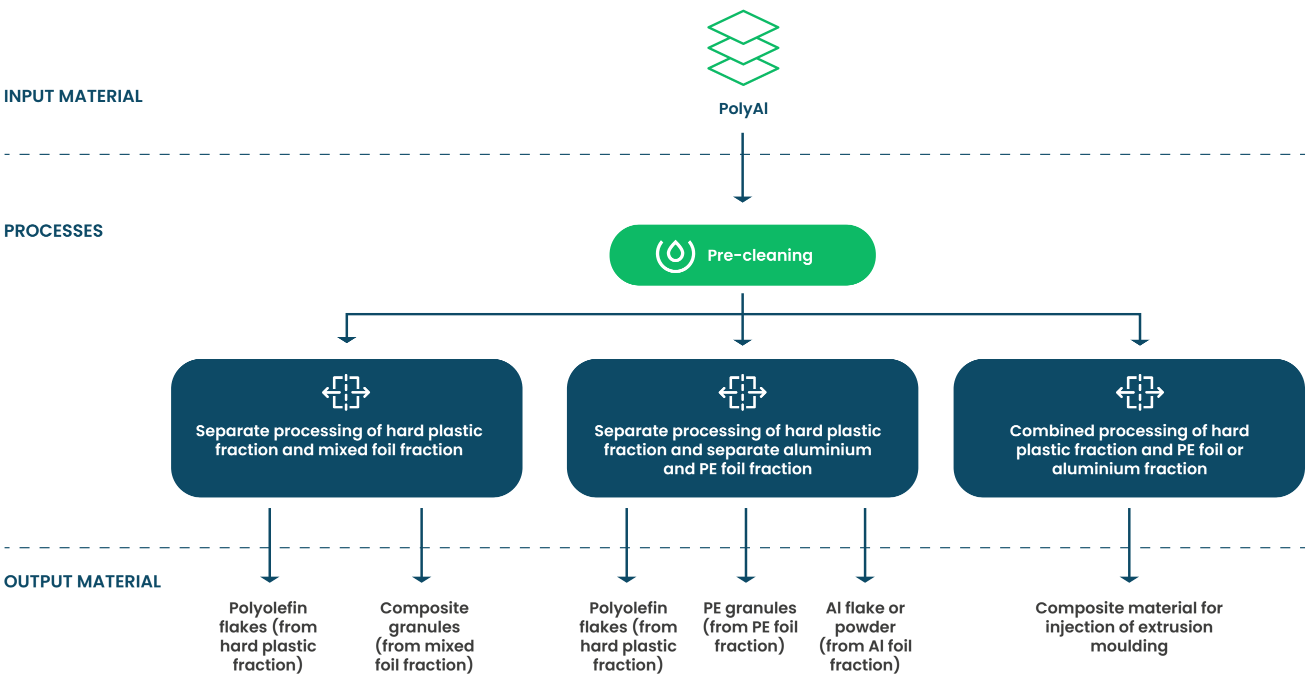


Figure 5 High level overview of generic routes for reprocessing the PolyAl fraction

[9] Physical recycling preserves the molecular structure of the polymer. This can be achieved using mechanical treatment or solvent based separation of the of the layers. This is opposed to chemical recycling, which converts polymeric waste by changing its chemical structure to produce substances that can be used as precursors (or raw materials) for the manufacturing of new polymers.

For processes where the plastic and aluminium foil fraction are processed together the composite material is compacted either as a pressed granulate or as an extruded granulate. The material is directly suitable for injection moulding.

For processes where the PE and aluminium foil layer are processed separately, separation of the PE from the aluminium may be achieved using mechanical processes, sometimes supported by chemical additives, for example formic acid. In this case, the formic acid is weakening the bonding, leading to separation. Other separation reagents, for example solvents, may also be used. The LDPE and HDPE from the foil is then extruded into granulates and the aluminium is formed into a flake or powder. Separation of the aluminium from the polymer is essential if the recycled polymer granules are to be used in applications such as film blowing.

By eliminating the impurities and foreign polymers, it is possible to clean the material enough to produce a granulate that can be processed in a number of ways, including injection moulding, blow moulding, blending and compounding. In an example of this type of process, the input to the process is used beverage cartons and an initial pulping process is followed by settling and then centrifuging to obtain a solid PolyAl fraction, shredding, drying to <2% moisture content, compacting, extruding and sub-dividing into granules. The final material is 80% polymers and approximately 20% aluminium.

As of today, capacity exists or is in the process of being upscaled to recycle approximately 50,000 tonnes, or 30%, of PolyAl in Europe annually (EXTR:ACT, 2022). Further expansion of these processing options is expected for the near future, underscoring the investment and innovative solutions being explored to ensure that the beverage cartons placed on the EU market are fully recyclable. The recycled plastic components can be used in products such as plastic pipes, pallets, boxes or panels, while the aluminum will be compounded and re-used.

4. STANDARDS AND GUIDELINES **RELEVANT TO THE RECYCLABILITY OF BEVERAGE CARTONS**

Assessing recyclability of packaging solutions is an emerging discipline. There are few standards and guidelines that are directly relevant for informing design for recyclability for beverage cartons. Table 1 summarises the standards and guidelines which have been referenced in the preparation of this document. As further work becomes available, additional insights will be incorporated into this guidance document.

Standard or guideline	Status	Overview	Relevance and application
4evergreen initiative	Ongoing	4evergreen is a cross-industry alliance with the goal of optimizing fibre-based packaging circularity and climate performance. The platform is currently working towards the development, publication and adoption of a recyclability evaluation protocols, test methodologies and "circularity by design" guidelines for fibre-based packaging in three parts (part I for standard recycling processes released end of February 2022, part II for deinking and part III for enhanced recycling processes scheduled for end of 2022). According to the draft 4evergreen guidelines, packaging consisting of >50% fibre is defined as paper packaging and is included in the scope of the guidance.	Part I of the recyclability evaluation protocol considers standard recycling mill conditions. Part III will mimic "enhanced processes" for recycling of fibre packaging that requires dedicated processes. Part III will also cover reject valorisation/quality assessment. It may therefore be appropriate for evaluating the repulpability of the fibre and for evaluating the recyclability of the entire beverage carton including the PolyAl fraction. The first version of Part I of the 4evergreen "circularity by design" guidelines, currently only covering standard mill processes, have provided the basis for the structure of the guidance provided in Section 5 of this document (Maximising the recyclability of beverage cartons – design recommendations). Where relevant, the guidance in this document aligns with the current 4evergreen guidelines.
The German Minimum standard for determining the recyclability of packaging 2021 (hereby referred to as the German Minimum Standard) (Stiftung Zentrale Stelle Verpackungsregister, 2021)	Version considered: 31 August 2021	This document defines the minimum requirements for Packaging Recovery Organizations (PRO) to measure recyclability with respect to setting lower/higher compliance fees for individual packaging formats. Measurement and classification is made by each PRO separately. PRO's can add individual additional criteria and therefore the recyclability result of the same pack may vary between different PROs.	This document takes a holistic approach to quantifying recyclability (collection, sorting, reprocessing), and quantifies the proportion of a package that is recyclable. The standard specifically references beverage cartons and recognises that PolyAl recycling options are available. The standard requires that where polyolefin and metal shares are to be accounted for as recyclable material, individual evidence must be produced for their high-quality mechanical recycling. The standard has been referred to in defining the factors influencing the recyclability of beverage cartons when compiling the guidance provided in Section 5 of this document (Maximising the recyclability of beverage cartons – design recommendations).

Standard or guideline	Status	Overview	Relevance and application
The Verification and examination of recyclability: Requirements and assessment catalogue of the Institute cyclos HTP for EU-wide certification (hereby referred to as the Institute cyclos-HTP method) (Institute cyclos-HTP, 2021)	Version considered: Revision 5.0, 2021	Institute cyclos HTP assesses and certifies the recyclability of packaging and goods. To facilitate this, they have developed a conceptual framework as well as a catalogue of requirements and assessment criteria for the examination and verification of recyclability. The cyclos HTP assessment fulfils the minimum standard without exemptions	This document takes a holistic approach to recyclability (collection, sorting, reprocessing), and quantifies the proportion of a package that is recyclable. The method specifically references beverage cartons. It has recently recognised that the PolyAl fraction is recyclable. The method has been applied to evaluate beverage carton recyclability in Section 4 of this report (Implications of structure and design for the recyclability of beverage cartons) and the factors influencing the recyclability score of beverage cartons have been considered when compiling the guidance provided in Section 5 of this document (Maximising the recyclability of beverage cartons – design recommendations).
Designing for a Circular Economy: Recyclability of polyolefin-based flexible packaging (hereby referred to as the D4ACE guidelines) (CEFLEX, 2020)	Published	The D4ACE guidelines have been developed for the whole value chain to build understanding of end-of-life processes, give practical support and advice on circular economy design principles for flexible plastic packaging	These guidelines address plastic films, but not within the context of films as part of a multi-material laminate construction. Nonetheless, the guidelines provide some insights into what is possible with these materials, and they have therefore been considered when compiling the guidance provided in Section 5 of this document (Maximising the recyclability of beverage cartons – design recommendations).
Paper based packaging recyclability guidelines (Cepi, ACE, FEFCO, Citpa, 2020)	Published	These guidelines have been developed by the main trade associations representing fibre-based packaging to improve the recyclability of paper packaging products in the paper recycling process.	The guidelines provide a high-level view on the relevant factors influencing the recyclability of fibre-based packaging. They have been used to inform the definition of design features and materials relevant specifically to beverage carton design and recyclability investigated in more depth in this document.
Recyclass Design for recycling guidelines	Published	which has developed a series of polymer-specific design guidelines	The Recyclass approach and guidelines take a similar structure to these ACE guidelines, regarding compatibility of different elements with appropriate recycling solutions. It addresses the polymers used in beverage carton constructions, although its classification system does not apply specifically to these polymers when used in beverage carton constructions.

