LIQUID PACKAGING CARTONS:

DESIGN FOR RECYCLING GUIDELINES

Version 2.0 2025

Prepared by **RISE Bioeconomy** on behalf of **FBCA**

Essential.
Renewable.
Circular.

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About the FBCA

The Food and Beverage Carton Alliance (FBCA) is a global industry platform uniting food and beverage carton manufacturers and their paperboard suppliers. Leveraging its unique convening power, FBCA brings together stakeholders across the entire value chain - from raw material sourcing to recycling - to drive safe, sustainable, and circular packaging solutions worldwide. As demand grows for low-carbon, resource-efficient packaging, food and beverage cartons play an essential role in resilient food systems by reducing waste, extending shelf life, and ensuring product safety.

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PREFACE

While design for recycling guidelines exist for generic fibre-based packaging solutions, specific guidelines are required which focus on the unique structure of liquid packaging cartons (LPCs) that comprise liquid packaging board (LPB) laminated with polymers (predominantly polyethylene, PE and polypropylene, PP) and sometimes small amounts of aluminium.

Due to this unique structure, LPCs are recycled in a separate stream. The high-value fibres are recovered in specialized mills. The mixed polymer and aluminium (PolyAl) that remains after the fibres have been recovered is a unique material, and consequently PolyAl recycling is unique. While the end product is a substitute for plastic materials, the recycling process is not the same as plastic recycling. There are some commonalities in the processes for PolyAl recycling and recycling of polyolefins (POs); there are also critical differences.

For this reason, it is necessary to have design for recycling criteria specific to LPCs as recycled in specialized mills and for the PolyAl stream as recycled in specialized recycling facilities. Ensuring that the LPCs placed on the market are compatible with these recycling processes will contribute to the continued success of the industry in promoting the circularity of LPCs, reflected in the already significant recycling rates achieved.

ACKNOWLEDGEMENTS

The Food and Beverage Carton Alliance (FBCA) would like to thank the members of the working group responsible for generating these guidelines. The following companies and organizations were represented in the working group.

FOREWORD

Sebastian Bartels
FBCA Director General

Design for Recycling Guidelines (DfR) for Liquid Packaging Cartons are crucial for enabling the efficient recovery of high-quality materials, minimizing environmental impact through reduced landfill and incineration, improving the technical and economic viability of recycling processes, and advancing a circular economy by ensuring food and beverage cartons are designed for recyclability from the outset

The guidelines have been updated by our member companies, Billerud, Elopak, SIG, Stora Enso, and Tetra Pak. The members of the Food and Beverage Carton Alliance are united in our commitment to ensuring food and beverage cartons remain a sustainable, low carbon, and recyclable packaging choice.

These guidelines have been developed to support food and beverage carton producers by providing clear technical guidance for evaluating recyclability and making design choices that improve recycling outcomes. They also serve as a useful resource for recyclers, waste management professionals, equipment manufacturers, those who work for Producer Responsibility Organizations, and policymakers working to strengthen recycling infrastructure and practices.

To enable efficient and effective recycling, considerations for recyclability must be integrated at the design stage of packaging development, ensuring compatibility with existing collection, sorting, and recycling systems. Food and beverage cartons are already recyclable and recycled at scale; this document outlines updated, evidence-based design elements that influence recyclability, offers practical recommendations, and provides guidance for developers to maximize the recyclability of their products.

A high-level self-assessment tool is also included to assist in evaluating current recyclability performance. It is essential that the necessary infrastructure and legislative frameworks are in place to support separate collection and sorting of food and beverage cartons from general municipal waste, as this is the first step towards successful recycling.

We recognize that technologies, market conditions, and legal frameworks continue to evolve. For this reason, these guidelines will be reviewed and updated regularly to reflect new insights, emerging technologies, and evolving best practices.

We are also pleased to acknowledge that the 4evergreen alliance has developed complementary guidelines for designing fibre-based packaging with circularity in mind. The latest edition of the 4evergreen guidelines not only addresses fibre-based packaging that is recycled in a conventional recycling mill but also considers Liquid Packaging Cartons as compatible with recycling in specialized mills using specialized recycling processes. These updated FBCA guidelines serve as the primary reference for design-for-recycling criteria for all LPCs intended for recycling in specialized mills. While they complement the 4evergreen guidelines, they go further in scope and detail, reflecting the latest technical and regulatory developments and ensuring a holistic approach to recyclability of Liquid Packaging Cartons.

I would like to take this opportunity to express my sincere thanks to the FBCA DfR Working Group for their commitment and collaboration in preparing this publication.

Let's work together to make sure every food and beverage carton on the market is designed with recyclability in mind, because the decisions we make today shape the sustainable future we all want.

Sebastian Bartels
FBCA Director General

1 - 4evergreen is a cross-industry alliance of over 100 members representing the entire lifecycle of fibre-based packaging – from forests to producers, designers, brand owners and recyclers. https://4evergreenforum.eu/

2 - The current 4evergreen Circularity by Design Guideline can be downloaded from: https://4evergreenforum.eu/wp-content/uploads/4evergreen-Circularity-by-Design3.pdf

GLOSSARY

Aluminium foil fraction: The proportion of the **PolyAl** that consists of the aluminium foil after separation from the hard plastic fraction and the film fraction.

Aseptic: In the context of food and beverage products, aseptic refers to product which has been sterilized before or during the packaging process.

Beverage carton: A **liquid packaging carton** specifically used to contain food and beverages including dairy and fruit juices. Beverage cartons can be both **aseptic** and **non-aseptic**.

Bio-based polymers: Bio-based low-density polyethylene (LDPE) can be produced from renewable sources like sugarcane.

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

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

Conventional paper recycling mill: (or 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). Coarse- and fine-screening cleaners are used to separate the fibre from 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.

EN 643 - European List of Standard Grades of Paper and Board for Recycling: EN 643 is the European standard that categorizes and defines grades of paper and board for recycling. It provides a detailed list of categories and specifications to facilitate the buying and selling of paper for recycling within the industry as well as ensuring consistency in paper for recycling.

Fibre-based packaging material: Refers to the complete composition of components used in its production and assembly, including the following:

Base materials:
- Papermaking fibres
- Fillers and functional chemicals added in the wet-end of the paper machine
- Starch and other dry strength agents

Coating and printing components:
- Pigments and binders used in coating
- Printing inks
- Overprint varnish

Bonding and structural elements:
- Adhesives used to bond layers of paper or paper with plastic film
- Barrier layers

Additional/Auxiliary items:
- Closures
- Tape
- Labels

Fossil-based: Materials or fuels derived from fossil resources such as oil or natural gas.

Hard fraction: The proportion of the PolyAl that consists of the hard plastic materials after separation from the polymer film and **aluminium foil fractions**. It will include the materials used for caps and closures.

Laminated liquid packaging board: Combined liquid packaging board and laminated materials including polymers and aluminium foil.

Lightweight packaging (LWP): Sales packaging made from plastics, composite materials, tin plates, and aluminium, and in some countries collected together in one bin, separately from residual waste.

Liquid packaging board (LPB): Board designed for the manufacture of liquid packaging cartons.

Liquid packaging carton (LPC): Closed multilayer board composite packaging mainly used for beverages or foods and in which LPB is the main material. Other denominations commonly used are drink cartons, **beverage cartons**, and food cartons. The most typical include, but are not limited to, brick and gable top-shaped cartons. Depending on the product to be filled and the desired shelf life, LPCs can be aseptic, non-aseptic or retorted. Drinking cups, plates, and trays are not covered by this definition.

Near-infrared (NIR) sorting: Near-infrared sorting technologies measure the reflected light of an object in the range of 760–2,500 nm. NIR is used in the sorting process to separate packaging based on reflected surface material.

Non-aseptic: In the context of food and beverage products, non-aseptic refers to product which has not been sterilized before or during the packaging process.

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

Paperboard: Generic term applied to certain types of paper frequently characterized by their relative high rigidity (ISO 4046-3:2016).[3] 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. Products made predominately from paper and board, which may include other constituents that cannot be removed by dry sorting, such as coatings and laminates or spiral bindings.

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

PolyAl: In simple terms, PolyAl is the mixed polymer and aluminium fraction that remains after the paper repulping process, found in recycling mills with specialized processes. PolyAl is a by-product from the processing of paper grades 5.03.00 according to EN 643 or fraction number 512 consisting of polyolefin-based plastics, plastic-aluminium composites and aluminium, largely fibre-free.

Polymer film fraction: The proportion of the PolyAl that consists of the flexible polymer materials after separation from the foil fraction and the hard plastic fraction. It will be composed of the materials laminated to LPB, including fossil- or bio-based polymers used as barrier layers, and carrier films vacuum deposited with SiOx and AlOx or metallization.

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 papermaking process. The fibres are separated from one another into a dispersion of individual fibres called paper pulp. 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.

Recycling: Recycling means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or backfilling operations.[4]

Retortable: For pasty or lumpy food like tomatoes, baked beans, sauces & soups, or pet food, retortable cartons are typically used. It means that the product is filled unsterile and only processed after the packaging has been sealed. Retorting is a process where food is heat-treated inside the package. The heat treatment is applied to generate a commercially sterile product that is stable in ambient conditions prior to opening. The goal when retorting is to retain the highest possible product quality without compromising on food safety. By using the lowest possible temperature in combination with the shortest possible heating time, the product is kept fresh. Therefore, the heat treatment process is optimized for each product. A typical retort process usually takes between 60 and 180 minutes depending on the product and necessary retort temperature between 105 and 130°C. Food cartons typically use polypropylene (PP) as coating and barrier material because the melting temperature of PP is much higher than the retorting process. For some products requiring retorting at lower temperature ranges, polyethylene (PE) may be used.

Specialized paper recycling mill: These mills treat a mix of special grades (group 5 of EN 643) and grades from other groups (1–4 from EN 643).[5] 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 specialized recycling mills can treat fibre-based packaging that has been coated with non-water-soluble materials, such as plastic film or other layers including aluminium, polyester, and polyethylene, entering the recycling process in homogeneous lots.

These specialized recycling mills can also recycle or recover the non-fibre fraction for further processing. In order to optimize the recycling process, paper composite packaging, which cannot be handled in standard processes, should be delivered to specialized paper mills in EN 643 identified flows.

The fibres from LPCs are recovered at specialized recycling mills with dedicated processing equipment and the capacity to separate the PolyAl fraction for further processing.

As in **conventional mills**, the result of the process is also very high-quality fibrous material suspended in water ready for papermaking. Compared with other fibre-based composite packaging, the recycling path for LPCs is a well-defined stream Europe wide.

3 - ISO 4046-3:2016, Paper, board, pulps and related terms - Vocabulary. Part 3: Paper-making terminology

4 - EUR-Lex - 02008L0098-20240218 - EN - EUR-Lex

5 - EN 643:2014, Paper and board: European list of standard grades of paper and board for recycling

LIST OF ABBREVIATIONS

AKD	Alkyl ketene dimer
AlOx	Aluminium oxide
ASA	Alkenyl succinic anhydride
DfR	Design for Recycling
EuPIA	European Printing Ink Association
EVA	Ethylene vinyl acetate
EVOH	Ethylene vinyl alcohol
FBCA	Food and Beverage Carton Alliance
FBCP	Fibre-based composite packaging
GPAM	Glyoxal polyacrylamide
HDPE	High-density polyethylene
LDPE	Low-density polyethylene and rLDPE for recycled
LPB	Liquid packaging board
LPC	Liquid packaging carton
NIR	Near-infrared
PA	Polyamide
PAE	Polyamide epichlorohydrin
PE	Polyethylene
PET	Polyethylene terephthalate
PLA	Polylactic acid
PO	Polyolefin
PP	Polypropylene
PPWR	Packaging and Packaging Waste Regulation
SiOx	Silicon oxide

01 ABOUT LIQUID PACKAGING CARTONS (LPCs)

A liquid packaging carton (LPC) is defined as a closed multilayer board composite mainly used for beverages or foods and in which liquid packaging board (LPB) is the main material. LPCs are sometimes referred to as beverage cartons, drink cartons or food cartons of which the most typical include, but are not limited to, brick and gable top-shaped cartons. Depending on the product to be filled and the desired shelf life, LPCs can be aseptic, non-aseptic or retorted.[6] LPB provides strength and stiffness whereas the other layers - polymers and in most cases also thin aluminium foil - 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, while preventing food waste by protecting the contents from deterioration and nutrient loss.

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 current and future materials used for LPCs should be compatible with the enhanced recycling processes in specialized recycling mills, as well as the mixed polymer and aluminium fraction (PolyAl).

