CIRCULARITY BY DESIGN GUIDELINE FOR PAPER-BASED PACKAGING

VERSION 4

4ever green

Table of contents

Introduction

Paper-based packaging* designers, manufacturers, and recyclers are continuously striving to innovate and develop new products and technologies to actively drive the transition towards a more sustainable industry. The development of recyclable paper-based packaging plays a crucial and positive role in shaping Europe's climate-neutral future, as it maximises the potential for circularity within the sector.

Packaging needs to fulfil various functions, such as protecting the contents, communicating information about the product, representing a brand, and facilitating both, the storage and the transportation of the packed product.

Depending on the packaging and end use, different combinations of constituents and components in paper-based packaging can be utilised to achieve all of these performance criteria. The right combination of constituents and components in packaging allows for significant advantages, including longer shelf-life and increased protection against external damage. Thus, suitable packaging has the potential to reduce food losses and make a positive contribution to sustainability. It is important to highlight that the diverse range of paper-based packaging solutions necessitates different recycling processes to ensure optimal material recovery. Additionally, as the amount and types of paper-based packaging on the market are set to grow further, investments and innovative solutions will play a role in both maintaining and further increasing recycling rates across Europe.

This document, the Circularity by Design Guideline, has been developed by the 4evergreen alliance, involving paper, paper packaging, recycling, and sustainability experts from companies acting across the entire supply chain in the paper-based packaging industry. The publication aims to help packaging designers and industry experts design and specify paper-based packaging that is recyclable at scale as defined in The EU Packaging and Packaging Waste Regulation (PPWR); Regulation (EU) 2025/40.

Therefore, the primary purpose of the document is to explain how different constituents and components of paper-based packaging impact recycling processes and subsequent pulping reject recovery. The first version of the guideline document, issued in 2022 (PART I), indicated whether the different constituents and components can be classified as "fully compatible with the conventional recycling process", "limited compatibility with the conventional recycling process" or "not compatible with the conventional recycling process". The second edition, published one year later in 2023, was an extended version which addressed the compatibility of certain fibre-based composite packaging formats (such as liquid packaging carton and paper cups) with the recycling process in paper mills with specialised recycling process (PART III – LPC), explicitly applicable for mills that treat used liquid packaging carton waste.

The current version of the document further provides general recommendations for recycling of paper-based packaging in fibre-based composite packaging (FBCP) other than LPC mills and paper mills with flotation-deinking recycling process (PART II).

This Circularity by Design Guideline is based mainly on expert opinion. Evidence based on the recyclability results of a relevant Cepi test methodology is ongoing and a future version will be published once the relevant methodologies have been finalised and supporting testing completed.

Any paper-based packaging that is not suitable for one dedicated recycling process (i.e. Recyclability Evaluation Protocol (PART I)) could potentially be recycled in another type of mill. Thus, a negative recyclability evaluation for a dedicated process does not suggest that the packaging is not recyclable per se. The current version of the Circularity by Design Guideline document includes a decision tree (see Chapter 4 Decision Tree) to support designers in determining the relevant type of paper mill where their packaging could be recycled.

This decision tree will enable designers to apply the correct design tables (PART I or PART II or PART III) for assessing the compatibility of their paper-based packaging design with the particular recycling process and guide them to improve recyclability.

* 4evergreen uses the term 'paper-based packaging' to describe all packaging and packaging materials that are predominantly made of paper, including all composite packaging in which the predominant material is paper. For 4evergreen, the term 'paper' includes cellulosic fibres processed into sheets or webs of paper or cardboard, into corrugated board, and into moulded fibre products. For illustration, 'paper-based packaging' formats include - but are not limited to - boxes, trays, cups, flexible pouches, lids, cones, wrappers, as well as liquid packaging cartons.

Scope of this document

This design guideline provides recommendations for the design of paper-based packaging and it is recommended for all packaging designers along the entire value chain, from manufacturers to retailers.

This document addresses all types of paper-based packaging, but particular emphasis is placed on household and on-the-go consumer packaging. This guideline is intended to be applied in the EU, as it reflects the requirements of recycling technologies used in Europe.

For the duration of the alliance, 4evergreen will continue the ongoing dialogue with members and external stakeholders to review this and other guidelines regularly, amending them in response to changes in collection, sorting, and recycling technologies, as well as future material developments.