Table 1: Standards and guidelines considered in the preparation of this document

5. IMPLICATIONS OF STRUCTURE & DESIGN FOR THE RECYCLABILITY OF BEVERAGE CARTONS

The following requirements must be taken into consideration when evaluating the recyclability of a packaging format:

1 The existence of a collection, sorting and recycling infrastructure on an industrial scale that allows for high-quality recycling for the packaging solution.

2 The sortability of the packaging as well as, where applicable, the separability of its components.

3 The packaging design needs to allow for the reprocessability of packaging into recycled materials that replace virgin materials.

Beverage cartons are already collected, sorted, and mechanically recycled at scale to produce high-quality materials. This is reflected in the results of the self-assessment of recyclability when applying the Institute cyclos-HTP method for assessing recyclability to beverage cartons.

According to the results of the self-assessment, beverage cartons of representative design and structure (as described in Figures 1 and 2) are substantially recyclable (Table 2). These results apply only to beverage cartons of the representative structure, manufacturers should make their own evaluation based on the actual design and structure of their beverage cartons.

Standard applied	Results	Format evaluated	Comments
Institute cyclos-HTP method	**71%** recyclable - Class A (good recyclable)	Considering a representative beverage carton structure of 75% board, 25% PE and/or aluminium (including caps and lids)	Considering that the PolyAl fraction is not recycled
Institute cyclos-HTP method	**96%** recyclable - Class AAA (excellent recyclable)	Considering a representative beverage carton structure of 75% board, 25% PE and/or aluminium (including caps and lids)	Considering that the PolyAl fraction is recycled

Table 2 Results of recyclability self-assessment of representative beverage cartons[10]

[10] See Annex for the full self-evaluation of beverage cartons using these methods

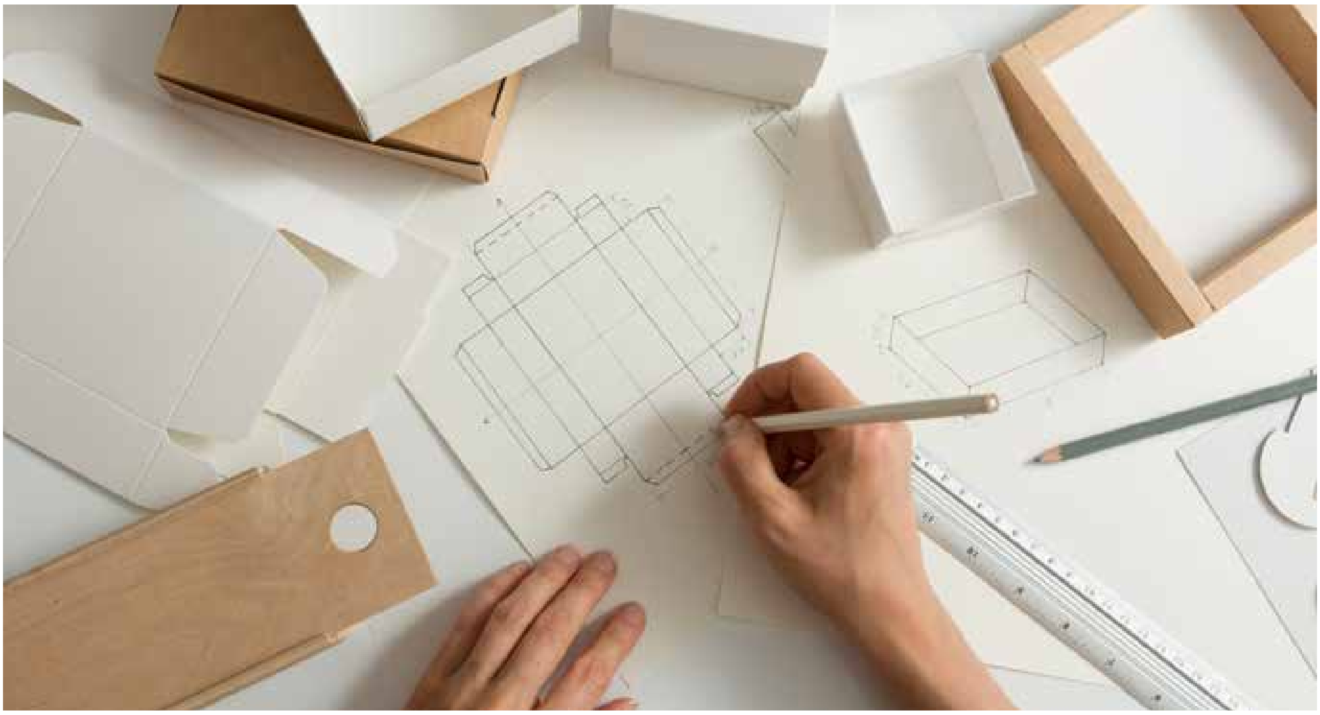
These results consider a representative beverage carton structure of 75% board, 25% PE and/or aluminium (including caps and lids). However, considering different structures and designs could impact on the recyclability score achieved. Design features and materials that have the potential to change the recyclability score achieved by either of these methods are summarised in Table 3.

The fibre recovery process is well established and the implications of these parameters on recyclability of this fraction are well understood. Subsequently, the fibre recovery process is robust and can handle beverage cartons of different structures and designs.

Techniques for valorisation of the PolyAl fraction have a long history, but PolyAl recycling is still less well established than fibre recovery processes. The implications of different structures and materials on all processes is currently subject to investigation. However, what is already clear is that some PolyAl recycling processes are more sensitive to the presence of different materials in the used beverage carton stream than others.

As a general rule, where the plastics and aluminium are reprocessed together, thin-walled applications are more sensitive to the presence of aluminium in the mix compared to bulkier applications of the recyclate. More value can be reached if the aluminium foil and PE foil fraction are separated into different material streams, as the PE fraction can be used for more applications. Where separation of the plastics from the aluminium is performed to facilitate the production of a PE fraction and an aluminium fraction, some processes and end-use applications may be more sensitive to the presence of non-polyolefin polymers in the stream than others, depending on the process and/or the separation reagents used, although further investigations are required in order to ascertain the situation conclusively.

When producing extruded granulate, some contamination can subsequently be removed by the extruder filters. However, a proportion of the LDPE will also be removed with the contaminants, resulting in a lower yield. Alternatively, depending on the melting temperature of the non-PE polymers, they may stick to (or even block) the filters. On the other hand, if there is too much non-LDPE content which cannot be handled by the recycling process in the stream, it may go straight through the system to contaminate the rLDPE granulate.



Feature/material	Potential influence on recyclability
Wet strength agents	By definition, wet strengths reduce the susceptibility of the board to wettability. As the fibre recovery process relies on hydraulic forces to separate the fibres, then wet strengths have the potential to reduce the yield from the fibre recovery process. Practical experience in the market does not indicate that beverage cartons containing wet strength boards are currently a problem for dedicated beverage carton recycling operations.
Water resistant coatings	Coatings can provide liquid packaging board with resistance to water vapour/moisture penetration. As the fibre recovery process relies on hydraulic forces to separate the fibres, then water resistant coatings have the potential to reduce the yield from the fibre recovery process. According to the German Minimum Standard, a wax coating for beverage cartons is not considered as an incompatibility, but the dissolvability has to be measured with an appropriate test method. In the Institut-cyclos HTP method, the products need to be dissolved under the technical operating parameters in typical beverage carton reprocessing facilities. Wax coated beverage cartons would not achieve the same dissolution rate in water as standard beverage cartons. Recyclability would need to be determined through measurements, according to the relevant evaluation and test protocol.
Alternative materials	As previously described, beverage cartons are typically composed of liquid packaging board and PE or liquid packaging board, PE and aluminium, with additional components such as closures manufactured from HDPE, LDPE or PP. The recyclability evaluation in the German Minimum Standard specifically refers to beverage cartons constructed of liquid packaging board and PE or liquid packaging board, PE and aluminium (including caps, lids, etc). Whilst bio-based PE and PP are functionally equivalent to fossil-based PE and PP (and are therefore fully compatible with the established recycling technologies, the implications of the use of in the structure of non-polyolefins and biodegradable polymers (e.g. PLA) on recyclability would need to be ascertained as some PolyAl recycling processes may be more sensitive to the presence of non-polyolefins in the overall material stream than others.
Adhesives	Adhesives are integral to the manufacture of packaging and standard paper recycling mill technology is designed to separate and remove these during the papermaking process. However, some adhesives have potential to soften or plasticise in the heat of the process to form “stickies” that can end up on the finished paper, spoiling the performance and appearance of the paper and/or the paper making or converting processes. The German Minimum Standard lists water-insoluble or re-dispersing adhesive applications as incompatible with recycling processes for beverage cartons, where it has not been specifically proven that they can be removed. The Institut-cyclos HTP method also identifies insoluble dispersing adhesives as incompatible with recycling processes, unless it can be proved that they are removable by INGEDE Method 12 or 4.
Printing inks	Inks that are not easily removed by the de-inking process can pass into the new sheet, causing flecking, visual impurities, dirt specks and pin holes, thereby reducing the quality of the recycled product. Currently most used beverage carton recycling mills do not include deinking stages (except tissue mills utilising used beverage cartons as a fibre source). According to the Institut-cyclos HTP method, EuPIA provides an exclusion list for printing Inks and related products that are contaminants and not separable by the recycling processes.