6 - ISO 4046, proposal in CD 2025 (committed draft).

1.1 Liquid packaging board

Liquid packaging board is designed for the manufacture of LPCs and is manufactured from sustainably sourced bleached or unbleached virgin fibres.[7]

The type of packaging board used depends on the product being packed, the regional market where it will be sold, and the manufacturing conditions. In order to achieve a good balance between performance and lightweighting, LPB is generally produced as 1 ply or as a multi-layer laminate structure of up to five fibre plies/layers, with a bleached or pigment-coated outer layer of sulfate kraft and with a middle layer which can contain different proportions of bleached and unbleached sulfate kraft and bleached or unbleached CTMP (chemi-thermomechanical pulp) fibres.

Fully unbleached LPCs are also on the market which are made from unbleached fibres.

Sizing agents such as alkyl ketene dimer (AKD), Rosin, or alkenyl succinic anhydride (ASA) are often used in LPB; these are very common within the paper industry. Sizing agents are used to control the absorption of liquids into the structure of the finished paper/board and to improve the wear characteristics. Generally, sizing agents do not cause any problem in the recycling process, but their usage should be optimal to ensure a high level of recyclability.. Retention aids are also used to improve the retention of fibres, fibre fines as well as chemical additives.

Where wet strength agents are used, temporary wet strength agents, such as glyoxal polyacrylamide (GPAM), are preferred at limited levels. These substances improve the performance of the board if exposed to moisture/high relative humidity, yet allow fibre dispersion during the paper recycling process.

7 - See: https://fsc.org/en/businesses/fibre

1.2 Polymers used in the laminate

Typically, for both aseptic and non-aseptic LPCs, 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, while protecting the printed surface. For LPCs which are subject to a retort process, polyethylene (PE) is not sufficient to withstand the high retorting temperatures in the production process so polypropylene (PP) is required for the external lamination. The presence of the outer LDPE or PP layer in combination with the LPB gives the LPCs a unique near-infrared fingerprint and therefore allows the cartons to be sorted in automatic sorting lines using near-infrared (NIR) technology. While the LPB provides the LPCs 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. 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 sterilized, distributed, and stored at room temperature. The majority of LPCs on the market are composed of LPB with layers of PE with or without aluminium foil. Barrier properties may also be provided by vapour deposition of SiOx, AlOx, or metallization. In these cases, polymer films will act as carrier layers. LPCs with alternative barrier layers are also available. Solutions already in the market include polyamide (PA) and ethylene vinyl alcohol (EVOH) barrier layers.

These guidelines indicate the level of compatibility of those alternative polymers with the recycling processes for the dominant LDPE polymer.

1.3 Printing of liquid packaging cartons

Different technologies are used for the printing of LPCs. For some LPCs, ink is applied directly to the LPB, in which case the outer LDPE or PP layer also protects the printing ink layer. For other LPCs, the laminated reel is printed and therefore the printing ink is applied to the outer side of the outer LDPE or PP layer.

1.4 Polymers used for additional components

LPCs may incorporate an easy opening device, and multi-serve LPCs 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 LPCs.

From 2024 onwards, European legislation has required that closures for most LPCs in the European market remain attached to the LPC after opening and disposal.

Opening and closure devices are predominantly manufactured from high-density polyethylene (HDPE), LDPE, or PP, or a combination of them. Minor parts such as cutting rings are sometimes manufactured from other polymers. These parts of the LPCs, along with carton tops and necks from certain LPCs, are often (though not always) separated from the laminate or film fraction during 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 mixed polyolefin (PO) recycling to a minimum.

For single-serve LPCs targeting the on-the-go market, bags containing fully recyclable paper drinking straws including U-bend straws are often attached to the outer surface of the LPC by using holtmelt. These paper straws, which after consumption are usually pushed into the package, are fully compatible with the recycling processes used by specialized recycling mills.

1.5 Alternative polymers

Currently, the majority of PE used as laminate 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 and barrier layers.

While designers and manufacturers cannot influence how LPCs are collected, it is important that they consider sortability and recyclability in the early stage of the design process. At the same time, they should be able to continue to innovate and to investigate alternative materials and solutions which may offer improved functionality and reduced environmental impact. The impact on sortability and recyclability needs to be assessed during the innovation process. It is also essential that recycling processes are developed that are capable and robust enough to handle the materials commonly used in LPCs, including sorting quality/impurity challenges of sorted bales of used LPCs.

1.6 Typical liquid packaging carton structures

Aseptic LPCs, which contain sterilized product, are typically composed of layers of LPB, LDPE, and aluminium. Aluminium foil thickness varies depending on required barrier properties but is very thin (in the range 5–10 μm), constituting around 4–5% of the total weight of the carton. The aluminium foil provides an odor, 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 such as 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. Example structures are presented in Figure 1. Non-aseptic LPCs contain fresh product and require refrigeration; they do not require the additional aluminium foil layer. Example structures are presented in Figure 2.

For retortable LPCs, PP is required to withstand high retorting temperatures in the production process. A typical retort carton structure is indicated in Figure 3.

For both aseptic and non aseptic LPCs, an inner layer of LDPE is applied to enable heat sealing of the carton and to ensure meeting of rigorous food safety requirements.

Figure 1: Typical structure of aseptic LPCs

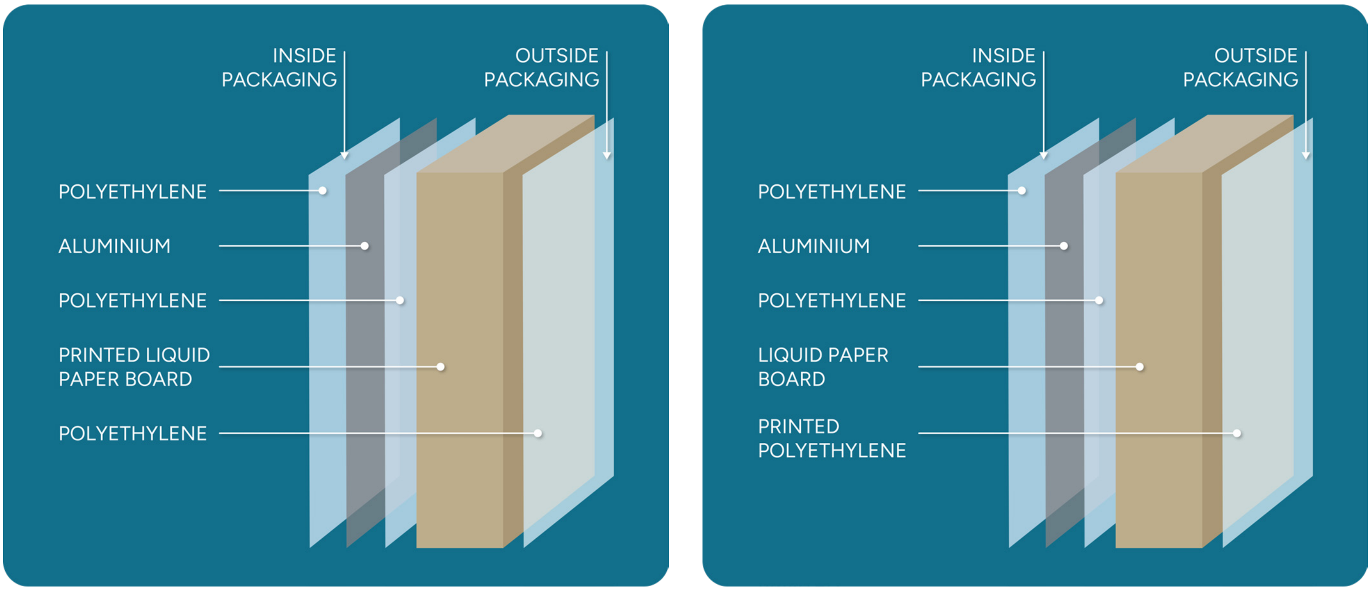
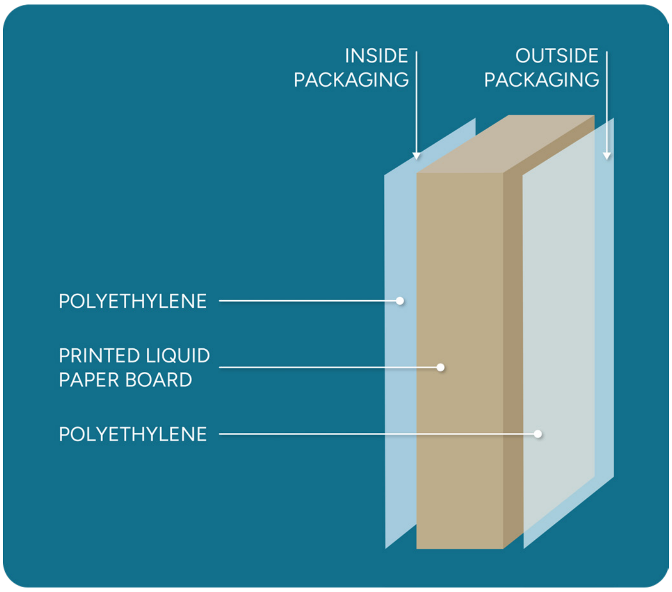


Figure 2: Typical structure of non-aseptic LPCs



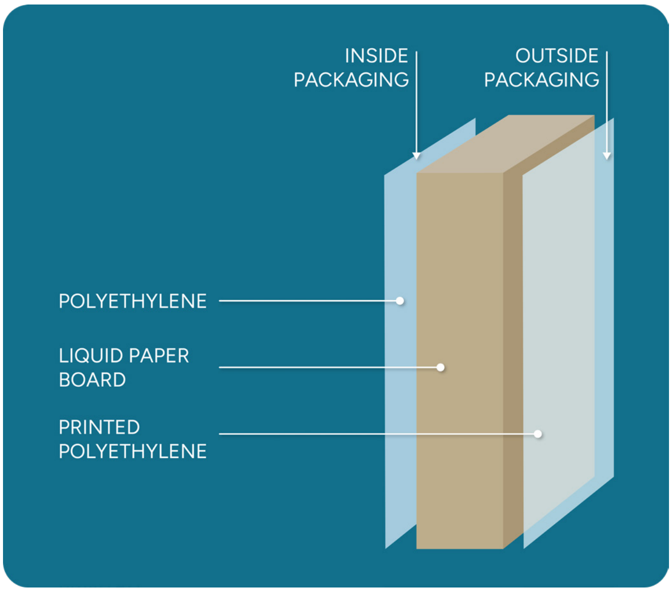
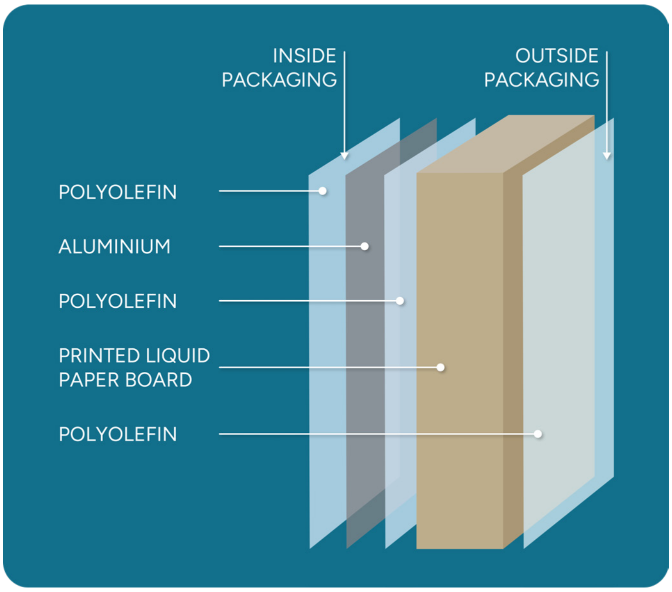
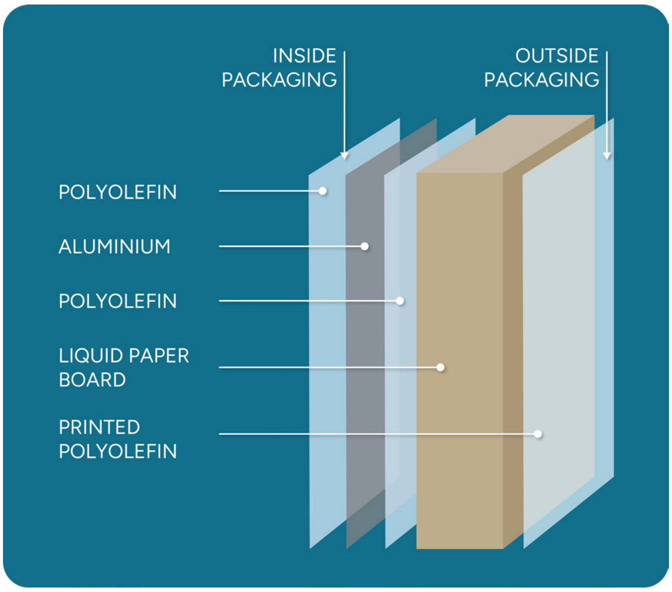


Figure 3: Typical structure of retortable LPCs





02 DEFINING RECYCLABILITY

The Packaging and Packaging Waste Regulation (PPWR), published on 22 January 2025, introduces an ambitious recyclability goal that all packaging placed on the EU market must be recyclable by 2030. The PPWR defines recyclability as the compatibility of packaging with the management and processing of waste by design, based on separate collection, sorting in separate streams, recycling at scale, and use of recycled materials to replace primary raw materials. This regulation reflects a broader international trend toward circular economy principles, where packaging must be compatible with waste management and recycling systems by design. As such, the PPWR provides a framework that could influence global standards and inspire similar regulatory developments in other regions, adapted to local conditions.