DISCLAIMER

Evaluation basis and test requirements
This document represents general recommendations on how to design better recyclable paper-based packaging. The given recommendations are based on the expertise and knowledge of the 4evergreen members. Final packaging designs following the principles laid out in the guideline should still be tested for actual recyclability, as the behaviour of paper-based packaging in the recycling process depends on specific constituents and integrated components, and the final composition of the converted packaging. The ultimate aim is to provide a comprehensive and fact-based guideline, for conventional, flotation-deinking and specialised processes. Therefore, certain recommendations mainly for which the compatibility with the recycling process is unknown will be verified with tests based on the Cepi recyclability laboratory test method, and the 4evergreen Recyclability Evaluation Protocol.

Applicability
This document is intended to support the design of paper-based packaging suitable for recycling using conventional, flotation-deinking, and specialised processes. The guideline is therefore applicable to paper-based packaging that is likely to be recycled in paper mills implementing the respective processes, provided that product-specific regulations for the packaging are observed. The given recommendations in 7.2 PART III are explicitly applicable for fibre-based composite packaging recycling in paper mills with specialised recycling process (LPC). Recommendations for paper mill with specialised recycling process (FBCP) processing other types of fibre-based composite packaging can be found in the section 7.3. Due to the lack of available information and the variations in specialised mill processes aligned to input material, 4evergreen has decided to focus on general guidance for this process and not to provide design recommendation tables.

Innovations and future versions
This guideline is intended to support the use of paper-based packaging through innovation and novel solutions by improving the environmental performance of packaging. The focus of the guideline is to ensure that the materials and packaging solutions placed on the market are designed for recycling. Packaging using novel constituents and integrated components requires testing to assess its compatibility with recycling processes. Future relevant innovations will be observed, evaluated, and assessed by 4evergreen and the guidelines will be updated in future versions of this document.

List of abbreviations

ABS	Acrylonitrile Butadiene Styrene
AKD	Alkyl Ketene Dimer
Alu	Aluminium
ASA	Alkenyl Succinic Anhydride
BOD	Biological Oxygen Demand
BOPP	Biaxially Oriented Polypropylene
Cepi	Confederation of European Paper Industry
CMC	Carboxymethyl Cellulose
COD	Chemical Oxygen Demand
DIN	German Institute for Standardisation (Deutsches Institut für Normung)
EB	Electro-Beam
EEA	Ethylene and Acrylic Acid
EPRC	European Paper Recycling Council
EuPIA	European Printing Ink Association
EVA	Ethylene Vinyl Acetate
EVOH	Ethylene-Vinyl-Alcohol
FBCP	Fibre-Based Composite Packaging
HDPE	High-Density Polyethylene
INGEDE	International Association of the Deinking Industry
ISO	International Organisation for Standardisation
LDPE/PE-LD	Low-Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
LPB	Liquid Packaging Board
LPC	Liquid Packaging Carton
mPET	Metallised Polyethylene Terephthalate
MG	Machine Glazed
NIR	Near-infrared
OBA	Optical Brightening Agents
OCC	Old Corrugated Container
OPP	Orientated Polypropylene
PA	Polyamide
PAE	Polyamide-epichlorohydrin
PCC	Precipitated Calcium Carbonate
PET	Polyethylene Terephthalate
PE	Polyethylene
PFA	Perfluoroalkoxy Alkanes
PLA	Polylactic Acid
PfR	Paper for Recycling
PP	Polypropylene
PolyAL Recycling	Recycling of the residual of polyolefins and aluminium
PPWR	Packaging and Packaging Waste Regulation
PS	Polystyrene
PVA	Polyvinyl Acetate
PVOH	Polyvinyl Alcohol
SB	Solvent-Based
SBB	Solid Bleached Board
SiOx	Silicon Oxide
UV	Ultraviolet
WB	Water-Based
w/w	Weight per Weight
WFD	Waste Framework Directive

GENERAL INFORMATION

1. REGULATORY BACKGROUND

The packaging industry is working to improve recycling processes and enhance sustainable packaging design to meet legal requirements (e.g. mandatory recycling targets) and improve the circular economy by closing the loop on material and production cycles.