Table 3 Design features and materials and their implications for the recyclability of beverage cartons

6. MAXIMISING THE RECYCLABILITY OF BEVERAGE CARTONS

DESIGN RECOMMENDATIONS

Although the evaluation and evidence bear out that beverage cartons are inherently recyclable, it has been demonstrated that there are still characteristics of carton structures and designs which may influence the recyclability of individual beverage cartons as measured by recyclability criteria. In this section, we discuss the relevance of each of these parameters and identify actions that could be taken to maximise the recyclability of beverage carton materials and designs.

The carton structure and design features which can potentially influence recyclability of beverage cartons were identified through the following processes:

- **Parameters identified in the German Minimum Standard and Institute cyclos-HTP recyclability assessment methods**
- **Literature review and consideration of other design for recyclability guidelines (GreenBlue, 2011), (CPI, 2019), (Cepi, ACE, FEFCO, Citpa, 2020), (CEFLEX, 2020), (FEFCO, 2021), (Recyclass, 2021) (CIRC-PACK, 2022)**
- **Interviews with stakeholders, including suppliers of sorting technology, suppliers of repulping equipment designed for liquid beverage cartons, and developers and operators of PolyAl recycling technology.**

Each specific structure or design component was then assessed against the categories outlined in Table 4.

Fully compatible with UBC recycling processes	Conditionally compatible with some UBC recycling processes	Not compatible with UBC recycling processes unless testing proves otherwise	Compatibility with UBC recycling processes unknown – testing required to prove recyclability
Beverage cartons containing these elements are fully compatible with existing sorting technologies, they do not disturb neither the fibre recovery through enhanced recycling processes nor the promoted PolyAl recycling processes. This is demonstrated through existing test results and/or practical experience.	Beverage cartons containing these elements are still sortable and recyclable but are seen as less favourable for either the enhanced fibre recovery process or some promoted PolyAl recycling processes, as they make the process more difficult or reduce the quality of the output material. Specific testing can demonstrate that these constituents do not negatively impact recycling.	Beverage cartons containing these elements either cause major issues during sorting and recycling or render the quality of the output material from recycling processes unusable. Beverage cartons containing such elements are therefore considered unrecyclable, unless recyclability can be proved via relevant testing.	The recyclability implications of beverage cartons containing these elements is unknown and further research and/or testing is required to establish compatibility with existing sorting processes, the enhanced fibre recovery process and/or PolyAl recycling processes.

Table 4 Categories considered for the recyclability implications of different compositions and design components, adapted from (4evergreen, 2022)

6.1 Fibres used in liquid packaging board

All fibre types used in beverage cartons are recyclable in the dedicated fibre recovery processes operated across Europe.

The recovered fibres from used beverage cartons are consumed in the manufacture of a wide range of recycled-content paper products, including packaging grades (corrugated case medium, carton board, core board) and tissue papers.

Component	Sub-category	Recyclability	Implications for recyclability
Fibres used in liquid packaging board	Sulphate kraft, bleached	**Fully compatible with UBC recycling processes**	No implications for the recyclability – all fibre types used in beverage cartons are recyclable in the dedicated fibre recovery processes operated across Europe
	Sulphate kraft, unbleached	**Fully compatible with UBC recycling processes**	
	CTMP	**Fully compatible with UBC recycling processes**	

Table 5 Recycling compatibility of different fibres used in liquid packaging board

6.2 Additives used in liquid packaging board

The presence of wet strength papers in the fibre furnish may require an extended repulping duration, potentially higher temperatures and changes to the water chemistry to ensure sheet disintegration and fibre release. The fibre yield may be lower for wet strength products compared to non-wet strength products, leaving a higher proportion of residual fibres in the PolyAl fraction. Residual fibres in the PolyAl fraction are undesirable as they reduce the yield, efficiency and quality of the recyclate from the PolyAl recycling process.

However, practical experience demonstrates that fibres are successfully recovered from beverage cartons containing wet strength by the dedicated fibre recovery facilities in operation today. The 4evergreen design for circularity guidelines (4evergreen, 2022) clarify which wet strength resins and which neutral sizing agents really influence recyclability of paper and board packaging generally. This helps to narrow down the instances for which testing may be required in order to determine if there is a lower fibre yield.

Component	Sub-category	Recyclability	Implications for recyclability assessment
Additives – wet strength resins	Glyoxylated polyacrylamide (GPAM).	**Fully compatible with UBC recycling processes**	Recyclability depends on a number of factors, such as relative wet-strength (WS) level, amount of WS agent, etc. Minimising or avoiding these wet strength resins can make the recycling process more efficient, facilitating lower pulping temperature and time, and reduced chemicals usage, , etc. Further testing may be required to demonstrate the fibre yield from liquid packaging board containing PAE as a wet strength resin to demonstrate recyclability or otherwise.
	Polyamide-epichlorohydrin (PAE)	**Conditionally compatible with some UBC recycling processes**	
	Urea/Formaldehyde	**Conditionally compatible with some UBC recycling processes**	
Sizing, wet end	Alkylketene dimers (AKD)	**Fully compatible with UBC recycling processes**	
	Alkenylsuccinic anhydride (ASA)	**Fully compatible with UBC recycling processes**	
	Rosin	**Fully compatible with UBC recycling processes**	

Table 6 Recycling compatibility of additives used in liquid packaging board

6.3 Liquid packaging board coatings

Liquid packaging boards may be clay or pigment coated. There are lightly coated and fully coated boards in the market. Fully coated boards provide improved printability (for beverage cartons where the ink is applied directly to the board) and are required to meet the design needs for some brand owners. Both lightly and fully coated boards are recyclable. Specialist facilities which reprocess used beverage cartons aim to remove insoluble/soluble coatings during the fibre preparation stages which incurs disposal costs.

The presence of residual clay coating in the recycled fibre output may decreases the recycled fibre quality and could lead to optical inhomogeneities in the recycled product. Board producers should therefore seek to reduce the quantity of clay coating required, within the limitations of meeting the printability requirements.

Wax coatings are not commonly used for beverage cartons in Europe but should be avoided as these are not compatible with the fibre separation and repulping process.

Component	Sub-category	Recyclability	Implications for recyclability assessment
Liquid packaging board coatings	Clay/pigment coatings	**Fully compatible with UBC recycling**	Coated boards are compatible with the fibre recovery process, but board producers should seek to reduce the quantity of clay coating required, within the limitations of meeting printability requirements.
	Wax coatings	**Conditionally compatible with some UBC recycling processes**	In the Institut-cyclos HTP method, the products need to be dissolved under the technical operating parameters in typical beverage carton reprocessing facilities. Wax coated beverage cartons would not achieve the same dissolution rate in water as standard beverage cartons. For wax coated liquid packaging board, recyclability would need to be determined through measurements, according to the relevant evaluation and test protocol.

Table 7 Recycling compatibility of coatings

6.4 Polymers used for lamination and barrier films; vapour deposition barriers

Today's typical beverage cartons composed of board, polyethylene and/or aluminium are fully compatible with existing collection, sorting and recycling systems available for beverage cartons. However, alternative and additional materials can be used in the structure:

- **Alternatives to polyethylene which can be used in the lamination or as an alternative to aluminium as a barrier layer include polypropylene, ethylene vinyl alcohol (EVOH), polyamide (PA) and polyethylene terephthalate (PET).**
- **Very thin layers of materials such as AlOx, SiOx or metallisation can be applied by vapour deposition to provide barrier properties**
- **For beverage cartons delivered as pre-formed blanks, sealing is performed using the LDPE coatings. Roll-fed carton material requires a longitudinal seal strip to be applied internally to prevent contact between the edge of the aluminium and/or the edge of the liquid packaging board and the product. Depending on the oxygen sensitivity of the product, this strip may be made from PET, PA or EVOH copolymer. Other adhesives are also used for the sealing strip but with limited market penetration.**

Beverage cartons of typical structure provide unique spectral properties which allow their identification and automated sorting at commercial speeds and with high yield and purity. Any non-standard structure with an outer layer other than PE requires empirical testing to ensure that they can still be identified in NIR sensor-based sorting systems.