According to the Ellen MacArthur Foundation, *"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."*[8]

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" (Institut 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).

8 - For more information see: https://www.ellenmacarthurfoundation.org/global-commitment-2024/overview

Therefore, recyclability involves two important complementary requirements, which are also underscored in Article 6 of the PPWR:

- Packaging must be designed for recycling.
- There must be an existing collection, sorting, recycling infrastructure in place that recycles the packaging.

From 2030 or 2 years after entry into force of the delegated acts defining Design for Recycling (DfR) criteria under PPWR, packaging recyclability will be expressed in performance grades A (higher or equal to 95%), B (higher or equal to 80%) or C (higher or equal to 70%). Only packaging attaining performance grade A, B, and C will be allowed to be placed on the EU market. From 2038, only packaging attaining performance grade A and B will be allowed to be placed on the EU market. From 2035 or 5 years after the date of entry into force of the implementing acts, the definition of the methodology to assess recyclability at scale will be published.

LPCs are a type of paper/cardboard composite packaging, made predominantly of LPB. Recyclability of a unit of LPC shall be assessed based on the following aspects:

- Design for compatibility with sorting system
- Design for compatibility with material recycling system
    - Specialized mill LPC recycling process
    - PolyAl recycling

When packaging is recycled, the resulting secondary raw materials should be of sufficient quality when compared to the original material that they can be used to substitute primary raw materials.

03 ABOUT LIQUID PACKAGING CARTON RECYCLING

A high level of recyclability is evidenced by the fact that LPCs are already extensively collected and recycled in Europe. Within the EU27+3, in excess of 490,000 tonnes of material was reprocessed in 2021. This represents a recycling rate of 52%[9] of all LPCs sold in Europe (Alliance for Beverage Cartons and the Environment, 2024[10]), with some countries such as Belgium and Germany achieving rates of over 70%. LPC recycling capacity is forecast to grow to over 800,000 tonnes by 2030 to reprocess 70% of LPCs collected. LPCs can be described as an integrated packaging unit, meaning that the fibre, polymer, and aluminium[11] are recycled primarily for their virgin fibre content, which makes up ~75% of the pack weight, and which brings important strength properties to recycled paper products such as test liner and core board. LPCs also serve as important sources of PE and PP, and aluminium, which make up on average ~21% and 4% of pack weight respectively. With further reprocessing, these materials will become increasingly valuable as replacements for primary materials.

9 - Using the calculation method as defined before the adoption of the Implementing Act (EU) 2019/665

10 - Beverage Carton Recycling Facts and Figures. EXTR:ACT January 2024

11 - PPWR Art 3 (24) Texts adopted - Packaging and packaging waste - Wednesday, 24 April 2024

3.1 Collection

Collection is a precondition for 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 LPCs vary between EU Member States; several countries have specific legal collection/recycling targets in place (e.g., in Belgium (90%), Germany (80%), Austria (80%), and Spain (70%)). Increased collection rates will assist in reaching the "recycled at scale" requirement of PPWR.

Generally, LPCs are collected with other lightweight packaging or with other paper-based products. Used mainly for beverages and soups or sauces, LPCs can be described as an "easy to empty" package which offers potential for minimum food contamination.

According to the RECY:CHECK criteria, this means that < 5% of product content remains with the pack following emptying, which then has the potential to be transferred to the recycler.[12] Systems and infrastructure for collecting these material streams already exist in most EU Member States and their performance will evolve further over time to increase the collection of LPCs ready for recycling.

12 - Easy-to-empty / Easy-to-access - RecyClass. Easy-to empty (e.g., tubes): a package where the declared quantity of product has to empty easily without being forced (i.e., for liquids just holding the open package vertically for one minute with open side downwards; for pasty products just squeezing the tube as in its normal use, for creams taking them out of the cup/tub as per normal use, etc.)

3.2 Sorting

In some countries, LPCs are collected as part of the lightweight packaging stream including other fibre-based composite packaging (FBCP) and they are then sorted out separately. When collected as part of the overall paper-based products stream, LPCs sorting is recommended, otherwise used LPCs in an unsorted paper-based products stream would enter the conventional mill recycling process and would not be recycled as efficiently as in a specialized mill. When designed according to the recommendations in this document, LPCs can be easily sorted from other materials as long as they are collected with mixed material streams, using the existing automated optical sorting technologies that are widely installed at material sorting plants.

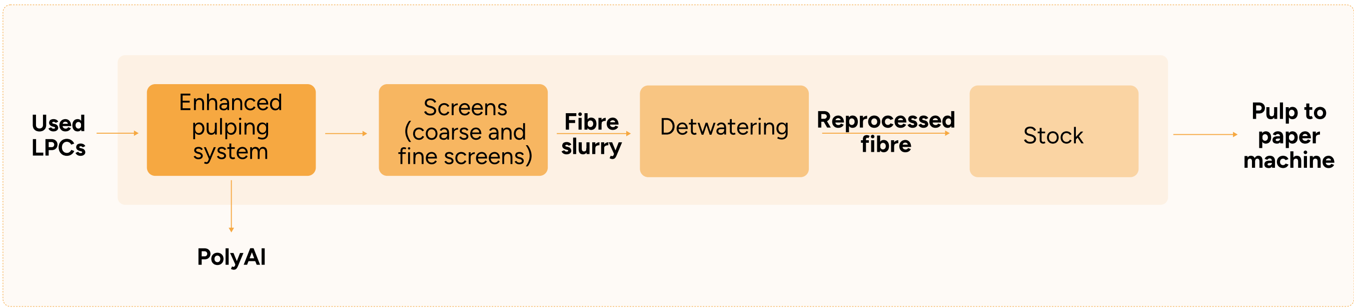
The structure of LPCs provides unique spectral properties which allow their identification and automated separation at commercial speeds and with high yield and purity. The presence of the outer PE or PP layer plays a key role in the identification and optical sorting of LPCs by means of NIR sensors. NIR sorting is also augmented by object recognition sorting which enables identification and sorting of LPCs from other FBCP with two side thermoplastic extrusion coatings, to achieve a high yield and pure LPC fraction.

3.3 Recovery and recycling of the fibres

Recycling of LPCs begins with the recovery of the paper fibres, which constitute approximately 75% of the total weight of the LPC. These fibres are used by recycled paper manufacturers to increase the strength of their paper products. The effect of including the once-used fibres from the LPCs in the recovered fibre furnish is to increase important mechanical properties such as tear, burst index, and tensile index[13,14].

The fibres are recovered from used LPCs at recycling mills with specialized processes for LPC. The process is summarized in Figure 4.

Figure 4: Typical process of a recycling mill with specialized processes for LPC

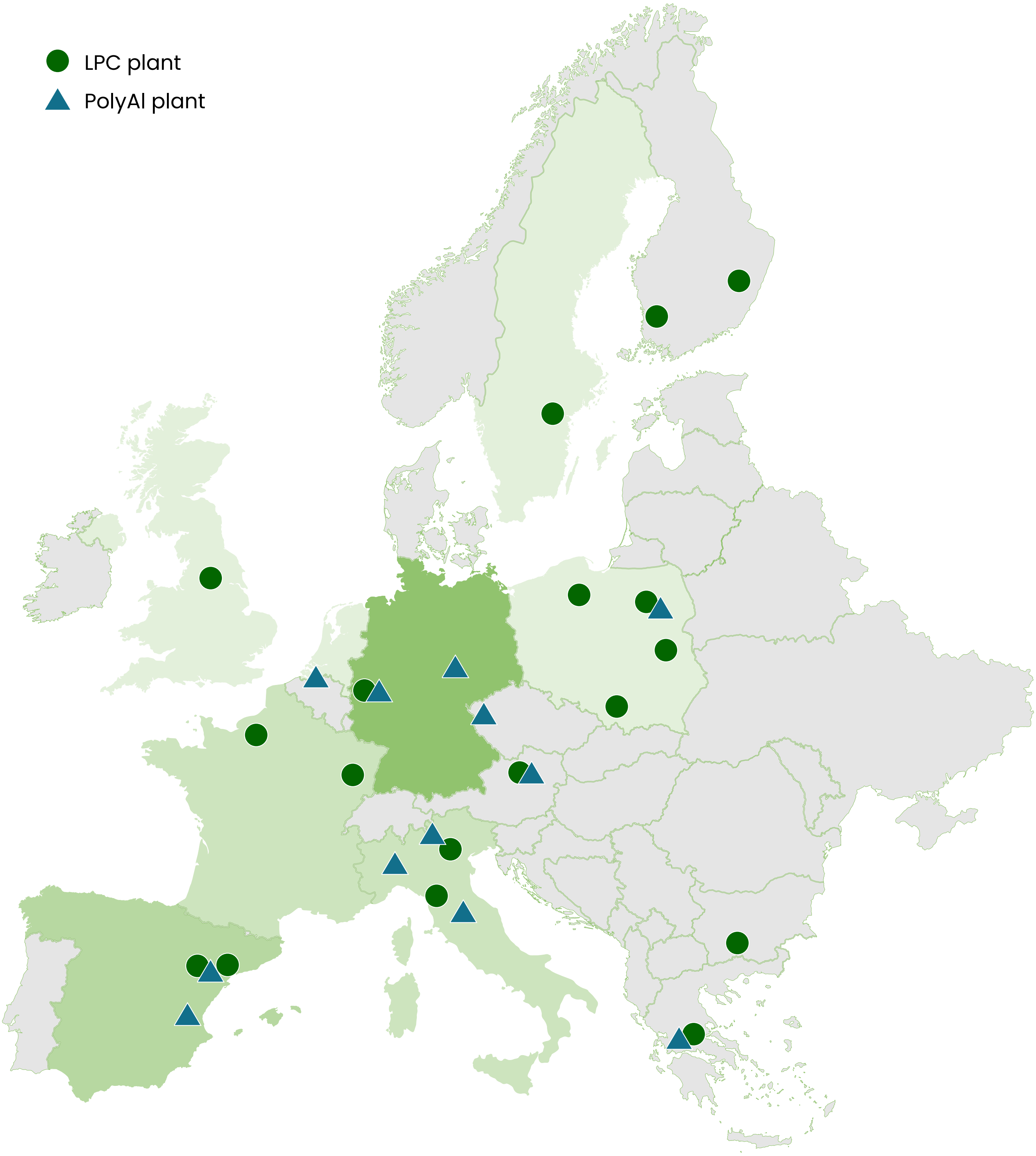


13 - Czene T & Koltai L (2020)

14 - Kay, M, Sturges M and Langley R (2023)

About 20 reprocessing facilities exist across Europe (Figure 5) which specifically target LPCs as a valuable recovered fibre stream and recycle all currently collected LPCs.

Figure 5: LPC and PolyAl recycling plants in Europe, 2025
Source: FBCA website[15]



15 - FBCA, https://fbcaglobal.com/news-and-resources/resources/food-and-beverage-carton-recycling-facts-and-figures

These facilities use specific process conditions to separate the paper fibres from the plastic and aluminium. Typically, this is accomplished using a pulper which breaks apart the paper fibres and produces a dilute slurry of fibres that can be further processed within a paper mill.

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 coarse screens to remove coarse material such as PolyAl. 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.