The Circular Economy Package by the European Union (EU), which was published in July 2018, is a major driver of progress in environmental standards and actions. Among other things, the package led to modifications of several regulations concerning packaging, including Directive 94/62/EC, also known as the Packaging and Packaging Waste Directive (PPWD), and the EU Waste Framework Directive (Directive 2008/98/EC).

The PPWD laid down measures to prevent excess packaging waste generation, promote reuse and recycling of packaging.

As part of the European Green Deal and Circular Action Plan, the European Commission put forward a revision of the PPWD in November 2022, in the form of a regulation, the EU Packaging and Packaging Waste Regulation (PPWR); Regulation (EU) 2025/40. This legislation is directly binding and no adaptation to national law is necessary. Please see further explanation below Packaging and Packaging Waste Regulation.

The Table 1 below provides an overview of the European regulations concerning packaging and packaging waste.

Legislation	Reference	Content
Packaging and Packaging Waste Regulation	**Regulation (EU) 2025/40**	> Recyclability performances grades and design for recycling criteria from earliest 2030 for packaging > Mandatory use of post-consumer plastic recyclate > Waste and packaging minimisation; empty space ratio limits > Mandatory harmonised consumer sorting label for packaging and waste containers
Waste Framework Directive 2008/98 (WFD)	**Directive (EU) 2008/98**	> Definition of waste terms (recycling, waste, reuse) and waste hierarchy > Promotes separate collection and high-quality recycling
Amendment to WFD	**Directive (EU) 2018/851**	> Recycling target for municipal waste > Mandatory separate collection > Eco-modulation of extended producer fees
Single Use Plastic Directive	**Directive (EU) 2019/904**	> Definition of single use plastic products > Market restriction for certain single use plastic products > Labelling requirements for certain single use plastic products

Table 1. European packaging and waste regulations and directives

1.1 Packaging and Packaging Waste Regulation

The EU Commission put forward in November 2022 a proposal for a Packaging and Packaging Waste Regulation that would replace the existing Directive. Regulations have binding legal force throughout the Union and enter into force as applicable law on a set date in all the Member States, whereas Directives leave more decision power to Member States to decide how to transpose the rules nationally. The legislative change to a regulation includes a significant shift of accountability for certain obligations from Member States to economic operators for achieving compliance. The regulation entered into force beginning of 2025.

The distinguishing feature of the PPWR is the establishment of minimum packaging design criteria as prerequisites for accessing the EU market. This progress is driven by the mandate that all packaging has to be recyclable and recycled at scale to be accepted at the EU market.

The Regulation addresses various topics such as substances in packaging, recyclability, recycled plastic content, compostability, reusability, packaging efficiency, Extended Producer Responsibility (EPR) including eco-modulation of EPR fees, packaging restrictions, packaging reusability including deposit return systems, waste reduction and recycling targets for member states.

The PPWR emphasises the highest priority of the waste hierarchy, promoting waste prevention and reduction. Overall packaging waste prevention targets are implemented to reduce the packaging waste in comparison to 2018 by 5% by 2030, 10% by 2035 and 15% by 2040. The Regulation also requires minimising the packaging weight and volume as low as possible by 1 January 2030 while the safety and functionality of the packaging must continue to be guaranteed. Additionally, packaging not meeting the minimisation requirements such as use of double walls or double bottoms are not allowed to be placed on the market.

Moreover, for e-commerce, transportation and grouped packaging, the empty space must be reduced to the necessary minimum with an empty space ratio per packaging unit of 50%. PPWR also requires that a share of specific packaging types (e.g. transport and grouped packaging) are reusable within a system.

Packaging placed on the EU market must be recyclable as of earliest 2030 – a minimum of 24 months will be granted to industry upon availability of ‘design for recycling criteria’. As of 2035, packaging must also be ‘recycled at scale’, i.e. it must be effectively collected, sorted, and recycled in processes proven in an operational environment. The Commission is expected to draft delegated acts by 2028 and enforce this secondary legislation by early 2030. Criteria for design for recycling and recyclability performance grades will be developed based on ability of the packaging waste to be separated into different material streams for recycling and ensure that the resulting secondary material is of a sufficient quality to replace the primary raw material. The criteria will vary depending on the packaging materials and types (indicative list of packaging materials, types and categories found in Annex II Table 1 of PPWR).