Beverage cartons need to be repulped under suitable conditions which are applied in typical beverage carton reprocessing facilities. Therefore, the repulpability in those operating conditions would need to be ascertained for beverage cartons of non-standard structure where alternative materials are applied. If the non-standard structure achieves the same dissolution rate as the standard structure, then the fibres are considered as recyclable. However, if it does not achieve the same repulping rate in water as standard beverage cartons it would be considered less recyclable (or potentially even non-recyclable).

PE/Al laminates are fully compatible with all PolyAl recycling processes, but the presence of alternative polymer layers or of an alternative barrier layer may contaminate the output of some PolyAl recycling processes, reducing processability and affecting the physical properties of the output. Different strategies exist for processing the PolyAl stream. Some technologies process the aluminium and PE lamination and barrier films together as a composite material, whereas other separate out the aluminium and PE foil fraction for processing Depending on the end-application they target for the recyclates, and on the process they use, PolyAl recyclers will be more or less sensitive to non-PE material in the stream of PolyAl they are able to process.

According to the D4ACE guidelines for recyclability of polyolefin-based flexible packaging, packaging is fully compatible with mechanical recycling processes producing recycled polyethylene pellets (for example, the recycling of the separate PE foil fraction into PE granules) when it is composed of >90% PE. At 80-90% PE, the material has limited compatibility, and at less than 80% it is not compatible. Further trials and investigations are required in order to ascertain if these compatibility principles apply to PolyAl recycling processes.

Biodegradable polymers may be incompatible with the sorting processes. They may also negatively influence the properties, performance and value of materials and products derived from the recycling of the PolyAl fraction. Further research and/or testing is required on this topic.

It is not only technical compatibility with recycling processes that is important. Optimising the value of recycled materials is critical to improve recycling rates.

Component	Sub-category	Recyclability	Implications for recyclability assessment
Polymers used for lamination and barrier films (*)	>90% Polyethylene (PE) – fossil based and bio-based	**Fully compatible with UBC recycling processes**	If the principles outlined in D4ACE guidelines are considered, then beverage cartons containing more than 90% polyethylene in the polymer component of the structure are fully compatible with all PolyAl recycling processes. At 80-90%, the material has limited compatibility, and at less than 80% it is not compatible.
	80-90% Polyethylene (PE) – fossil based and bio-based	**Conditionally compatible with some UBC recycling processes**	
	<80% Polyethylene (PE) – fossil based and bio-based	**Not compatible with UBC recycling processes unless testing proves otherwise**	
	<10% Polypropylene (PP) – fossil based and bio-based	**Fully compatible with UBC recycling processes**	If the principles outlined in D4ACE guidelines are considered, then for PolyAl recycling processes producing recycled PE pellets, beverage cartons containing less than 10% polypropylene in the polymer component of the structure is likely to be fully compatible with the recycling processes. At 10-20%, the material has limited compatibility, and at more than 20% it is not compatible.
	10-20% Polypropylene (PP) – fossil based and bio-based	**Conditionally compatible with some UBC recycling processes**	
	>20% Polypropylene (PP) – fossil based and bio-based	**Not compatible with UBC recycling processes unless testing proves otherwise**	
	<5% EVOH	**Fully compatible with UBC recycling processes**	A maximum of 5% of EVOH in the structure of the polymer component of the structure is likely to be compatible with PolyAl recycling processes. Quantities above this are thought to result in issues during reprocessing and impact the quality of the recyclate (CEFLEX, 2020). However, further trials and investigations with PolyAl recyclers are required to confirm this threshold.
	>5% EVOH	**Not compatible with UBC recycling processes unless testing proves otherwise**	
	Up to 20% polyamide 6 (PA 6) or co-poly-amide 6/6.6 as coextruded layer, with at least one surrounding layer containing maleic anhydride-grafted PE as a tie layer specified for PA/PE coextrusion in a ratio of ≥ 0.5 g per g PA	**Fully compatible with UBC recycling processes until a ratio of 30% of this structure in the mix**	A maximum of 20% of PA6 or PA6/6.6 in the total weight of the polymers (as specified on the left) has been proven in compatibility tests done by Cyclos HTP Institute to be fully compatible with existing PolyAl recycling processes until a ratio of 30% of the structure in the mix of polymers arriving at the PolyAl recycler site
		Compatibility with UBC recycling process unknown for a ration >30% of this structure in the mix - testing required to prove recyclability	

(*) Subject to passing of independent industry approved recyclability testing. Testing to ensure that this specific PA barrier, when adopted widely, does not contaminate the recycling process for polyolefins.

Testing to be performed within the annual ACE DfR Guidelines review period.

Component	Sub-category	Recyclability	Implications for recyclability assessment
Polymers used for lamination and barrier films (*)	>20% Polyamide 6 (PA6) or co-polyamide 6/6.6 (PA 6/6.6) as coextruder layer, with at least one surrounding layer containing maleic anhydride-grafted PE as a tie layer specified for PA/PE coextrusion in a ratio of <= 0,5 g per g PA.5	**Compatibility with UBC recycling process unknown - testing required to prove recyclability**	Structures using more than 20% PA6 or PA6/6.6 in the total wight of the polymers have not been covered in the compatibility tests performed
	Polyamide 6 (PA 6) or co-polyamide 6/6.6 with less than 0.5 g per g PA of maleic anhydride-grafted PE as tie layer in the coating structure	**Compatibility with UBC recycling process unknown for a ration >30% of this structure in the mix - testing required to prove recyclability**	These combinations of materials have not been tested for compatibility with PolyAl recycling processes. Discussions in German minimum standard group regarding PA and recyclability are ongoing as well as within CEFLEX, who express that further work will be done to agree to a limit regards to PA.
	PA in combination with EVOH as coextruded layer of laminated layer	**Compatibility with UBC recycling processes unknown – testing required to prove recyclability**	

(*) Subject to passing of independent industry approved recyclability testing. Testing to ensure that this specific PA barrier, when adopted widely, does not contaminate the recycling process for polyolefins.

Testing to be performed within the annual ACE DfR Guidelines review period.

Component	Sub-category	Recyclabilit	Implications for recyclability assessment
Polymers used for lamination and barrier films (*)	<5% PET	**Conditionally compatible with some UBC recycling processes**	PET is not compatible with a PE mechanical recycling process (CEFLEX, 2020). It will partly be removed (PET-fines may slip through the filter and some is removed in washing steps due to the higher density of PET that is 1.0 g/cm3, although if PET is present as a thin film then it may also float due to air bubbles on the surface), but this also removes PE and reduces the yield of the recycling process. Beverage cartons containing less than 5% PET in the polymer component of the structure (i.e. >95% PE) are likely to result in contamination levels that are undesirable but nonetheless manageable for the recycling processes. Beverage cartons containing above 5% PET in the polymer component are definitely not compatible. These thresholds are based on expert opinion, further research and testing may lead to refinements to these guidelines in the future. For example, the impact of flexible packaging laminated structures containing PET in polyolefin-based mechanical recycling process will be further assessed in phase 2 of the CEFLEX D4ACE guidelines. In the meantime, minimising and/or phasing out the use of PET will increase recyclate quality/yield. When assessing the recyclability of specific beverage cartons, the PET share of the structure would need to be deducted from recyclability score, along with recycling process losses of the PE share of the structure.
	>5% PET	**Not compatible with UBC recycling processes unless testing proves otherwise**	
	Biodegradable polymers	**Not compatible with UBC recycling processes unless testing proves otherwise**	According to the D4ACE guidelines, biodegradable and compostable polymers, even at low levels, are expected to cause disruption of the mechanical PE, PP and mixed PO recycling processes and negatively affect the quality and value of final recyclate. They should not therefore be used in PE, PP or mixed PO structures intended to be mechanically recycled, unless testing establishes the compatibility of a particular biodegradable polymer with PolyAl recycling processes.
Vapour deposition barriers	AlOx at <5% share by weight	**Fully compatible with UBC recycling processes**	If the principles outlined in D4ACE guidelines are considered, then for PolyAl recycling processes producing recycled PE pellets, beverage cartons containing less than 5% AlOx, SiOx or metallisation by weight in the foil component of the structure is likely to be fully compatible with the recycling processes. At >5%, the material has limited compatibility.
	SiOx at <5% share by weight	**Fully compatible with UBC recycling processes**	
	Metallisation at <5% share by weight	**Fully compatible with UBC recycling processes**	
	AlOx at >5% share by weight	**Conditionally compatible with some UBC recycling processes**	
	SiOx at >5% share by weight	**Conditionally compatible with some UBC recycling processes**	
	Metallisation at >5% share by weight	**Conditionally compatible with some UBC recycling processes**	

Table 8 Recycling compatibility of polymers used for lamination and barrier films and vapour deposition barriers

(*) Subject to passing of independent industry approved recyclability testing. Testing to ensure that this specific PA barrier, when adopted widely, does not contaminate the recycling process for polyolefins.
Testing to be performed within the annual ACE DfR Guidelines review period.

6.5 Polymers used for caps and closures

The caps and closures will typically be separated out and recycled as a mixed polyolefin stream.