Washing drums can also be used to further clean the PolyAl, to recover additional fibres. This can minimize the amount of fibres present in the material in order to address the needs of the PolyAl recycling process.

The main difference between the repulping process to recover fibre from used LPCs compared to the repulping process to recover fibre from other paper fractions, such as old corrugated containers (OCC), newspapers, and magazines, is the dwell time required in the pulper. A considerably longer repulping regime is required for recovering fibre from used LPCs. Additionally, the capacity to remove and process the PolyAl fraction is better in a specialized process than in a conventional recycling mill.

Once recovered, the high-quality, strong, virgin fibres from LPCs are 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, core board, and tissue paper).

3.4 Recycling of the PolyAl fraction

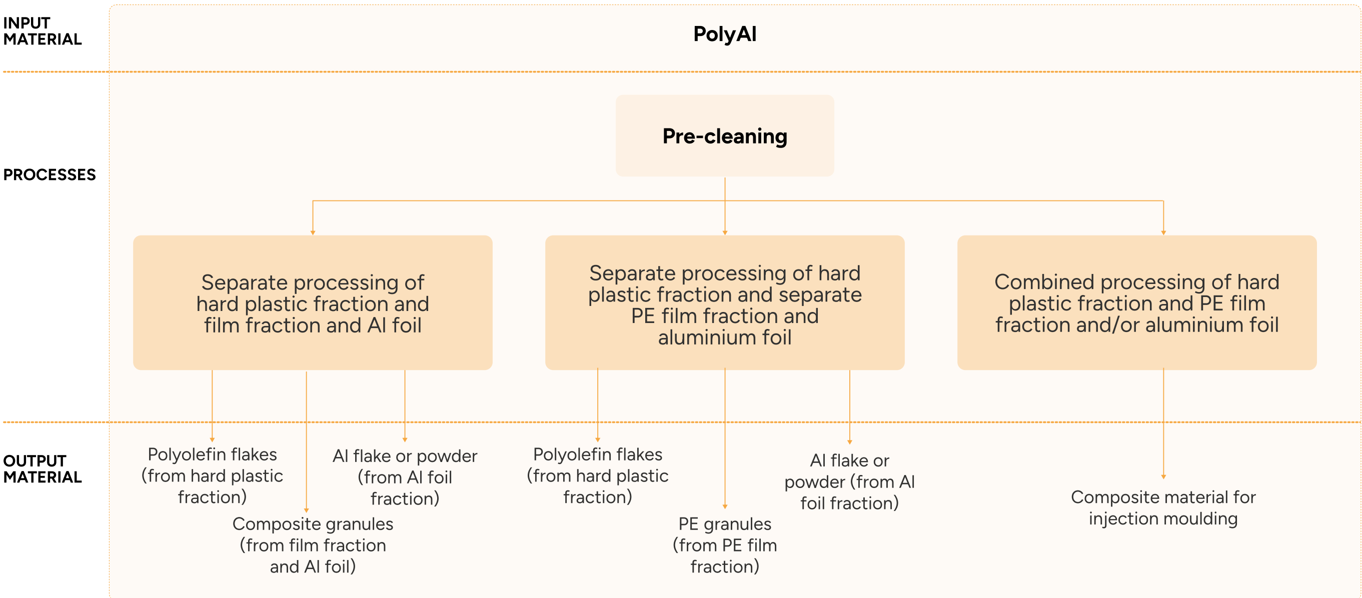
Several technologies are currently applied in order to recycle the PolyAl fraction. Mechanical recycling preserves the molecular structure of the polymer after it is mechanically pre-treated (e.g., shredding, washing, cleaning, and drying) and remelted into granulate. This is opposed to chemical recycling, in which polymer chains are split and the resulting output provides products such as fuel, chemical precursors or pyrolysis oil for new virgin polymers. Currently, all commercial technologies for recycling of the PolyAl fraction are basically mechanical.[16] Chemical recycling technologies are emerging and may be available in the future to a larger extent but are not considered in this assessment yet.

After the paper fibres have been removed by repulping, a residual of polymer and aluminium (PolyAl) remains, with a moisture content of approximately 20–40%. The PolyAl fraction contains predominantly POs (mostly PE with some PP), with around 20% aluminium foils 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 6, the available mechanical recycling technologies can be broadly grouped as processes where the polymer film and aluminium foil are reprocessed together as a composite material, and processes where the polymer film and aluminium foil are separated into different fractions before mechanical recycling of each fraction.

Some PolyAl recyclers reprocess the combined rigid fraction and the laminate fractions together to produce a composite material which is compatible with injection moulding processes.

Figure 6: High-level overview of generic routes for reprocessing the PolyAl fraction



16 - Physical recycling preserves the molecular structure of the polymer. This can be achieved using mechanical treatment or solvent-based separation of the layers. In contrast, chemical recycling 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.

Where the polymer film fraction and the aluminium foil fraction are processed separately, separation of the polymer from the aluminium may be achieved using mechanical processes, sometimes supported by solvents such as acids. Acid weakens the bonding, leading to separation. Other separation reagents may also be used. The polymer from the film is then extruded into granulates and the aluminium is formed into a flake or powder which can be further recycled. 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 as much as possible the impurities and non-compatible polymers, it is possible to clean the targeted material enough to produce a granulate that can be processed in several ways, including by injection moulding, blow moulding, blending, and compounding. In an example of this type of process, the input to the process is LPCs 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 75,000 tonnes of PolyAl in Europe annually. At the end of 2025, PolyAl recycling capacity could potentially reach 150,000 tonnes rising to over 225,000 tonnes by 2030 (ACE and EXTR:ACT Recycling Brochure, 2024). The recycled plastic components can be used in products such as plastic pipes, pallets, boxes or panels, while the aluminium will be compounded and re-used.

04 IMPLICATIONS OF STRUCTURE AND DESIGN FOR THE RECYCLABILITY OF LPCs

Various standards, test methods, and guidance are available to inform the design for recyclability of LPCs. Annex 1 summarizes 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.

The packaging design needs to allow for the sortability of packaging and its reprocessability into recycled materials that replace virgin materials. LPCs 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 of LPCs when applying the principles outlined in the RECY:CHECK Recyclability Certification PROTOCOL. According to the results of the self-assessment, LPCs of representative design and structure (as described in Figure 1 and Figure 2) are substantially recyclable (Table 1).

These results apply only to LPCs of the representative structure. Manufacturers should make their own evaluation based on the actual design and structure of their LPCs. See Annex 2 for more information about the RECY:CHECK methodology.

Table 1: Results of the self-assessment of recyclability of LPCs[17]

**Note: This relates to the recycling class according to the RECY:CHECK methodology. This does not indicate the recycling performance grade which will be attained according to the requirements of the PPWR.*

STANDARD APPLIED	FORMAT EVALUATED	COMMENTS	RECYCLABLE CONTENT SCORE (OUT OF 100)	RELEVANCE & APPLICATION
RECY:CHECK Recyclability Certification PROTOCOL	Considering a representative food or beverage LPC structure of 75% LPB, 25% PE and/or aluminium (including caps and lids)	Considering that the PolyAl fraction is not recycled	75	C*
RECY:CHECK Recyclability Certification PROTOCOL	Considering a representative food or beverage LPC structure of 75% LPB, 25% PE and/or aluminium (including caps and lids)	Considering that the PolyAl fraction is recycled back into PE, PP, and aluminium fractions to replace virgin materials	100	A*

These results consider a representative LPC structure of 75% board, 25% PE, sometimes a small amount of aluminium (including caps and lids). However, considering different structures and designs could have an impact on the recyclability score achieved. Design features and materials that have the potential to change the recyclability score achieved are summarized in Table 2.

The fibre recovery process is well established and the implications of these parameters for recyclability of this fraction are well understood. Consequently, the fibre recovery process is robust and can handle LPCs of different structures and designs.

Techniques for valorization 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 for all processes are 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 LPC stream than others.

17 - See Annex 1 for the full self-evaluation of beverage cartons using these methods.

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 fraction and polymer film fraction are separated into different material streams, as the recovered polymer can then be used for more applications. Where the plastics are separated from the aluminium to produce a separate polymer fraction and an aluminium foil fraction, some processes and end-use applications may be more sensitive to the presence of non-PO polymers in the stream than others. This sensitivity depends on the process and/or the separation reagents used, although further investigations are required to establish this 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 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.

Table 2: Design features and materials and their implications for the recyclability of LPCs

FEATURE/ MATERIAL	POTENTIAL INFLUENCE ON RECYCLABILITY
Wet strength agents	By definition, wet strength agents increase the wet tensile strength of the paper. The fibre recovery process relies on hydraulic forces to separate the fibres. Wet strengths have the potential to reduce the yield from the fibre recovery process. Practical experience in the market does not indicate that LPCs containing wet strength boards are currently a problem for dedicated beverage carton recycling operations.
Water resistant coatings	Coatings can provide LPB 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. A wax coating for LPCs is not considered as an incompatibility, but the dissolvability has to be measured with an appropriate test method. The products need to be dissolved under the technical operating parameters in typical LPC reprocessing facilities. Wax-coated LPCs 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, LPCs are typically composed of LPB and PE or LPB, PE, and aluminium, with additional components such as closures manufactured from HDPE, LDPE or PP. While 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 their use in the structure of non-POs and biodegradable polymers (e.g., polylactic acid, PLA) for recyclability would need to be ascertained, as some PolyAl recycling processes may be more sensitive to the presence of non-POs in the overall material stream than others.
Adhesives	Adhesives are integral to the manufacture of packaging, and paper recycling technology is designed to separate and remove these during the papermaking process. However, some adhesives have potential to soften or plasticize 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 papermaking or converting processes. Water-insoluble or re-dispersing adhesive applications may be incompatible with recycling processes for LPCs, where it has not been specifically proven that they can be removed. Compliance can be demonstrated using INGEDE Method 12 INGEDE, 2013a, b).[18]
Printing inks	Inks that are not easily removed by the deinking 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 recycling mills utilizing LPCs as a fibre furnish do not include deinking stages.

18 - INGEDE, https://pub.ingede.com/en/ingede-methods-to-evaluate-recyclability-and-deinkability/

05 MAXIMIZING THE RECYCLABILITY OF LPCs: DESIGN RECOMMENDATIONS

In this section, design for recycling criteria are defined for LPCs. As previously described, LPCs are manufactured from LPB and laminated with polymers or with polymers and aluminium. Other components may be incorporated into the design, such as caps/closures, straws, and wrappers.

When an LPC is collected and sent for sorting, the carton is handled as a single unit of packaging, along with any attached components. Once sorted into an LPC stream, the fibres which make up the LPB are recovered in a specialized mill to produce a high-quality pulp fraction for manufacture of recycled content paper or board. The non-fibre components, consisting of the polymer and aluminium laminate and any other components such as caps/closures, form a distinct material stream (known as PolyAl). The PolyAl recycling process is described in Section 3.4.

Design for recycling criteria must therefore be applied at four different levels as shown in Table 3.

Table 3: Design for recycling criteria, applied at four different levels

	LEVEL CRITERIA ARE APPLIED AT:
Design for compatibility with sorting	LPC: the packaging unit level
Design for compatibility in a mill with specialized process	Laminated LPB: the laminated board
Design for compatibility with PolyAl recycling	Lamination/barrier layers (polymer film and aluminium foil) and caps, closures, etc. (hard fraction) remaining after removal of the fibres
Design for compatibility with standard rigid plastics recycling: hard plastic fraction	Caps, closures, etc.

The following tables (4-14) present design for recycling criteria for ensuring that LPCs placed on the market are compatible with all of the relevant processes in the recycling value chain. In each case, the components or constituents of LPCs are classified according to their compatibility with the relevant state-of-the-art sorting and recycling processes, as defined in Chapter 5 of these guidelines.

For PolyAl recycling, the reference process considers separation of the polymer film fraction, the aluminium foil fraction, and the hard fraction, followed by recovery of the polymer film fraction for use in injection moulding processes and reprocessing of the hard fraction using standard hard plastic recycling processes. These practices represent the state-of-the-art for PolyAl recycling, although there is also currently a market for processes which process the film fraction and hard fraction together to produce outputs with different process sensitivities. Also, PolyAl reprocessing technology is developing fast and compatibility with other processes may be considered in future updates of these guidelines.

Each specific structure or design element is assessed against the categories outlined in Table 4.

Table 4: Categories considered for the recyclability implications of different compositions and design components, adapted from the European Committee for Standardization (CEN[19]).

GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise
Components or constituents of LPCs that are compatible with state-of-the-art collection, sorting, and recycling or are demonstrated as suitable for recycling through technical evaluation and can fully meet the quality requirements of secondary raw material in the recycling process	Components or constituents of LPCs that are recognized as acceptable with limited compatibility with state-of-the-art collection, sorting, and recycling, or are demonstrated as having conditional compatibility through technical evaluation, or will not meet all quality requirements of secondary raw material in the recycling process	Components or constituents of LPCs that are generally recognized as detrimental (disrupting) for recycling or are demonstrated as disrupting for recycling through technical evaluation, or are demonstrated as unacceptable, downgrading the yield or the quality of recycled material

5.1 Compatibility of liquid packaging cartons with NIR sorting processes

Liquid packaging cartons of typical structure (i.e., LPB laminated with PE on the outer surface) provide unique spectral properties which allow their identification and automated sorting at commercial speeds and with high yield and purity. LPCs laminated with PP on the outer surface are also identified by a unique spectral calibration and separated using NIR sorting technology. Any other non-standard structure with an outer layer other than PE or PP may require empirical testing to ensure that they can still be identified in NIR sensor-based sorting systems.

19 - https://www.cencenelec.eu/about-cen/

Table 5: Compatibility of LPCs with NIR sorting processes

	GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise	**EVIDENCE OR REFERENCE**
Polymer outer layers	PE or printed PE outer layer PP or printed PP outer layer		Other polymer outer layers	Present at operational scale
Inks containing carbon black	Surface coverage is less than 50% of the surface area		Surface coverage more than 50% (unless proven to be compatible by testing)	German Minimum Standard
Decorative metallic components		Metallization, which is achieved through direct or hot and cold transfer techniques, should not cover the surface of fibre-based products fully, as this could cause issues identifying or detecting fibre products		4evergreen *Circularity by Design Guideline for Fibre-Based Packaging* version 3 October 2024

Two different solutions are used for printing LPCs. Either the LPB is printed prior to the attachment of the outer LDPE or PP layer, or the laminated reel is printed, with the ink applied to the outer side of the outer LDPE or PP layer. Both standard printing processes are compatible with current NIR sorting processes.

5.2 Compatibility of liquid packaging board in mill with specialized process

5.2.1 Fibres used in liquid packaging board

High-quality virgin fibres make up approximately 75% of an LPC by weight. Therefore, the first focus when recycling LPCs must be on maximizing the recovery of these valuable fibres.

All fibre types used in LPCs are recyclable in the dedicated fibre recovery processes operated across Europe. The recovered fibres from used LPCs are consumed in the manufacture of a wide range of recycled content paper products, including packaging grades (corrugated case medium, cartonboard, core board) and tissue papers.

Table 6: Recycling compatibility of different fibres used in LPB with recycling processes at specialized mills

	GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise	**EVIDENCE OR REFERENCE**
Fibres used in LPB	Bleached and unbleached sulfate kraft, bleached or unbleached CTMP			Present at operational scale Recycling mills with specialized processes target high-quality (virgin) fibres with high mechanical properties

5.2.2 Fillers and chemical components used in LPB

A wide range of fillers, additives, and agents can be used in very small quantities in the production of LPB. Most of these are fully compatible with the recycling processes at the specialized mills which recycle LPCs.

Operational practice demonstrates that fibres are successfully recovered from LPCs containing moderate wet strength by the dedicated fibre recovery facilities in operation today. The 4evergreen *Circularity by Design Guideline* (4Evergreen, 2024) clarifies which wet strength agents and which sizing agents may 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. Moderate levels of wet strength agents used in LPCs are known to be compatible in mills with specialized processes.

Since the additives are embedded within the board, they will be separated from the PolyAl during the repulping process at the specialized mill. As a result, they are not expected to enter the PolyAl recycling stream, and therefore should not pose any compatibility issues. However, depending on the type and amount of wet strength used, the fibre yield may be lower for packages containing wet strength agents compared to packages without wet strength additives, leaving a higher proportion of residual fibres in the PolyAl fraction after separation. The PolyAl stream will still be recyclable, but residual fibres in the PolyAl fraction are undesirable as they reduce the yield, efficiency, and quality of the recyclate from the PolyAl recycling process. Ultimately, recyclability depends on various factors, such as relative wet strength level or amount of wet strength agent. Recyclability can be improved by increased pulping temperature and time, chemicals, and high consistency pulping, among others. Investigations are ongoing which will provide quantitative and specific information on what constitutes moderate wet strength. However, additional time is required for completion of these investigations.

Table 7: Recycling compatibility of fillers, additives, and agents used in LPB with processes at LPC paper recycling mills

	GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise	**EVIDENCE OR REFERENCE**
Filler/ Inorganic pigments[20]	Clay (kaolin); CaCO3, Talc, Titanium dioxide			Present at operational scale and cited in 4evergreen *Circularity by Design Guideline for Fibre-Based Packaging* version 3 October 2024 *Present at operational scale
Sizing, wet-end	AKD, ASA, Rosin			
Dry strength	Starch, Carboxymethyl Cellulose (CMC), Polyacrylamide, Guar gum, Glyoxalated polyacrylamide (GPAM)*, polyvinylamine (PVAm)*			
Wet strength agent	Glyoxalatedbpoly-acrylamide (GPAM), polyvinylamine (PVAm) Other wet strength agents: Polyamide epichlorohydrin (PAE), and Urea/Formaldehyde, if relative wet strength is less than 15%, determined by measuring dry tensile strength according to ISO 1924 and wet tensile strength according to ISO 3781:2011			Testing performed based on 4evergreen evaluation protocol Part III (Version 1) that up to 15% relative wet-strength is compatible in recycling mill with specialized process
Colourants /dye for shading	Colourants/dyes approved for food packaging applications		Colourants/dyes not approved for food packaging applications should be avoided	Present at operational scale 4evergreen *Circularity by Design Guideline for Fibre-Based Packaging* Version 3 October 2024
Others	Surface sizing, Surface starch Colourants/pigments Polyvinyl alcohol (PVOH) Polyaluminium Chloride (PAC) Retention polymers, retention aids		Siliconizing agents	

20 - High ash content may have a negative impact on mechanical strength depending on the relative amount in the paper for recycling stream.

5.2.3 Liquid packaging board pigment coatings

Liquid packaging boards may be coated with clay or other pigments. There are lightly coated and fully coated boards in the market. Fully coated boards provide improved printability (for LPCs where the ink is applied directly to the board) and are required to meet the design needs of some brand owners. Both lightly- and fully-coated boards are recyclable. Specialized mills that reprocess used LPCs aim to remove insoluble/soluble coatings during the fibre preparation stages, which incurs disposal costs for the inorganic components, but the board for LPCs typically contains fewer inorganic components than recovered fibres from other sources such as office and graphic papers or OCC (old corrugated containers).

The presence of residual pigment coating in the recycled fibre output may decrease 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 LPCs in Europe. Wax-coated LPCs would not achieve the same dissolution rate in water as standard LPCs. For wax-coated LPB, recyclability would need to be determined through measurements, according to the relevant evaluation and test protocol.

Generally, LPB pigment coatings are fed forward with the fibres during the recycling process. The material should not pass through to the PolyAl recycling process and therefore compatibility with PolyAl recycling should not be an issue.

Table 8: Recycling compatibility of pigment coatings used for LPB with processes at specialized LPC recycling mills

	GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise	**EVIDENCE OR REFERENCE**
Pigment coatings	**Clay and other pigment coatings**: Fully compatible with recycling processes at specialized mills, but board producers should seek to reduce the quantity of clay coating required, within the limitations of meeting printability requirements.		**Wax coatings**: For wax-coated LPB, recyclability would need to be determined through measurements, according to the relevant evaluation and test protocol.	Present at operational scale 4evergreen *Circularity by Design Guideline for Fibre-Based Packaging* Version 3 October 2024
Binder	S/B latex, S/A latex[21]; Starch-biobinder			

5.2.4 Adhesives for attachments

Only a limited amount of adhesive is required for the production of LPCs. Adhesives may be used for attaching drinking straws to the outer surface of the carton and for attaching caps/closures to the carton (although in some LPCs direct injection moulded caps are deployed and these do not require any adhesive).

For all LPCs where application of straws or caps/closures using adhesives is required, hotmelt adhesives are used (4evergreen, 2024). The hotmelt adhesives used can be made out of POs or ethylene vinyl acetate (EVA).

These hot-melt adhesives are not water soluble. By keeping their application size above 2 mm x 2 mm, 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 > 68°C (above the temperatures encountered in paper recycling), secondary microsticky and macrosticky formation can be minimized.

Generally, adhesives should be removed during the recycling process at the specialized mill. The material should not pass through to the PolyAl recycling process and therefore compatibility with PolyAl recycling should not be an issue.

21 - S/B latex and S/A latex (depending on amount, adhesive strength, etc.)

Table 9: Recycling compatibility of adhesives used for attachments with processes at specialized LPC recycling mills

	GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise	**EVIDENCE OR REFERENCE**
Adhesives	Water-soluble adhesives Hotmelt adhesive (with softening temperatures ≥ 68°C) with an application size above 2mm x 2mm	Water-insoluble or re-dispersing adhesives: Potential to cause generation of stickies in the products manufactured from the recovered fibres, thereby reducing quality Hot melt adhesive (with softening temperatures ≥68 °C) with an application size below 2mm x 2mm	Hotmelt adhesives with softening temperatures ≤ 68°C: compatibility with recycling processes at specialized mills is unknown	Expert opinion 4evergreen *Circularity by Design Guideline for Fibre-Based Packaging* Version 3 October 2024 *Assessment of Printed Product Recyclability: Scorecard for the Removability of Adhesive Applications*; European Paper Recycling Council, 2017

5.2.5 Printing inks/printing techniques

LPCs are printed using conventional printing techniques such as offset, flexo, gravure, and digital printing. LPB is either printed prior to the attachment of the outer LDPE or PP layer, or the laminated reel is printed, with the ink applied to the outer side of the outer LDPE or PP layer.

Both of these standard printing processes are compatible with current recycling processes applied at specialized mills.

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. Otherwise, if the recovered fibres are going to be used for brown packaging grades, then the ink particles are incorporated into the paper sheet. Inks that are cured using UV light are fully compatible with fibre recovery processes, but their influence on some PolyAl recycling processes may require further investigation.

An exception is inks non-compliant with the EuPIA Exclusion Policy. This exclusion list of raw materials is based on hazard classification and/or toxicological evidence.

Their exclusion is not directly related to reprocessing, but due to hazardous and toxicological implications. Switzerland also has specific regulations for inks used in food packaging to ensure safety and compliance. The Swiss Ordinance on Materials and Articles in Contact with Food (RS 817.023.21) governs these regulations.

For all printing inks, their compatibility with food contact applications would need to be ascertained.

Where print is applied to the outer surface of the outer LDPE or PP layer, the printed LDPE or PP layer is removed from the fibre recovery process as part of the PolyAl stream. Even when printed on paperboard, a proportion of the ink sticks to the inner side of the outer PE layer. Thus, for both printing variants the ink can be included in the PolyAl stream and its compatibility with the recycling processes for the film fraction of the PolyAl must be considered.

Table 10: Compatibility of inks with recycling processes at specialized mills and with recycling processes for the foil fraction of the PolyAl

	GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise	**EVIDENCE OR REFERENCE**
Ink type	Vegetable oil-based inks Water-based inks and varnishes Solvent-based inks and varnishes Liquid and solid toner-based inks Two component-based inks and varnishes	UV cured inks and varnishes Mineral oil-based inks - Not relevant for LPC recycling process. Inks based on mineral oils are fully compatible with the recycling process. However, the use of mineral oil-based inks restricts the use of the recovered fibres to non-food applications. Therefore, it is not used for LPCs today and it is not recommended to be used	**Inks non-compliant with EuPIA Exclusion Policy[22]** Not compatible with PolyAl recycling processes. Their exclusion from recycling is not directly related to reprocessing, but due to hazardous and toxicology implications. Digital-hotmelt inks	Operational practice Exclusion Policy for Printing inks and Related Products. 7th Edition, EuPIA, November 2024 4evergreen *Circularity by Design Guideline for Fibre-Based Packaging* Version 3 October 2024
Binders in ink systems	Total quantity of dry inkfilm should not exceed 5wt% of packaging structure, whether a single ink/ overprint varnish or a combination of ink and overprint varnish Nitrocellulose (NC) based inks, and overprint varnishes up to a maximum of 0.8% NC binder by weight of the total packaging structure	NC-based inks and overprint varnishes from > 0.8% to 1.3% NC binder by weight of the total packaging structure	Inks and overprint varnishes containing PVC co- and terpolymers Any other chlorinated binders	CEFLEX Phase 2 testing results or from original Phase 1 design guidance Printing inks and Plastic Recycling – Q & A (EuPIA, n.d.)