Annex II of the Regulation mentions two indicative categories for paper-based packaging. Examples under its ‘category 2’ (paper/cardboard packaging) include boxes, trays, and flexible paper packaging. Examples under its ‘category 3’ (composite packaging of which the majority is paper/cardboard) include liquid packaging board and plastic laminate paper/cardboard.

For each category separate design for recycling criteria will be defined.

The differentiation between the legal definition of composite packaging and the definition in 4evergreen are explained in the part **“Terminology alignment and explanation (PPWR and 4evergreen)”**.

Furthermore, the design for recycling criteria and recyclability performance grades will be based on various criteria such as separability of components, efficiency of sorting (yield), but also on the presence of additives, labels, sleeves, closures, colours, coatings, product residues or ease of dismantling, according to Annex II Table 4 of PPWR. Further details on criteria will be defined by the EU Commission in delegated acts by 2028.

Accordingly, recyclability performance grades are as follows:

Recyclability performance grades	Assessment of recyclability per unit, in terms of weighting
Grade A	≥ 95 %
Grade B	≥ 80%
Grade C	≥ 70%
Technically non-recyclable	< 70%

Table 2. Recyclability performance grades

Packaging with Grade C can no longer be placed on the market from 2038. However, exemptions are provided for innovative packaging for a maximum of five years from 2030 and for special packaging (e.g. pharmaceutical and medicinal products) until 2035. Further secondary legislation will define the criteria and methodology, to calculate the recyclability of packaging, within the timeline of the delegated act on design for recycling and recyclability evaluation, expected no later than 2028, with the implementing act on recycling at scale scheduled for 2030.

The Regulation mandates a minimum percentage of post-consumer recycled plastic content for different types of packaging (Art. 7) depending on the type of packaging, with specific targets for 2030 and 2040. The regulation applies to any plastic part that accounts for more than 5% of the total weight of the entire packaging unit. For example, contact-sensitive packaging (such as for cosmetics or food) must contain at least 10% recyclate by 2030.

Reuse and refill targets (Art.11, Art. 29 and Art. 30) are also addressed in the Regulation whereby reusable packaging must be conceived, designed, and placed on the market with specific targets for packaging of beverages and for sales, grouped and transport packaging for transporting goods.

Eco-modulation of the Extended Producer Responsibility fees with harmonised criteria based on recyclability performance grades achieved through packaging recyclability evaluation will be required. Producers will be charged differentiated fees according to its recyclability, which will support upstream design changes to incentivise sustainably designed products.

In the EPR system, producers pay EPR fees to Producer Responsibility Organisation (PRO) based on packaging weight or number of units placed on the market, and the PRO uses the fees to collectively fulfil the responsibility placed on the producers to ensure packaging is collected, sorted and recycled.

It has been shown that specific packaging[1] are frequently disposed of with other waste products, resulting in contamination of the recycling stream. In accordance with legislation, the practice of composting should only be considered if the residual food content is too high for a meaningful recycling. In the case of paper-based packaging that has been severely contaminated, and which cannot be recovered in any significant quantity, composting can be a valid end of life option.

In accordance with Article 9 of PPWR, specific packaging types must be compatible with the composting standard for industrially controlled conditions. Member States may further demand that they be compatible with the standards for home composting or require other types of packaging, in addition to the above, to be compostable within their territory. It is crucial to note that only packaging categories specified in Article 9 or further required by Member States can be compostable. Apart from those, all other packaging types must adhere to the recyclability requirements outlined in the PPWR.

4evergreen advocates for material recycling of paper-based packaging and therefore, provides detailed design recommendations outlined in Chapters 5, 6, and 7.

* For further reading refer to: https://www.europarl.europa.eu/doceo/document/TA-9-2024-0318_EN.pdf (version 24.04.2024).

[1] Permeable tea, coffee, or other beverage bags, or soft after-use system single-serve units containing tea, coffee, or another beverage, and sticky labels attached to fruit and vegetables and intended for use and disposal with the product.

Terminology differentiation between PPWR and 4evergreen

Composite packaging

4evergreen's Circularity by Design Guideline is based on the guiding principle to assess the suitability of paper-based packaging for a recycling process (Part I – II – III), as the recyclability of packaging is linked to the value of the material present and its compatibility with the recycling process in the dedicated recycling mill.