For mechanical recycling processes producing a mixed polyolefin stream, material that is >90% polyolefins (PE and PP) is fully compatible with recycling. At 80-90% PE/PP, the material has limited compatibility, and at less than 80% it is not compatible with the process. The more of one polymer in the mixed stream (>80%) the better.

Biodegradable polymers may negatively influence the properties, performance and value of materials and products derived from the recycling of the caps and closures. Further research and/or testing is required on this topic.

Component	Sub-category	Recyclability	Implications for recyclability assessment
Polymers used for caps and closures	>90% polyolefin	**Fully compatible with UBC recycling processes**	If the principles outlined in D4ACE guidelines are considered, then for recycling processes producing a mixed polyolefin stream from the hard fraction (caps and closures), beverage cartons containing >90% polyolefin in the polymer component of the structure are likely to be fully compatible with the recycling processes. At 80-90%, the material has limited compatibility, and at less than 80% it is not compatible.
	80-90% polyolefin	**Conditionally compatible with some UBC recycling processes**	
	<80% polyolefin	**Not compatible with UBC recycling processes unless testing proves otherwise**	
	Biodegradable polymers	**Not compatible with UBC recycling processes unless testing proves otherwise**	According to the D4ACE guidelines, biodegradable and compostable polymers, even at low levels, are expected to cause disruption of the mechanical PE, PP and mixed PO recycling processes and negatively affect the quality and value of final recyclate. They should not therefore be used in PE, PP or mixed PO structures intended to be mechanically recycled, unless testing establishes the compatibility of a particular biodegradable polymer with PolyAl recycling processes.

Table 9 Recycling compatibility of polymers used for caps and closures

6.6 Adhesives for attachments

Only a limited amount of adhesive is required for the production of beverage cartons. Adhesives may be used for attaching drinking straws to the outer surface of the carton and for attaching caps/closures to the carton. For these applications, hotmelt adhesives are used, typically polyolefins or ethylene-vinyl acetate (EVA). All beverage cartons in use and being recycled today employ hotmelts for cap and straw attachment (4evergreen, 2022).

These hotmelt adhesives are not water soluble. By keeping their application size above 2mm x 2mm, hotmelt applications can be removed effectively during screening (European Paper Recycling Council, 2017). Furthermore, hotmelts exhibit tackiness only above their softening point. Thus, by choosing hotmelts with a suitably high softening point i.e., >68°C (above the temperatures encountered in paper recycling), secondary microsticky and macrosticky formation can be minimized.

Component	Sub-category	Recyclability	Implications for recyclability assessment
Liquid carton board coatings	Water soluble adhesives	**Fully compatible with UBC recycling processes**	Any water-soluble adhesive application can be expected to dissolve into the process water during the fibre repulping process. These materials will become and remain part of the process water throughout the further processing steps (4evergreen, 2022).
	Water insoluble or re-dispersing adhesives	**Conditionally compatible with some UBC recycling processes**	Potential to cause generation of stickies in the products manufactured from the recovered fibres, thereby reducing quality. Testing is required where it has not been specifically proven that these applications can be removed. As an alternative to testing, removability can be estimated using the EPRC assessment methodology described in the Scorecard for the Removability of Adhesive Applications (European Paper Recycling Council, 2017).
	Hot melt adhesive (with softening temperatures ≥68°C)	**Fully compatibility with UBC recycling processes**	Hotmelts exhibit tackiness only above their softening point. Thus, by choosing hotmelts with a suitably high softening point, i.e. above the temperatures encountered in paper recycling, secondary microsticky formation can be minimized (4evergreen, 2022).
	Hot melt adhesives with softening temperatures ≤68°C	**Compatibility with UBC recycling processes unknown – testing required to prove recyclability**	Potential to cause generation of stickies in the products manufactured from the recovered fibres, thereby reducing quality. Testing is required where it has not been specifically proven that these applications can be removed. As an alternative to testing, removability can be estimated using the EPRC assessment methodology described in the Scorecard for the Removability of Adhesive Applications could be applied to determine removability (European Paper Recycling Council, 2017).

Table 10 Recycling compatibility of adhesives for attachments

6.7 Printing inks/printing techniques

Two different solutions are used for printing beverage cartons. Either the liquid packaging board is printed prior to the attachment of the outer LDPE layer, or the laminated reel is printed, with the ink applied to the outer side of the outer LDPE layer.

Both of these standard printing process are compatible with current sorting and recycling processes.

According to the experiences of ink suppliers, paper makers and recyclers of recovered paper, inks and varnishes applied directly to fibre-based packaging do not cause any major problems for the recovery and recycling of fibres. If required by the end product, inks can be removed by a deinking process. Otherwise, if the recovered fibres are going to be used for brown packaging grades, then the ink particles are incorporated into the paper sheet.

An exception to this is inks excluded by the EuPIA (Exclusion list for printing inks and related products). This exclusion list of raw materials is based on hazard classification and/or toxicological evidence. Their exclusion is not directly related to recyclability, but hazardous and toxicology implications, and therefore they are excluded for recycling.

Where print is applied to the outer surface of the outer LDPE layer, the printed LDPE layer is removed from the fibre recovery process as part of the PolyAl stream. In this case, the ink is included in the PolyAl stream and its compatibility with the sorting and PolyAl recycling processes has to be considered. Practical experience shows that applying the print to the outer LDPE layer does not affect the ability of the beverage cartons to be sorted by existing automated optical sorting technologies. However, for beverage cartons printed on the outer side of the LDPE layer, it is important that when special decoration techniques are applied (e.g. nearly all black or metallized packages) it is ensured that both the scale of the printed area and specific inks used does not prevent optical sorting by NIR spectroscopy.

Printing inks applied on the outer surface of packaging are not meant for or automatically safe to be used in direct contact with food and therefore may limit safe use of the recycled material for subsequent food contact applications.

For all printing inks, their compatibility with food contact applications would need to be ascertained in order to ensure they are fully compatible with UBC recycling processes.

Component	Sub-category	Recyclability	Implications for recyclability assessment
Printing inks and printing techniques	Offset print – oil-based ink (vegetable)	**Fully compatible with UBC recycling processes**	Does not limit the use of recovered fibres to non-food applications
	Offset print – oil-based ink (mineral)	**Conditionally compatible with some UBC recycling processes**	Fully recyclable, but limits the use of recovered fibre to non-food applications.
	Offset print – UV inks	**Compatibility with UBC recycling processes unknown – testing required to prove recyclability**	This printing technique and printing ink combination is fully compatible with fibre recovery processes, but its influence on some PolyAl recycling processes when print is applied directly to the outer LDPE layer may require further investigation.
	Flexo – SB	**Fully compatible with UBC recycling processes**	
	Flexo – Wb	**Fully compatible with UBC recycling processes**	
	Flexo – UV	**Compatibility with UBC recycling processes unknown – testing required to prove recyclability**	This printing technique and printing ink combination is fully compatible with fibre recovery processes, but its influence on some PolyAl recycling processes when print is applied directly to the outer LDPE layer may require further investigation.
	Gravure – SB	**Fully compatible with UBC recycling processes**	
	Gravure – Wb	**Fully compatible with recycling processes**	
	Gravure – UV	**Compatibility with recycling processes unknown – testing required to prove recyclability**	This printing technique and printing ink combination is fully compatible with fibre recovery processes, but its influence on some PolyAl recycling processes when print is applied directly to the outer LDPE layer may require further investigation.
	Inks excluded by the EuPIA (Exclusion list for printing inks and related products)	**Not compatible with UBC recycling processes**	According to the Institut-cyclos HTP method, these are contaminants. Their exclusion is not directly related to recyclability, but hazardous and toxicology implications, and therefore they are excluded for recycling.

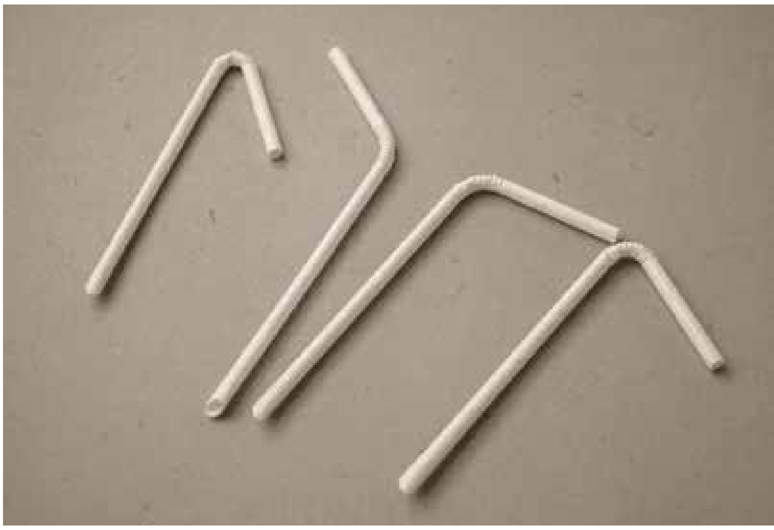
Table 11 Recycling compatibility of printing inks and techniques

6.8 Straws and protective wrappers

Consumers should be encouraged to push the drinking straw into the beverage carton when the beverage is finished. In this way, the drinking straw is captured in the waste management system and cannot unintentionally become litter. Paper drinking straws and paper wrappers are a renewable and potentially recyclable option. However, paper straws will be engineered to withstand water vapour/ moisture and therefore repulpability of paper drinking straws in the context of mills which recover fibre from beverage cartons should be ascertained before bringing to the market.