22 - AS 2023 836 - Verordnung des EDI über Materialie... | Fedlex [Available in German language only]

5.2.6 Straws and protective wrappers

Consumers should be encouraged to push the drinking straw into the LPC 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 material. However, paper straws should be engineered to withstand water vapour/moisture and therefore repulpability of paper drinking straws in the context of mills that recover fibre from LPCs should be ascertained before they are brought to the market.

PE and PP (including bio-based PE and PP) protective wrappers for drinking straws glued to the LPC will most likely be removed from the packages during collection and sorting processes before the cartons reach the recycling mill. In this case, they would be sorted into a PE or PP material stream which would allow them to be recycled. These wrappers should be designed for recycling according to the D4ACE guidelines (CEFLEX, 2023).

Table 11: Compatibility of straws and protective wrappers with recycling processes at specialized mills

	GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise	**EVIDENCE OR REFERENCE**
Straws	Paper straws			Operational practice 4evergreen *Circularity by Design Guideline for Fibre-Based Packaging* Version 3 October 2024
Protective wrappers	**PE (fossil-based and bio-based) protective wrappers** **PP (fossil-based and bio-based) protective wrappers** The wrappers will most likely be removed during collection and sorting and are therefore unlikely to be processed in the specialized mills **Paper protective wrappers** If not removed during collection and sorting, the wrappers will be repulped in the specialized mill			Operational practice *Designing for a Circular Economy: Recyclability of polyolefin-based flexible packaging* (CEFLEX, August 2023) 4evergreen *Circularity by Design Guideline for Fibre-Based Packaging* Version 3 October 2024

5.2.7 Lamination/barrier layers

To separate the fibres from the non-fibre components, liquid packaging cartons need to be repulped under suitable conditions which are applied in specialized mills. The vast majority of LPCs are used for non-aseptic chilled and aseptic applications and consist of LPB laminated on the outer surface with polyethylene and on the inner surface with polyethylene or polyethylene and aluminium. For retorted LPCs, Polypropylene (PP) may be used.

Both these standard structures are fully compatible with the repulping process performed at specialized mills. For non-standard structures where alternative materials are applied, repulpability in those operating conditions may need to be ascertained through testing. If a specific construction does not achieve the same repulping rate in water as typical LPCs it may be considered less recyclable or potentially even non-recyclable.

Once the fibres have been removed at the specialized mill, the barrier material is available as part of the PolyAl for recycling.

PolyAl is a unique material, and consequently PolyAl recycling is unique. While the end product is a substitute for plastic materials, the recycling process is not the same as plastic recycling. There are some commonalities in the processes for PolyAl recycling and recycling of POs; there are also critical differences. Therefore, not all conclusions regarding the recyclability of PolyAl and POs are the same due to subtle differences in the makeup and processing of the materials. For this reason, it is necessary to have design for recycling criteria specific to the PolyAl stream.

The most common recycling process for the combined polymer film and aluminium foil fraction of the PolyAl is the production of granulate for injection moulding. **This is the reference process considered in these guidelines.**

In addition to the standard barrier structures, alternative barrier layer materials can include EVOH, PA, and polyethylene terephthalate (PET). For chilled and ambient LPCs, PP may also be used as a carrier for very thin layers of materials such as AlOx, SiOx or metallization which are applied by vapour deposition to provide barrier properties.

For LPCs 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 LPB and the product. Depending on the oxygen sensitivity of the product, this strip may be made from PET, PA, or EVOH co-polymer. Other adhesives are also used for the sealing strip but with limited market penetration.

The presence of alternative polymers in the PolyAl stream 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. Most technologies process the polymers and the aluminium together as a composite material, whereas others separate the aluminium and PE film fraction for processing. Depending on the end-application target for the recyclates, and on the process they use, PolyAl recyclers will be more or less sensitive to non-PE components in the stream of PolyAl they are able to process. In the following tables (12-14), where percentage limits are stated for polymers, these refer to the percentage of the referenced material as part of the polymer structure (i.e., excluding aluminium foil if present).

If more than two polymers (PE plus one other polymer) are used, the combination needs to be tested to prove compatibility with PolyAl recycling processes.

Table 12: LPCs: Compatibility of PE-based laminate and barrier materials used in non-aseptic and aseptic LPCs with PolyAl film fraction recycling processes for injection moulding and LPC applications

	GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise	**EVIDENCE OR REFERENCE**
Polyethylene (PE): fossil-based and bio-based	> 75% (in the polymer film fraction) Mono-PE including co-extruded, orientated, co-polymers—Laminated PE/PE with or without barrier layers and coatings as indicated below		< 75% (in the polymer film fraction) Mono-PE including co-extruded, orientated, co-polymers—Laminated PE/PE with or without barrier layers and coatings as indicated below	Present at operational scale—PE-based solutions are the main fraction in the LPC stream
PP or PE carrier films with vapour deposition barriers	AlOx SiOx Metallization as applied by vapour deposition			Testing performed: Recyclability testing for AlOx performed by Institut Cyclos-HTP with PP carrier showed full compatibility. All other combinations: CEFLEX D4ACE classifies less than 5% of these in the foil fraction to be likely fully compatible. Limited compatibility > 5%
EVOH	Up to 10% EVOH as co-extruded layer in the polymer component of the PolyAl film fraction, with at least one surrounding layer containing maleic anhydride (MAH) grafted PE in a ratio ≥ 1 g per g EVOH		> 10% EVOH as co-extruded layer in the polymer component of the PolyAl film fraction, with at least one surrounding layer containing maleic anhydride (MAH) grafted PE in a ratio ≥ 1 g per g EVOH	Testing: A maximum of 10% of EVOH co-extruded with maleic anhydride grafted-PE tie layer in the minimum ratio 1 g per g EVOH, has proven to be fully recyclable in compatibility tests by Institut Cyclos-HTP
Polyamide (PA)	Up to 20% (in the polymer film fraction) polyamide 6 (PA6) or co-polyamide 6/6.6 as co-extruded layer, with at least one surrounding layer containing maleic anhydride grafted PE as a tie layer specified for PA/PE co-extrusion in a ratio of ≥ 0.5 g per g PA in the polymer film fraction		> 20% (in the polymer film fraction) polyamide 6 (PA6) or co-polyamide 6/6.6 (PA 6/6.6) as co-extruded layer, with at least one surrounding layer containing maleic anhydride grafted PE as a tie layer specified for PA/PE co-extrusion in a ratio of ≤ 0.5 g per g PA.5 in the polymer c film fraction Polyamide 6 (PA6) or co-polyamide 6/6.6 with less than 0.5 g per g PA of maleic anhydride grafted PE as a tie layer in the coating structure film fraction	Testing performed: Proven to be fully compatible by Institut Cyclos-HTP

Table 12 (continued): LPCs: Compatibility of PE-based laminate and barrier materials used in non-aseptic and aseptic LPCs with PolyAl film fraction recycling processes for injection moulding and LPC applications

	GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise	**EVIDENCE OR REFERENCE**
PET		≤ 5% PET in the polymer film fraction: LPCs containing less than 5% PET in the polymer component of the foil fraction (i.e., > 95% PE) are likely to result in contamination levels that are undesirable but nonetheless manageable for the recycling processes	> 5% PET in the polymer film fraction	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 (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.
Biodegradable polymers (such as but not limited to Polylactic Acid (PLA) and Polyhydroxybutyrate (PHB)			No compatibility with PolyAl recycling processes	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.
Aluminium foil	Gauge < 10 µm		Gauge > 10 µm	Present at operational scale
Fillers in polymer foil	Amount of fillers that do not raise the density of polymer to a value above 0.99 g/cm3 or beyond	Amount of fillers that raise the density of polymer to a value of 0.99 g/cm3 to 1.0 g/cm3	Amount of fillers that raise the density of the polymer to above 1.0 g/cm3	

Testing has shown that certain grades of PA as well as EVOH as specified in Table 12 are fully compatible with the recycling process for the laminate fraction of the PolyAl until a ratio of at least 30% of each of these structures in the mix is reached. Currently, these structures represent far less than 30% of the total LPC in the waste stream. If the presence of these structures in the PolyAl mix exceeds 30%, further testing shall be performed to prove that even higher shares are compatible with recycling. Retortable LPCs with an outer and inner PP layer represent much less than 5% of the total LPC in the waste stream. At these levels, the proportion of PP introduced into the polymer component of the PolyAl film fraction from retortable LPC is fully compatible with the recycling process. Based on test results, retortable LPC with an outer and inner PP layer at a ratio of < 10% in the PolyAl mix is considered as fully compatible with the recycling process for the laminate fraction of the PolyAl. Based on the experience of PolyAl recyclers, between 10 and 20% PP in the polymer structure in the PolyAl film fraction is conditionally compatible; > 20% is considered not compatible. If the presence of PP in the PolyAl mix increases significantly, further technologies (e.g., flake separation) can be installed to avoid quality losses in the recyclate.

These Design for Recycling guidelines will be reviewed and updated regularly and the presence of PA, EVOH, and PP in the PolyAl mix will be considered.

Table 13: LPCs: Compatibility of PP-based laminate materials and barrier solutions used for retortable LPCs with PolyAl foil fraction recycling processes where the PolyAl recyclate is used for injection moulding

	GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise	**EVIDENCE OR REFERENCE**
PP or PE: fossil-based and bio-based	PP or PE in the polymer component of the PolyAl film fraction			Present at operational scale: currently accounting for < 5% of the total PolyAl stream The presence of PP at this level in the PolyAl mix is not negatively disrupting recycling processes
Aluminium foil, PA, EVOH, PET, biodegradable polymers	For compatibility of these elements, the limits and classifications reported for PE-based laminates in Table 12 also apply for PP-based laminates			

5.3 Compatibility of the hard fraction with standard rigid plastics recycling processes

5.3.1 Polymers used for caps and closures

The caps and closures (hard plastic fraction) will typically be separated out and recycled as a mixed PO stream using standard rigid plastics recycling technologies, although in some cases the hard fraction and the foil fraction will be reprocessed together as a composite material used for injection moulding applications.

For mechanical recycling processes producing a mixed PO stream, material that is > 90% POs (PE and PP) is fully compatible with recycling. At 80–90% PE/PP, the material is conditionally compatible, and at less than 80% it is not compatible with the process. The more of one polymer in the mixed stream (> 80%) the better (CEFLEX, 2023).

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.

Table 14: Compatibility of polymers used for caps and closures with standard PO recycling processes

	GREEN CATEGORY Fully compatible	**YELLOW CATEGORY** Conditionally compatible	**RED CATEGORY** Not compatible unless testing proves otherwise	**EVIDENCE OR REFERENCE**
Polymers	**> 90% PO**	**80–90% PO**	**< 80% PO** **Biodegradable polymers** 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	*Designing for a Circular Economy: Recyclability of polyolefin-based flexible packaging* (CEFLEX, August 2023)

06 FUTURE-PROOFING THESE GUIDELINES

Technology, innovative materials, and policy relating to collection, sorting, and recycling are fast moving:

- Capabilities in sorting systems and reprocessing technologies are constantly changing. Existing technologies are evolving and new technologies are emerging which could revolutionize recycling value chains. The Food and Beverage Carton Alliance (FBCA) maintains a watching brief on those technologies pertinent to LPC 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 EU's Circular Economy Action Plan are finalized and delegated acts to implement the requirements of the PPWR are adopted.
- Also, other design for recycling guidance is being developed and revised which may provide further insights regarding the recyclability of used LPCs.

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.