With regard to composite packaging, PPWR defines: *'Composite packaging' means a unit of packaging made of two or more different materials, which are part of the weight of the main packaging material and cannot be separated manually and therefore form a single integral unit, unless a given material constitutes an insignificant part of the packaging unit and in no case more than 5% of the total mass of the packaging unit and excluding labels, varnishes, paints, inks, adhesives, lacquers.*

4evergreen does not include a threshold for the quantity of material in its definition for fibre-based composite packaging (FBCP), as follows:
Packaging composed of paper and a considerable share of non-paper integrated components, by design.

Considering recyclability of a packaging is linked to the value of the material present and its compatibility with the recycling process, a generic threshold is not to be equated with the recyclability of any packaging.

Thus, packaging that can be considered composite under PPWR can as well be recycled effectively in a paper mills with conventional recycling process, should it be designed for that mill type.

1.2 Food contact materials

The main target of 4evergreen, therefore, is to improve the design for recycling of on-the-go and household packaging. Food packaging represents a large part of this sector. Besides the above described legislation concerning recycling and circular design of materials, food packaging needs to fulfil safety requirements as parts of the packaging can be in direct contact with food.

The two most important Regulations concerning packaging material in direct contact with food are Regulation (EC) No 1935/2004 and Regulation (EC) No 2023/2006. They establish the framework for producing safe food packaging materials and defining the requirements for materials allowed on the EU market.

For additional information, please refer to the 'Food Contact Guideline for the compliance of Paper and Board' by Cepi, 2019.

2. DEFINING RECYCLABILITY IN THIS GUIDELINE

Recyclable packaging implies systems enabled for industrial-scale recycling. The exact scale of the activity in different countries and regions is better understood by examining the current collection, sorting and recycling technologies and systems being deployed. Generally, the recycling process seeks to deliver a safe, high quality and viable secondary material that meet the quality and safety standards to replace primary materials (also called 'virgin material'). Moreover, recycled fibres need to fulfil food-safety requirements if they are intended to substitute material for food packaging. Recycling in the sense of this Guideline does not include energy recovery.

The Circularity by Design Guideline includes recommendations that refer to the recyclability of paper-based packaging by classifying constituents and integrated components according to their compatibility with:

- Conventional recycling processes (PART I)
- Flotation-deinking recycling processes (PART II)
- Specialised recycling processes (PART III – LPC)
- Specialised recycling processes (PART III – FBCP)

The recommendations included in this document refer to conventional recycling processes (PART I), flotation-deinking recycling processes (Part II) and specialised recycling processes (PART III). The table below shows the definition by which constituents and integrated components are classified.

Fully compatible with dedicated process	Limited compatibility with dedicated process	Not compatible with dedicated process	Compatibility with dedicated process unknown
> compatible with sorting according to standard paper grades of EN 643 > no disturbing parts within the recycling process > expected positive output quality after recycling > **test results show good compatibility with dedicated recycling process**	> sorting not guaranteed in all cases > the efficiency of the recycling process is affected > **compromised output quality after recycling with dedicated recycling process**	> major issues during sorting and/or recycling > non-feasible output quality for further treatment after recycling > **test results show low or no compatibility with dedicated recycling process**	> based on current knowledge no clear guidance is possible > **testing is required to examine the recyclability of the packaging with dedicated recycling process**

Table 3. Description of compatibility with dedicated recycling process

NOTE: The evaluation of recyclability referring to different dedicated recycling processes (paper mills with conventional recycling process, paper mills with flotation-deinking recycling process or paper mills with specialised recycling process) can be different. **4evergreen's current testing and evaluation is expected to provide more detailed guidance in future.**

2.1 Pre-requisite for paper-based packaging

Definition of paper and paper-based packaging in this guideline

Paper consists mainly of natural fibres (both of primary and secondary fibre source) and typically contains other constituents such as filling materials, starch, different coating colorants including binders, as well as additives usually used in the paper industry, such as wet-strength agents, sizing agents and water.

These constituent parts may or may not contribute positively to the final recycling quality. The packaging designer should refer to the applicable design-for-recycling guidance. Broadly, however, the higher the fibre content the better the suitability for paper recycling.

Paper-based packaging material essentially means a product containing paper as per definition above, as well as other constituents such as printing inks, overprint varnish, adhesives (e.g. binding paper and plastic film), barrier layers, and other components (e.g. tapes, labels, caps and closures).

The paper content calculation effectively assesses the packaging material's paper content and is derived from the Paper weight/Paper-based packaging material weight*100%.