PE (including bio-based PE) and PP (including bio-based PP) protective wrappers glued to the beverage carton used for drinking straws will most likely be removed from the packages during collection and sorting processes prior to the used beverage cartons reaching the recycling mill. In this case, they would be sorted into a PE or PP material stream which would allow them to be recycled. As these wrappers are mono-material, they are 100% recyclable according to the D4ACE guidelines (CEFLEX, 2020) and the Cyclos HTP methodology.

Should any of the protective wrappers be carried through to the recycling mill, they would become separated from the beverage carton during the fibre recovery process and would become part of the PolyAl stream. They would constitute a very low proportion of the non-fibre fraction of the beverage carton, and they are fully compatible with all PolyAl recycling processes.



Component	Sub-category	Recyclability	Implications for recyclability assessment
Straws	Paper straws	**Fully compatible with UBC recycling processes**	Paper straws are engineered to withstand water vapour/moisture and therefore repulpability of paper drinking straws in the context of mills which recover fibre from beverage cartons should be ascertained.
Protective wrappers	PE (fossil based and bio-based) protective wrappers	**Fully compatibility with UBC recycling processes**	Fully compatible with all PolyAl recycling processes.
	PP (fossil based and bio-based) protective wrappers	**Fully compatibility with UBC recycling processes**	Fully compatible with PolyAl recycling processes producing a mixed polyolefin product. For PolyAl recycling processes producing recycled PE pellets, beverage cartons containing less than to 10% polypropylene in the polymer component of the structure are fully compatible with the recycling processes. The weight of the protective wrapper for straws is unlikely to exceed 10% of the polymer component of the beverage cartons.
	Paper protective wrappers	**Fully compatibility with UBC recycling processes**	As paper, these are fully compatible with the fibre recovery process.

Table 12 Recycling compatibility of straws and wrappers

7. FUTURE-PROOFING THESE GUIDELINES

Technology and policy relating to collection, sorting and recycling is fast moving:

- **Capabilities in sorting systems and reprocessing technologies are constantly changing. Existing technologies are evolving and new technologies are emerging which could revolutionise recycling value chains. ACE and EXTR:ACT maintain a watching brief on those technologies pertinent to beverage carton collection, sorting and recycling, especially emerging technologies for recycling of the PolyAl fraction.**
- **The legal requirements and definitions of recycling are under constant review, particularly as policies relating to the Circular Economy Action Plan are finalised.**
- **Also, other design for recycling guidance is being developed and revised which may provide further insights regarding the recyclability of used beverage cartons.**

These guidelines will therefore be reviewed annually and updated as necessary to reflect the dynamic situation. Users of the guidelines are encouraged to check that they are accessing the most recent version.

8. GLOSSARY

BIO-BASED Materials or fuels derived from biomass (living matter such as trees and plants, chitosan from shellfish, etc).

BIODEGRADABLE A substance or object capable of being decomposed by bacteria or other living organisms.

COLLECTION Separate collection of paper and paper products from industrial and commercial outlets, from households and offices for recovery. Collection includes transport to the sorting or recycling plant/paper mill, and is calculated as the utilisation plus exports minus imports of paper for recycling. The difference between collection and utilisation of paper for recycling can be explained by trade, stock variations and some volumes destined to other material recycling options.

CONVERTING Manufacture of products by processes or operations applied after the normal paper or board manufacturing process. The operation of treating, modifying, or otherwise manipulating the finished paper and paperboard so that it can be made into end-user products, such as special coating, waxing, printing, and gumming, and envelope, bag, and container manufacturing.

DEINKING Deinking (also de-inking) is any process, in addition to slushing and incidental washing, intended to remove most of the ink particles from pulp made from recovered printed paper or board (ISO 4046-2, 2016).

EN 643 – EUROPEAN LIST OF STANDARD GRADES OF PAPER AND BOARD FOR RECYCLING The EN 643 List gives a general description of the standard paper and board grades by defining what they do and do not contain.

FIBRE-BASED PACKAGING MATERIAL The sum of papermaking fibres, fillers added in the wet-end, pigments used in printability coating, binders used as a minor fraction in pigment printability coating, starch and other dry strength agents, and other functional and process chemicals used in the wet-end of paper machine, printing inks, overprint varnish, as well as adhesive used to bind two layers of paper (or paper and plastic film) together, barrier layers, and any additional/ auxiliary items (closure, tape, label).

FOSSIL-BASED Materials or fuels derived from fossil resources such as oil or natural gas.

LIQUID PACKAGING BOARD Term applied to paper board specifically intended for use in beverage cartons.

MECHANICAL PULPING Wood pulp, including reject pulp, obtained by grinding or milling into relatively short fibres, coniferous or non-coniferous rounds, quarters, billets, etc., or through refining coniferous or non-coniferous chips. Called stone groundwood pulp and refiner groundwood, it can include pre-treatment with chemicals (i.e. chemimechanical pulp), and it can be bleached or unbleached. This pulp is used mainly in newsprint and wood-containing papers, like LWC (light-weight coated) and SC papers.

MILL The building or buildings and area where the pulp and papermaking operations are carried out. Sometimes called a plant when referring to one area of the whole operation.

NEAR-INFRARED (NIR) SORTING Near-infrared sorting technologies measure the reflected light of an object in the range of 760 and 2,500 nm. NIR is used in the sorting process to separate packaging from each other based on reflected surface material.

PAPER Paper consists mainly of natural fibres and can possibly contain other ingredients such as fillers, starch, coating colour including binder, as well as additives typically used in the paper industry such as wet-strength agents, sizing agents and water.

PAPERBOARD Generic term applied to certain types of paper frequently characterised by their relative high rigidity (ISO 4046- 3:2016). The primary distinction between paper and board is normally based upon thickness or grammage, though in some instances the distinction will be based on the characteristics and/or end-use.

PAPER FOR RECYCLING (PFR) Natural fibre-based paper and board suitable for recycling and coming in any shape. Products made predominately from paper and board, which may include other constituents that cannot be removed by dry sorting, such as coatings and laminates, spiral bindings, etc.

POLYAL The mixed polymer and aluminium stream remaining after the UBC fibre recovery process.

RECYCLING The mechanical reprocessing of used materials in a production process into new materials.

PULP Fibrous material in papermaking produced in a pulp mill, either mechanically or chemically from fibrous cellulose raw material (wood most common).

PULPING The act of processing wood (or other plant-based sources) to obtain the primary raw material for making paper, usually cellulose fibre. Wood is the most widely used source of fibre for the paper making process. The fibres are separated from one another into a mass of individual fibres. The separation can be undertaken by a mechanical process, where the fibres are teased apart, or by chemical means, where the lignin binding the fibres together is dissolved away by cooking the woodchips in suitable chemicals. After separation, the fibres are washed and screened to remove any remaining fibre bundles.

STANDARD RECYCLING MILL Such mills produce high-quality end-products based on EN 643 groups 1 to 4 with a classic low consistency pulper (5% fibre concentration). Often such processes operate deflakers to separate fibre bundles into individual fibres, as well as coarse- and fine-screening cleaners. The aim is to separate the fibre from the other material. The final result is fibrous material suspended in water ready for papermaking (i.e. recycled pulp). This equipment and process can handle paper-based packaging with basic mechanical transformation. It can also handle paper containing inks, water-soluble chemicals and small amounts of converting products, such as staples, adhesive tape or glues based on starch or other water-soluble adhesives.

SPECIAL RECYCLING MILL These mills treat a mix of special grades (group 5 of EN 643) but also other groups (1-4 from EN 643). Each recycling mill determines the optimal mix and adds one or more piece of dedicated equipment, such as a horizontal high-density drum pulper, a separate batch pulper with longer pulping time, deinking, fine cleaners, hot dispersion, special process and wastewater systems. These specialised recycling mills can treat paper-based packaging that has been layered with non-water soluble products, such as wax, plastic film or other layers including aluminium, polyester and polyethylene entering the recycling process in homogeneous lots. In order to optimise the recycling process, paper composite packaging, which cannot be handled in standard processes, should be delivered to specialised paper mills in EN 643 identified flows. As in standard mills, the result of the process is also very high quality fibrous material suspended in water ready for papermaking.

USED BEVERAGE CARTONS Post-consumer beverage cartons.