ANNEXES

ANNEX 1

STANDARDS AND GUIDELINES RELEVANT TO THE RECYCLABILITY OF LPCs

Table 15: Standards and guidelines considered in the preparation of this document

Standard or guideline	STATUS	OVERVIEW	RELEVANCE AND APPLICATION
4EVERGREEN CIRCULARITY BY DESIGN GUIDELINE & RECYCLABILITY EVALUATION PROTOCOL	PUBLISHED	4evergreen is a cross-industry alliance which seeks to increase the recycling rate of fibre-based packaging to 90% by 2030. The platform recently published Circularity by Design Guideline for Fibre-Based Packaging Version 3 (October 2024) and is revising its “Fibre-based Packaging Recyclability Evaluation Protocol.” The document describes the assessment and score calculation procedures to assess the recyclability of fibre-based packaging for three different types of recycling mills: Part I recycling mill with conventional processes; Part II recycling mill with flotation-deinking processes; and Part III recycling mill with specialized processes (for processing LPCs).	Part I of the recyclability evaluation protocol considers conventional recycling mill conditions. Part III considers “specialized processes” dedicated to recycling of LPCs. Part III introduces a “mechanical properties score” which is based on the measurement of the tensile index and ash content of the paper sheet to reflect that recycling mills with specialized processes target the high-quality fibres present in LPCs. Part III also introduces methodology to assess the purity of the PolyAl coarse reject fraction and mechanisms to penalize fibres lost with the PolyAl fraction.
CEN/TC 261/SC 4/ WG 10 - PARTS 1, 3, 7 AND 13 (CEN ENQUIRY DRAFT) PACKAGING - DESIGN FOR RECYCLING OF PLASTIC PACKAGING	DRAFT	DIN EN 18120 consists of 15 parts which aim via a series of guidelines and protocols to establish consistency and improvement in the design for recycling of household, industrial, and commercial plastic packaging. Design for recycling guidelines describe compatibility with plastic packaging collection, sorting, and recycling into high-quality recycled plastic in state-of-the-art facilities. They provide guidance on the level of compatibility, defined as: • Green: Packaging constituents with full compatibility with recycling • Yellow: Packaging constituents with limited compatibility with recycling • Red: Packaging constituents which are not compatible with recycling.	Four parts are relevant to recycling of LPCs, and specifically to the recovered PolyAl fraction though not directly applicable: • Part 1: Definitions and principles for design for recycling of plastic packaging • Part 3: Sortability evaluation process for plastic packaging • Part 7: Guideline and protocol for PE and PP flexible packaging • Part 13: Recyclability evaluation process for plastic packaging - protocols for PE and PP flexible packaging

Table 15 (continued): Standards and guidelines considered in the preparation of this document

Standard or guideline	Status	overview	Relevance and application
RECY:CHECK RECYCLABILITY CERTIFICATION PROTOCOL: METHODOLOGY FOR ASSESSING THE RECYCLABILITY OF FIBRE-BASED COMPOSITE PACKAGING SUITABLE FOR SPECIALIZED MILLS REPROCESSING USED BEVERAGE CARTONS. CREATED FOR EXTR:ACT (NOW FBCA)	PUBLISHED	RECY:CHECK'S PROTOCOL describes the certification methodology to determine the actual recyclability of FBCP in specialized mills reprocessing used LPCs including the PolyAl fraction	The RECY:CHECK Recyclability Certification PROTOCOL provides a detailed methodology to carry out an objective quantitative analysis of the recyclability of FBCP suitable for a specialist mill reprocessing used LPCs through assessment of: 1. *Recyclable content: the amount of potentially recyclable content* 2. *Collection: evaluation of the collection system for this product/packaging combination* 3. *Sorting - operational sorting tests: evaluation of the sortability of the packaging in an operational industrial sorting facility* 4. *Reprocessing: evaluation of recycling incompatibilities* 5. *Application: evaluation of the quality of the recycled material.* A "performance score" is calculated from the sum of weighted criteria developed for the packaging unit. The methodology is based on quantitative assessment (reducing reliance on expert opinion) and also aligns with the qualitative assessments which were documented within the Design for recycling guidelines published by ACE in October 2022. Note: The RECY:CHECK scoring and performance score are designed according to existing and established industry proven methodologies and are different from that described in the PPWR.
DESIGNING FOR A CIRCULAR ECONOMY: RECYCLABILITY OF POLYOLEFIN-BASED FLEXIBLE PACKAGING (HEREAFTER REFERRED TO AS THE D4ACE GUIDELINES) (CEFLEX, 2023)	PUBLISHED	The D4ACE guidelines have been developed for the whole value chain to build understanding of end-of-life processes and 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 this document (Chapter 5, Maximizing the recyclability of LPCs: design recommendations).
CEFLEX D4ACE PHASE 2 UPDATE DESIGN GUIDANCE PROPOSAL WEBINAR (CEFLEX, 2025)	NOT PUBLICLY AVAILABLE	Webinar presenting proposed updates to the CEFLEX D4ACE guidelines	
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 LPC design and recyclability investigated in more depth in this document.

ANNEX 2

SELF-ASSESSMENT OF LPC RECYCLABILITY USING RECY:CHECK

In this Annex, a self-assessment of the recyclability of an LPC of standard structure has been carried out using the principles outlined in the RECY:CHECK Recyclability Certification PROTOCOL.

The RECY:CHECK Recyclability Certification PROTOCOL (recycheck.com) provides a detailed methodology to carry out an objective quantitative analysis of the recyclability of fibre-based composite packaging suitable for a specialist mill reprocessing LPCs at full scale through assessment of:

- Criterion 0: if the packaging is suitable for the analysis
- Criterion 1: the amount of potentially recyclable content
- Criterion 2: if the packaging is collected
- Criterion 3: if the packaging can be sorted for recycling
- Criterion 4: if the packaging design is compatible with reprocessing
- Criterion 5: if the recycled material can replace primary raw material and there is a market for it.

A recyclable content is calculated from the sum of weighted criteria developed for the LPC of standard structure being recycled at full scale. This self-assessment considers two situations: one where PolyAl is recycled at industrial scale with separation into fractions of sufficient quality, and one where the PolyAl fraction is not recycled, (Table 16). The RECY:CHECK methodology is valid for EU27+3 (Norway, Switzerland, and UK). Note: The RECY:CHECK scoring and recyclable content are designed according to existing and established industry proven methodologies and are different from that described in the PPWR.

Results

Applying the principles outlined in the RECY:CHECK Recyclability Certification PROTOCOL, the recyclable content is calculated to be 75 (Class C) if the PolyAl fraction is not recycled and 100 (Class A) if PolyAl recycling to separate streams of PE, PP, and aluminium to replace virgin materials is also considered in this assessment. These results apply only to LPCs of the representative structure, which are "easy to empty". Manufacturers should make their own evaluation based on the actual design and structure of their LPCs.

Table 16: Results of the self-assessment of recyclability of LPC

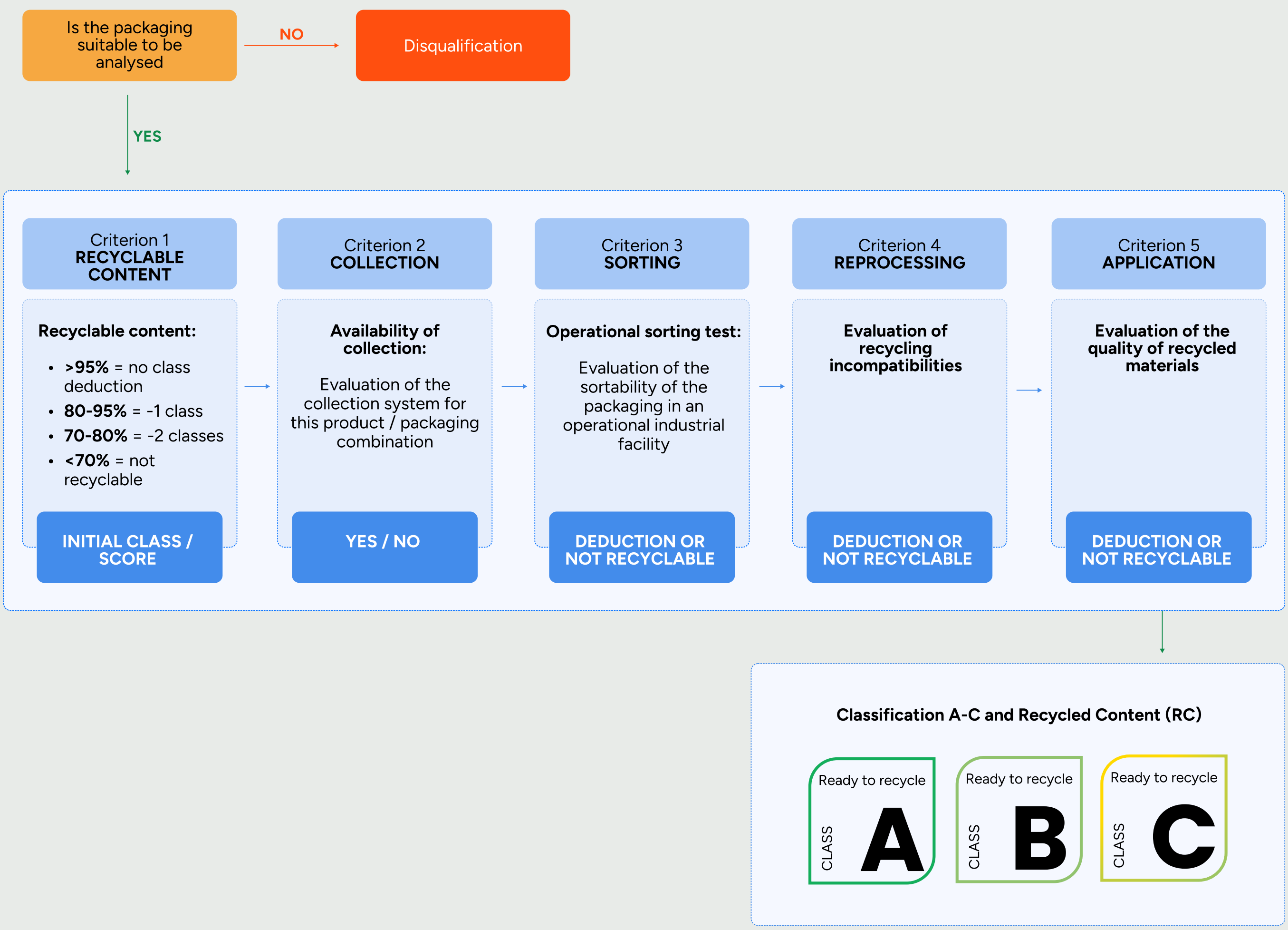
Format evaluated	Comments	Recyclable content (out of 100)	Class
Considering a representative LPC of 75% liquid packaging board, 25% PE, sometimes a small amount of aluminium (including caps and lids)	Considering that the PolyAl fraction is not recycled	75	C
Considering a representative LPC of 75% liquid packaging board, 25% PE, sometimes a small amount of aluminium (including caps and lids)	Considering that the PolyAl fraction is recycled back to PE, PP, and aluminium fractions to replace virgin materials	100	A

Schematic Overview of the RECY:CHECK Scoring Methodology

Figure 7 outlines the RECY:CHECK five-criterion process for assessing the recyclability of packaging. The evaluation begins by determining if the packaging is suitable for analysis. If it qualifies, it is assessed against five key criteria: (1) **Recyclable Content,** (2) **Collection**, (3) **Sorting**, (4) **Reprocessing**, and (5) **Application**. Each step examines the packaging's performance along the recycling chain, from material composition and collection availability to sorting ability, recycling compatibility, and final material quality. The process results in a recyclability classification of A, B, or C, or possible disqualification.

Figure 7: RECY:CHECK five-criterion process for assessing the recyclability of packaging

recycheck.com



ANNEX 3

EXAMPLES OF APPLICATION OF THE DESIGN FOR RECYCLING TABLES

Example 1: Aseptic liquid packaging carton

A new entrant to the burgeoning soya milk market has elected to use a 1-liter liquid packaging board (LPB) format to deliver its long shelf life product to customers. Recyclability of the LPC end-of-life is a critical component of the company ethos and brand. PolyAl recycling is in place. Using DfR guidance, LPB made from long fresh fibres and low ash content (3.42% of total pack weight) was selected to provide strength and stiffness to the pack. The tensile index of paper test samples was measured at 30 Nm/g. Glyoxylated polyacrylamide was used to ensure that the LPB retained “wet strength” over the product’s long shelf life. Polyethylene was extrusion coated on both sides of the LPB to provide liquid barrier and sealability (Figure 8). The PE extrusion coating is fully compatible with near-infrared (NIR) sorting processes. Vegetable oil-based inks which are not listed on the EuPIA Exclusion Policy were printed directly onto the LPB. No adhesives were used in the carton manufacture. The closure is made from rigid PP/PE. The weights of the main components are shown in Table 17. An assessment of compliance with DfR criteria is shown in Table 18.