In this guideline, the paper content of the packaging should therefore be at least 50% to be classified as paper-based packaging.

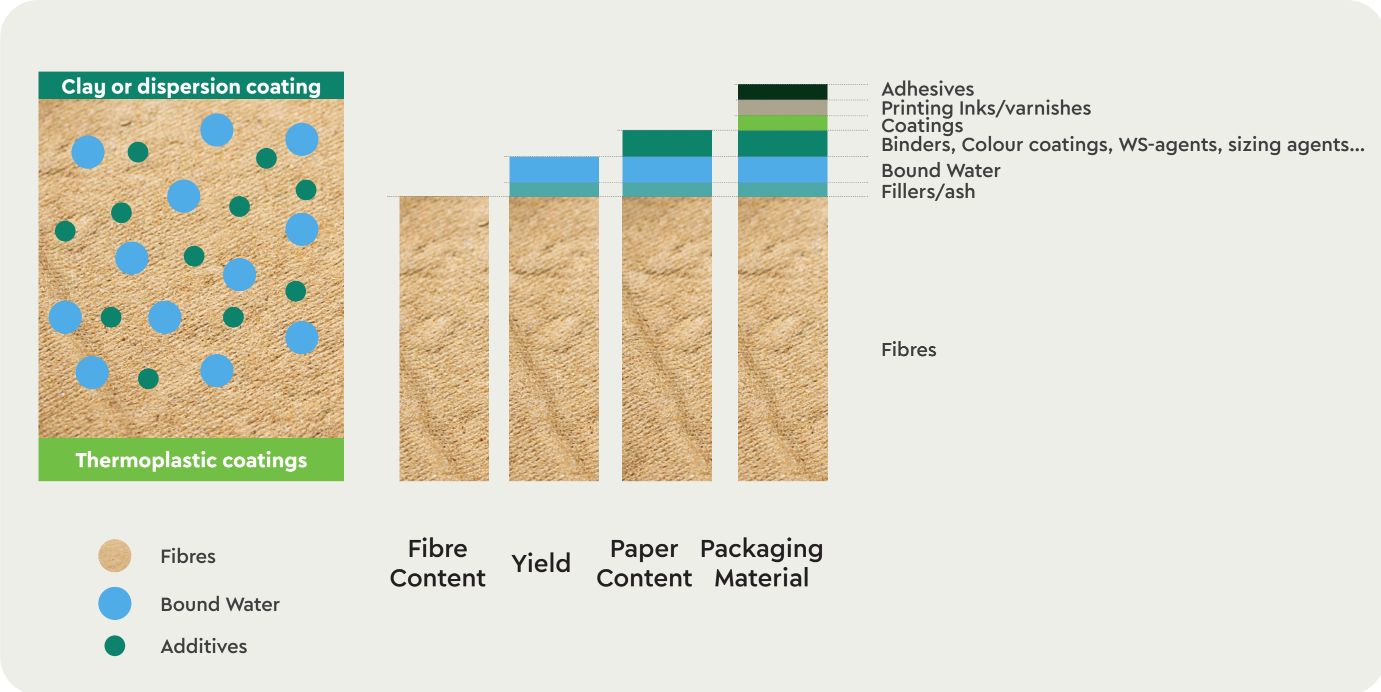


Figure 1. Distinction of fibre content, yield, paper content and packaging material

Constituents and integrated components to avoid in paper-based packaging

The presence of certain constituents and integrated components may lead to adverse effects across all types of packaging.

Therefore, it is essential to avoid any sources of toxic (including toxic to reproduction), mutagenic, carcinogenic, or endocrine-disrupting chemicals in any constituent or component.

2.2 Recyclability definitions

Design for recycling

Design for recycling means that the packaging can be collected, sorted, and recycled with state-of-the-art technologies. Recyclability by design encourages the development of infrastructure (when not at scale) by making higher quality waste available.

If the packaging under consideration complies with this guideline, it is considered designed for recycling. If not, it can still be proven recyclable with the Cepi recyclability laboratory test method and the 4evergreen Recyclability Evaluation Protocol.

Packaging can be classified as recyclable at scale if:

- The material used is collected by specific national or regional collection systems.*
- Sorting technologies for the packaging exist.*
- Processing technologies for the (material) recycling process exist.*
- There is market potential for the resulting secondary raw materials and their substitution for virgin material.