List of abbreviations

AKD Alkyl Ketene Dimer

ALOx Aluminium Oxide

ASA Alkenyl Succinic Anhydride

EuPIA European Printing Ink Association

EVA Ethylene-Vinyl-Acetate

EVOH Ethylene-Vinyl-Alcohol

LDPE Low-Density Polyethylene

LPB Liquid Packaging Board

NIR Near-infrared

PA Polyamide

PAAE Polyamidoamine-epichlorohydrin

PAE Polyamide-epichlorohydrin

PET Polyethylene Terephthalate

PE Polyethylene

PLA Polylactic Acid

PP Polypropylene

SiOx Silicon Oxide

UBC Used beverage cartons

ANNEX: SELF-ASSESSMENT OF BEVERAGE CARTON RECYCLABILITY

In this annex, a self-assessment of the recyclability of beverage cartons of standard structure has been performed using the principles outlined in the Verification and examination of recyclability: Requirements and assessment catalogue of the Institute cyclos-HTP for EU-wide certification (Institute cyclos-HTP, 2021). This method is based on the requirements of the German Minimum Standard (Stiftung Zentrale Stelle Verpackungsregister, 2021), The objective of the self-assessment was to better understand the factors that influence the recyclability of beverage cartons.

Result

Applying the principles outlined in the Verification and examination of recyclability: Requirements and assessment catalogue of the Institute cyclos-HTP for EU-wide certification (Institute cyclos-HTP, 2021), the recyclable content of beverage cartons of representative structure is quantified as 71% (Class A, good recyclable) if only recovery of the fibre is considered, and 96% (Class AAA, excellent recyclable) if PolyAl recycling is also considered in the assessment. These results apply only to beverage cartons of the representative structure, manufacturers should make their own evaluation based on the actual design and structure of their beverage cartons.

Results	Format evaluated	Comments
71% recyclable **Class A (good recyclable)**	**Considering a representative beverage carton structure of 75% liquid packaging board, 25% PE and/or aluminium (including caps and lids)**	Considering that the PolyAl fraction is not recycled
96% recyclable **Class AAA (excellent recyclable)**	**Considering a representative beverage carton structure of 75% liquid packaging board, 25% PE and/or aluminium (including caps and lids)**	Considering that the PolyAl fraction is recycled

Table 5 Results of the self-assessment of recyclability of beverage cartons

Estimating the recyclability of beverage cartons using the Institute cyclos-HTP method

This approach, which was first developed in 2011 to quantitatively measure the recyclability of packaging and other similar products, has been applied as an example of how recyclability assessments work and the inferences for beverage cartons. Since its first development, the approach has been updated regularly. Many brand manufacturers and producers of packaging material use this tool to define the recyclability and optimise the sustainability of their packaging. The Der Grüne Punkt-Duales System Deutschland GmbH Producer Responsibility Organisation (PRO) also evaluates the packaging of its licensees via this method.

The key aspects of this method are:

- **Recycling processes, which generate recyclate of such a quality that they can replace virgin material of the same material in a 1:1 ratio, served as benchmark for the recyclability assessment.**
- **These reference processes have to be available on an industrial scale and need to be supplied. This applies to the entire recovery chain, from collection to sorting and re-processing to the final recyclate.**
- **Recycling processes are material-specific. Correspondingly, the assessment criteria for specific packaging solutions are derived from respective, relevant reference processes.**
- **The quantitative assessment considers all possible uses arising from closing of the material cycle. Thus, after completing all separation, cleaning, melting and forming processes the recyclate can serve as a raw-material equivalent.**
- **The rating is between 0% (non-recyclable) and 100% (fully recyclable). The assessment "100% recyclability" thus means that the packaging or product meets the material and physical prerequisites to become, after its initial use phase, a secondary product comparable to a primary product with identical material. To achieve a score of 100%, all components in the packaging (including adhesives, inks, etc) would need to be recyclable. For this reason, a 100% score is not achievable when considering any consumer packaging.**

The procedure for the determination of recyclability according to the Institute cyclos-HTP method is presented in Figure 5. In this Annex, the procedure has been applied at a high-level to estimate the recyclability of beverage cartons of standard structure. The results for each evaluation stage considering beverage cartons are superimposed on the right-hand side of the chart in the blue text boxes/red text.
In the example assessment given in Figure 4, the recyclability has been assessed for a representative beverage carton structure, i.e. 75% liquid packaging board with the remainder consisting of polymer and, in some cases, a small quantity of aluminium (ImpactPapeRec, 2018). For this analysis, a structure of 75% liquid packaging board, 21% polyethylene and 4% aluminium has been considered (Alliance for Beverage Cartons and the Environment and EXTR:ACT, Undated). This is referred to as the "Object of determination".

For beverage cartons, assessment against the following criterion is mandatory:

- **C0 – Assignability to a recycling path**
- **C1 – Valuable material content**
- **C2 – Identifiability by NIR/optical detection**
- **C6 – Time and yield for dissolution in water**
- **C8 – Inseparable recyclate contaminants**
- **C9 – Other criteria**

The method describes reference scenarios for each

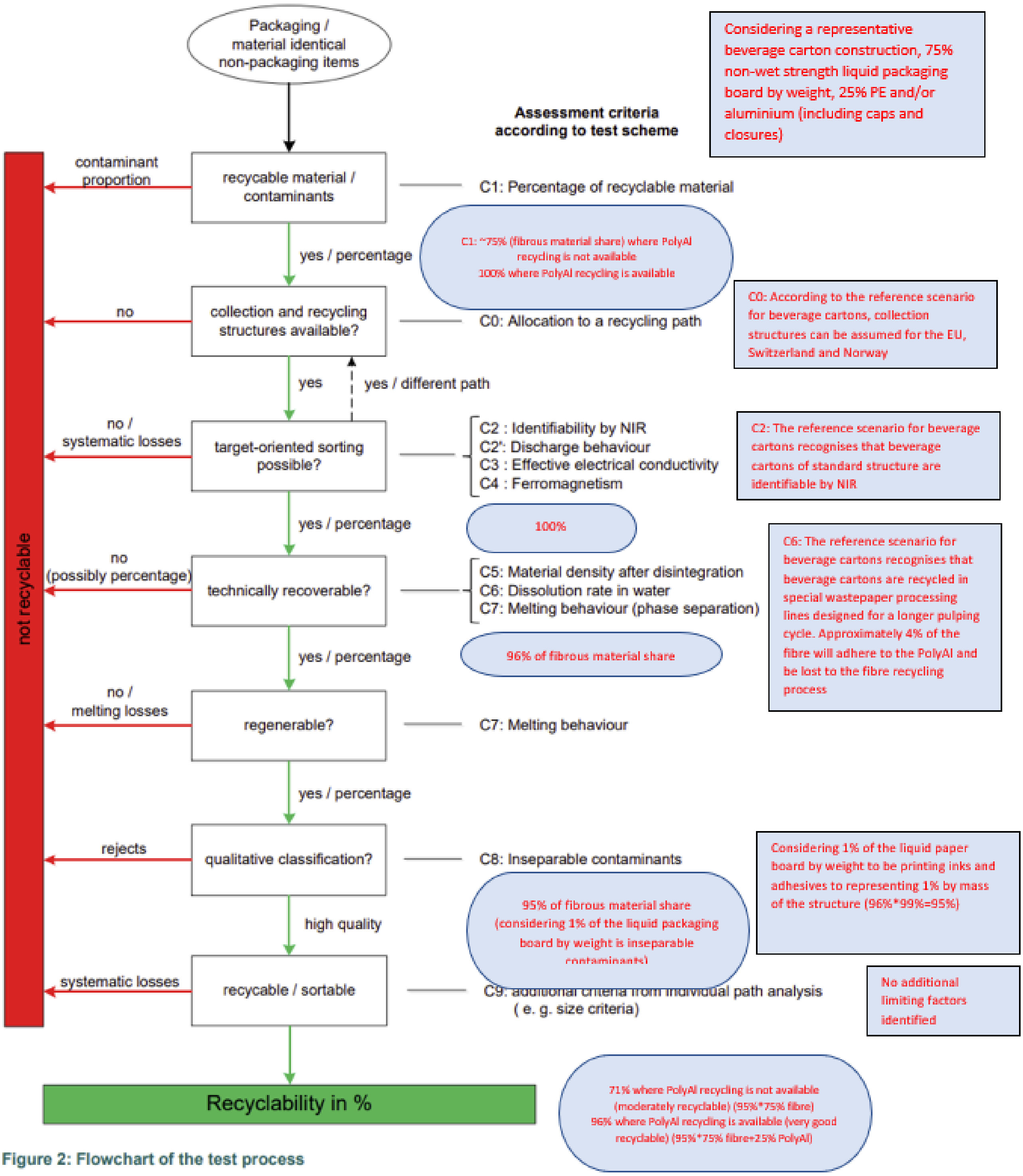


Figure 5 Flowchart of the recyclability determination procedure (assessment steps for beverage cartons shown in red)[8]