Figure 8: Typical structure of aseptic LPCs

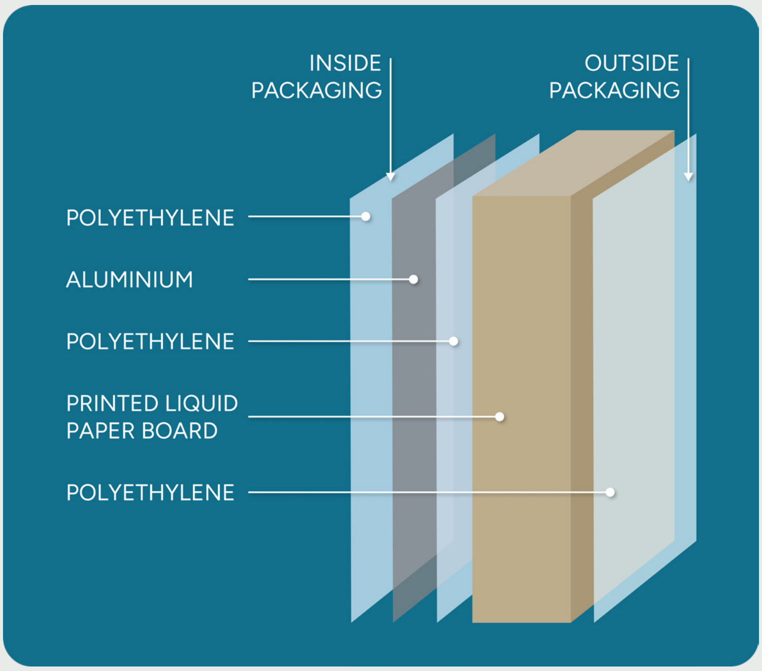


Table 17: Main pack components

			% of primary pack	of total pack
Volume	ml	1000.00		
Primary pack composition				
liquid packaging board (incl. ash)	g	20.00	75.76	68.49
liquid packaging board	g	19.00		65.07
ash	g	1.00		3.42
fossil PE	g	5.00	18.94	17.12
aluminium foil	g	1.40	5.30	4.79
Total primary pack	g	26.40		90.41
Closure composition			% of closure	
fossil PP	g	1.50	53.57	5.14
fossil PE	g	1.30	46.43	4.45
Total closure	g	2.80		9.59
Total pack weight (primary pack + closure)	g	29.20		
Total PolyAl	g	9.20	31.51	

Table 18: Compliance with Design for Recycling criteria

		Compatibility	Evidence
Compatibility with NIR sorting process	PE outer layer	Green category - fully compatible	
Fibres used in LPB	Sulfate kraft, bleached	Green category - fully compatible	
Recycling compatibility of wet strength agent used in LPB	Glyoxylated polyacrylamide	Green category - fully compatible	
Adhesives	Not used	Not applicable	
Printing inks/printing techniques	Offset print: oil-based (ink (vegetable	Green category - fully compatible	Ink not included in EuPIA Exclusion Policy
Straws and protective wrappers	Not used	Not applicable	
Lamination/barrier layers	Polyethylene: fossil-based	Green category - fully compatible	
Lamination/barrier layers	Aluminium	Green category - fully compatible	
Polymers used for caps and closures	Polyethylene cap	Green category - fully compatible	

Verdict: Fully compatible with LPC sorting and recycling processes

Example 2: Non-aseptic liquid packaging carton

A chilled soup brand is seeking to improve the sustainability of its 560-ml LPC through the use of a bio-based biodegradable extrusion coating for liquid barrier, heat sealability, and cap. PolyAl recycling is in place. LPB made from long fresh fibres and low ash content (3.33% of total pack weight) was selected to provide strength and stiffness to the pack. The tensile index of paper test samples was measured at 30 Nm/g. Wet strength agent was considered unnecessary as the pack is used for short shelf life produce only. Vegetable oil-based inks which are not listed on the EuPIA Exclusion Policy were printed directly onto the LPB. No adhesives were used in the pack manufacture. The weights of the main components are shown in Table 19.

Table 19: Main pack components

	Unit		% of primary pack	of total pack
Volume	ml	560.00		
Primary pack composition				
liquid packaging board (incl.ash)	g	11.20	79.86	66.57
liquid packaging board	g	10.64	75.86	63.24
ash	g	0.56	3.99	3.33
Bio-based biodegradable coating	g	2.83	20.14	16.79
aluminium foil	g	0.00	0.00	0.00
Total primary pack	g	14.03		83.36
Closure composition			% of closure	
Bio-based biodegradable polymer	g	2.80	100.00	16.64
Total closure	g	2.80		16.64
Total pack weight (primary pack + closure)		16.86		
Total PolyAl	g	5.63	33.43	

Outcome: Biodegradable polymers are not compatible with NIR sorting processes or PE/PP film or rigid PO recycling. An assessment of compliance with Design for Recycling criteria is shown in Table 20.

Table 20: Compliance with Design for Recycling criteria

		Compatibility	Evidence
Compatibility with NIR sorting process	Biodegradable polymer	Red category - Not compatible unless testing proves otherwise	
Fibres used in LPB	Sulfate kraft, bleached	Green category - fully compatible	
Recycling compatibility of wet strength agent used in LPB	Not used	Not applicable	
Adhesives	Not used	Not applicable	
Printing inks/printing techniques	Offset print: oil-based (ink (vegetable	Green category - fully compatible	Ink not included in EuPIA Exclusion Policy
Straws and protective wrappers	Not used	Not applicable	
Lamination/barrier layers	Biodegradable polymer	Red category - Not compatible unless testing proves otherwise	
Polymers used for caps and closures	Biodegradable cap	Red category - Not compatible unless testing proves otherwise	

Verdict: Not compatible with NIR sorting or PolyAl recycling processes
Advisory: Use PE or PP barrier layers and closures which are compatible with NIR sorting and PolyAl recycling

Example 3: Retortable liquid packaging carton

A soup manufacturer uses a 1-liter retortable LPC to package its long shelf life soup. The pack has been designed to meet DfR criteria. PolyAl recycling is in place. LPB made from long fresh fibres and low ash content (3.94% of total pack weight) was selected to provide strength and stiffness to the pack. The tensile index of paper test samples was measured at 30 Nm/g.

Glyoxylated polyacrylamide was used to ensure that the LPB retained "wet strength" during the retorting/sterilization process. Polypropylene (PP) (fossil-based), which resists the high temperatures used in the retorting/sterilization process, was extrusion coated on both sides of the LPC to provide liquid barrier and sealability (Figure 9).

The PP extrusion coating is fully compatible with NIR sorting processes, and at low levels (< 5% w/w) can be recycled with the PE which arises from recycling aseptic and non-aseptic LPCs. Vegetable oil-based inks which are not listed on the EuPIA Exclusion Policy were printed directly onto the LPB. No adhesives were used in the carton manufacture. The closure was made from rigid PE. The weights of the main components are shown in Table 5. An assessment of compliance with Design for Recycling criteria is shown in Table 22.

Figure 9: Structure of retortable LPC

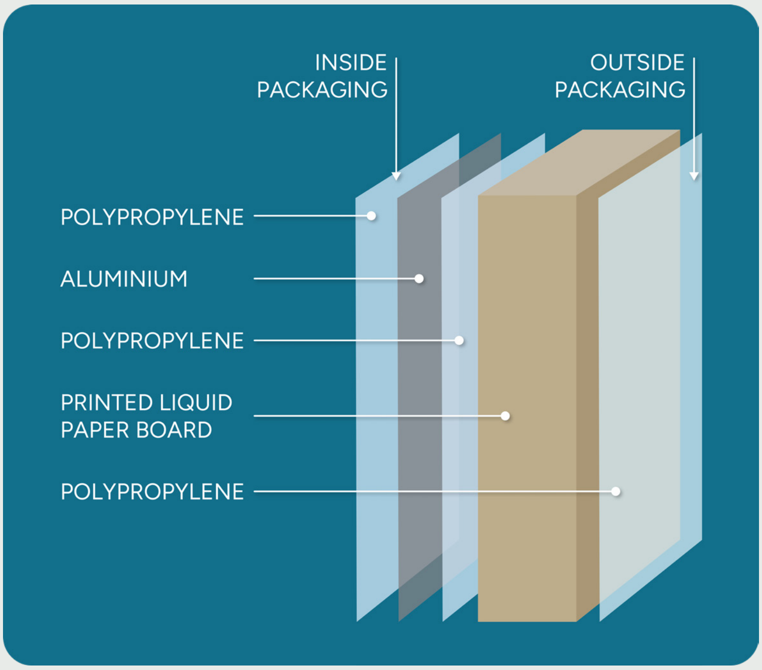


Table 21: Main pack components

	Unit		% of primary pack	% of total pack
Volume	ml	1000.00		
Primary pack composition				
liquid packaging board (incl.ash)	g	20.00	88.50	78.74
liquid packaging board	g	19.00	84.07	74.30
ash	g	1.00	4.42	3.94
fossil PP	g	1.20	5.31	4.72
aluminium foil	g	1.40	6.19	5.51
Total primary pack		22.60		88.98
Closure composition			% of closure	
fossil PE	g	2.80	100.00	11.02
Total closure	g	2.80		11.02
Total pack weight (primary pack + closure)		25.40		
Total PolyAl	g	5.40		21.26

Table 22: Compliance with Design for Recycling criteria

		Compatibility	Evidence
Compatibility with NIR sorting process	PP outer layer	Green category - fully compatible	
Fibres used in LPB	Sulfate kraft, bleached	Green category - fully compatible	
Recycling compatibility of wet strength agent used in LPB	Glyoxylated polyacrylamide	Green category - fully compatible	
Adhesives	Not used	Not applicable	
Printing inks/printing techniques	Offset print: oil-based ink ((vegetable	Green category - fully compatible	Ink not included in EuPIA Exclusion Policy
Straws and protective wrappers	Not used	Not applicable	
Lamination/barrier layers	PP: fossil-based	Green category - fully compatible	
Lamination/barrier layers	Aluminium foil	Green category - fully compatible	
Polymers used for caps and closures	Polyethylene cap	Green category - fully compatible	

Verdict: Fully compatible with LPC sorting and recycling processes

Example 4: Single-serve aseptic liquid packaging carton

A producer of single-serve orange juice (150 ml) has introduced paper straws with paper wrappers which are attached to the pack surface using a hotmelt glue with a high softening point temperature (> 68°C) and application area > 2 mm x 2 mm to ensure that its pack is compatible with LPC recyclability processes. The pack comprises LPB made from long fresh fibres and low ash content (3.36% of total pack weight) and wet strength additive together with a wet strength agent, glyoxylated polyacrylamide. The tensile index of the paper test samples was measured at 30 Nm/g. Vegetable oil-based ink which is not listed on the EuPIA Exclusion Policy was printed directly onto the LPB. The weights of the main components are shown in Table 23.

The producer is seeking to increase its brand recognition through the use of metallic effects which are to be achieved using vacuum metallized paper. An assessment of compliance with Design for Recycling criteria is shown in Table 24.

Table 23: Main pack components

	Unit		% of primary pack	% of total pack
Volume	ml	150.00		
Primary pack composition				
liquid packaging board (incl.ash)	g	3.00	75.76	67.26
liquid packaging board	g	2.85	71.97	63.90
ash	g	0.15	3.79	3.36
fossil PE	g	0.75	18.94	16.82
aluminium foil	g	0.21	5.30	4.71
Total primary pack	g	3.96		88.79
Paper straw	g	0.50		11.21
Total pack weight (primary pack + straw)		4.46		
Total PolyAl		0.96		21.52

Table 24: Compliance with Design for Recycling criteria

		COMPATIBILITY	EVIDENCE
Compatibility with NIR sorting process	Direct vacuum metallized paper	Yellow category - conditionally compatible	
Fibres used in LPB	Sulfate kraft, bleached	Green category - fully compatible	
Recycling compatibility of wet strength agent used in LPB	Glyoxylated polyacrylamide	Green category - fully compatible	
Adhesives	Insoluble hotmelt with high softening point (> 68°C), applied > 2 mm x 2 mm	Green category - fully compatible	
Printing inks/printing techniques	Offset print: oil-based ink ((vegetable	Green category - fully compatible	Ink not included in EuPIA Exclusion Policy
Straws and protective wrappers	Paper straws and wrapper	Green category - fully compatible	
Lamination/barrier layers	Polyethylene: fossil-based	Green category - fully compatible	
Lamination/barrier layers	Aluminium foil	Green category - fully compatible	
Polymers used for caps and closures	Not used	Not applicable	

Verdict:

Advisory: Carry out testing to verify that packs which carry direct vacuum metallized paper will sort correctly using NIR

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