[8] Source: cyclos-HTP

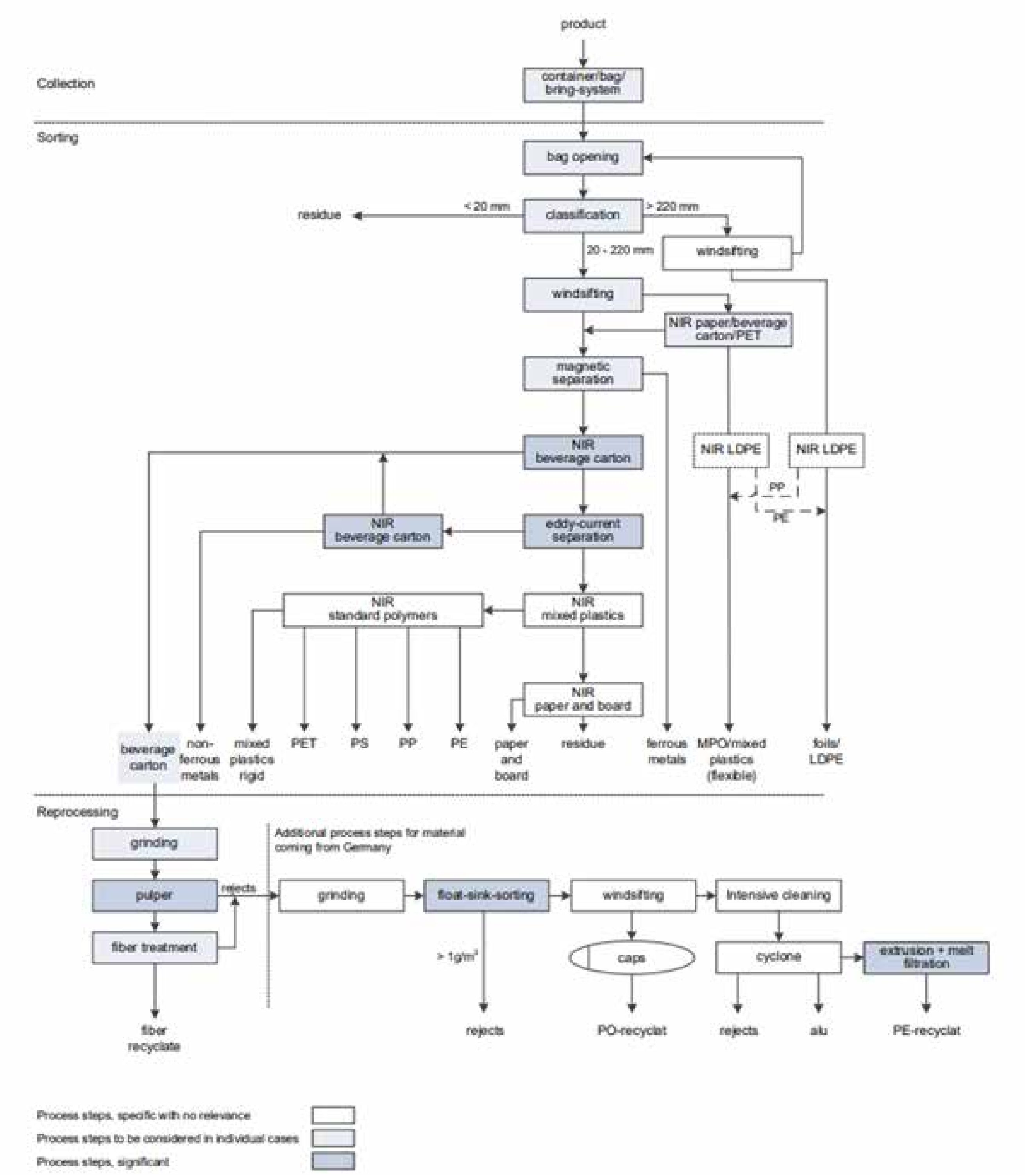


Figure 6 Reference scenario for beverage cartons[11]

[11] The reference scenario used is only a process example from one country

The determination of recyclability refers to the product as a whole (packaging is assessed without its content). According to the procedure, the first step (C0) is to establish the availability of sorting and recycling infrastructure for the packaging solution. The reference scenario for beverage cartons identifies that collection structures can be assumed for the following countries:

- **EU**
- **Switzerland**
- **Norway**
- **UK**

Beverage cartons are collected together with lightweight packaging in Germany. In most other European countries, there is a comparable collection (e.g., the PMD collection scheme in Belgium, etc.).

The reference scenario also acknowledges that in some instances the PolyAl fraction rejected from the pulping process is also recycled in a high-quality recycling process. An example process located in Germany is presented in the reference scenario.

Hence, the preconditions for the recycling of the board component exist throughout Europe, and the preconditions for the recycling of the PolyAl fraction exist in certain geographies.

The second step in the procedure (C1) is to establish the valuable material content. This specifies the theoretically recyclable proportion of the packaging by weight. For beverage cartons, the valuable material content is defined as the fibrous content. For determining the recyclable content 'fibrous material' can be defined as the sum of fibre, filling material, starch, coating colour including binder as well as additives typically used in the paper industry such as wet strength agents, glue and bound water. Typically, the plastic content, aluminium and other packaging components, plus adhesives and lacquers are characterised as non-recyclable, although this would be different in instances where PolyAl recycling is available.

Components that cannot be recovered in the recycling process are qualified as contaminants (irrespective of whether they can be factually separated from the reference process).

The typical contaminants identified for liquid beverage cartons are listed in Table 6 below.

CAT 1 contaminants are materials that are quantitatively separable by the treatment steps established in the recycling process. According to CAT 1, the proportion of contaminants leads to a quantitative limitation of the recyclability and is taken into account in C1 by respectively reducing the factor.

CAT 2 contaminants are materials that are not separable by the treatment steps established in the recycling process, having no or negligible impact on the recyclate properties in practice. The respective proportion is not added as valuable material within assessment criterion C1.

CAT 3 contaminants are materials that are not separable by the treatment steps established in the recycling process, and which degrade the quality of the recyclate to uselessness or otherwise lead to high valuable losses or disproportionately high process costs. The assessment of an existing contaminant proportion (incompatibility) of CAT 3 is specified under Criterion (C8) and defines that the recyclability cannot be verified (factor 0).

CAT 1	CAT 2	CAT 3
Plastic labels; plastic and metal layers; plastic and metal contents	Printing inks and adhesives; water soluble re-dispersive inks and adhesives; varnishes	Water-insoluble or non-redispersing adhesive applications where it has not been specifically proven that they can be removed; components of EuPIA (Exclusion list for printing Inks and related products)

Table 6 Typical contaminants for liquid packaging board

During Step C1, the available material content is adjusted to account for any C AT 1 and CAT 2 contaminants.
For beverage cartons of standard structure, CAT 1 contaminants are only relevant if the recycling route is considered where the PolyAl is not recycled. In this case, they make up 25% of the structure. The CAT 2 contaminants are likely to make up less than 1% of the packaging weight (considering 1% adhesives and inks).

In step C2, identifiability at the sorting plant through NIR is established. In cases where beverage cartons are collected as a separate stream, NIR sorting will not be necessary. Sorting of beverage cartons from other paper and plastic packaging is only necessary where the are collected as part of a mixed paper and board fraction or as part of a mixed light-weight packaging fraction. The reference scenario for beverage cartons identifies that, as a rule, beverage cartons form a separate sorting fraction within the sorting process, which is generated in high-tech plants exclusively via sorting machines. Beverage cartons of typical construction have a specific spectrum in the NIR reflection measurement. Hence, liquid beverage cartons of the representative construction considered in the self-assessment fully pass this criterion.

The next step relevant to beverage cartons is C6, which assesses the ability of the fibre to be repulped. The reference scenario for beverage cartons identifies that the fraction "liquid packaging board" is assigned to special wastepaper processing lines which are designed for the comparatively longer pulping time required to recover the fibres. Hence, liquid beverage cartons of representative construction, for which the repulping process is optimised, fully pass this criterion. In Step 6, fibre yield is also considered. Approximately 4% of the fibre will adhere to the PolyAl and be lost to the fibre recycling process.

Step C8 considers inseparable contaminants in the structure. In step C8, the valuable material content (C1) is adjusted to take into account the CAT3 contaminants. In the standard beverage carton structure, no CAT 3 contaminants are present.

The following are identified as Category 3 contaminants, i.e., being not separable by the treatment steps established in the recycling processes and degrading the quality of the recyclate to uselessness or leading to high valuable losses or disproportionately high process costs:

- **Components of EuPIA (Exclusion list for printing Inks and related products).**

The presence of these components would result in the assessment of the packaging as non-recyclable unless otherwise proved by testing.

Once the individual assessment steps have been completed, the overall assessment score in % can be determined. In the overall assessment, the factors for C1 to C9 are multiplied together. If the result is not 0%, then the packaging solution is classified as recyclable. The following classification scale is applied:

- **Class. C recyclable, recyclable proportion < 50 % (low recyclable)**
- **Class. B recyclable, recyclable proportion 50 % - 70 % (medium recyclable)**
- **Class. A recyclable, recyclable proportion 70 % - 90 % (good recyclable)**
- **Class. AA recyclable, recyclable proportion 90 % - 95 % (highly recyclable)**
- **Class. AAA recyclable, recyclable proportion ≥ 95 % (excellent recyclable)**
- **Class. AAA+ recyclable, recyclable proportion 100 % (fully recyclable)**

In this high-level assessment, the recyclability of beverage cartons is determined thus:

- **Where recycling of the PolyAl fraction is not available – 71% = Class. A recyclable, recyclable proportion 70% - 90% (good recyclable)**
- **Where recycling of the PolyAl fraction is available – 96% = Class. AAA recyclable, recyclable proportion >95% (excellent recyclable).**

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