PPWR defines recycled at scale as packaging waste which is separately collected, sorted and recycled in installed infrastructure, using established processes proven in an operational environment which ensure at EU level (Art. 3 (39)) an annual quantity of recycled material under each packaging category, equal or greater than 30% for wood and 55% for all other materials This includes such packaging waste exported from the Union for the purpose of waste management which can be considered as meeting the requirements of Article 53(11).

Currently, there is no harmonised European-wide method for the calculation of the recyclability under the PPWR.

As described in the sub-chapter 1.1 Packaging and Packaging Waste Regulation the EU-Commission intends to adopt secondary legislation (delegated acts) in which a harmonised recyclability calculation method will be embodied.

* Sufficient capacity is available

RECYCLING INFORMATION AND DESIGN RECOMMEN-DATIONS

3. RECYCLING PROCESSES FOR PAPER-BASED PACKAGING

Recycling of paper-based packaging enables certain environmental benefits. Depending on the requirements of the actual packaging applications, recycled fibres can be used in combination with or to replace virgin fibres. However, recycled fibres and virgin fibres are not two separate streams but are interconnected and interdependent. With every papermaking (re)cycle, the fibres gradually deteriorate until they may be rejected during preparatory pulp-cleaning process. According to several studies (Kreplin, Schabel and Putz, 2019 and Eckhart, 2021), thanks to low losses during recycling, fibres from corrugated boxes can be recycled 25 times without experiencing signs of a "recycling collapse". Depending on the specific paper-based product/fibre type and the corresponding recycling processes and losses during recycling, the average number of cycles can be lower. Introducing virgin fibres helps to maintain pulp volume, quality and mechanical properties.

Recycling processes in paper mills

When reprocessing paper-based packaging, the process needs to be carefully set up and calibrated to handle the different constituents and integrated components added during the packaging conversion process. Recycling facilities (paper mills) for paper-based packaging diverge from each other in how they handle different types of paper-based packaging.

Common to all types of paper packaging recycling is a pulping stage which disintegrates the paper and board structure into individual fibres, and several cleaning and screening stages.

a) Paper mills with conventional recycling process typically treat old corrugated containers (OCC) and/or mixed paper and mainly remove non-paper integrated components and foreign parts. The output is a brownish pulp.

b) Paper mills with flotation-deinking recycling process have similar pulping, cleaning and screening stages but additionally remove the ink. The inputs are paper and board products on white or off-white substrates. The output is a white or off-white pulp.

c) Paper mills with specialised recycling process use further process steps or different conditions that are not part of the setup of paper mills with conventional recycling process, to recycle fibre-based composite packaging. One well-established recycling method used for liquid packaging cartons (typically with two-sided lamination) requires enhanced pulping action and a process step to prepare the non-fibre fraction for recycling at a PolyAl recycler. Similar processes can be adapted and optimised for wet-strength products and those with high non-paper content, they will have a different repulping time and energy consumption.

The suitability of specific recycling processes can be evaluated using the Cepi recyclability laboratory test method and the corresponding 4evergreen Recyclability Evaluation Protocols listed in Table 4.

Part	Scope	Release
Part I	Paper mill with conventional recycling process	Q4, 2022. Updated version in Q1, 2025.
Part II	Paper mill with flotation-deinking recycling process	Q2, 2025
Part III	Paper mills with specialised recycling process	Q1, 2025

Table 4. 4evergreen Recyclability Evaluation Protocol

4. DECISION TREE

The compatibility of paper-based packaging with the recycling process depends on the type of process in which it is to be recycled. Certain packaging may not be recyclable in one of these processes but could be easily recycled in another.

National collection and sorting infrastructure alongside the potential for exporting packaging to countries where it can be recycled can determine the designation of paper for recycling to different types of processes. Therefore, it is highly relevant to examine which infrastructure conditions apply to the distribution market of the packaging. The following decision tree is intended to help users of this guideline to choose the most relevant design table for their packaging (on the basis in which type of recycling process the designed or planned packaging can be expected to be processed). It is important to note that this graphic may not encompass all types of paper-based packaging and should be viewed as recommended rather than a strict protocol.

Furthermore, the decision tree in itself does not constitute a recyclability statement; rather, it simply establishes whether a packaging is eligible for further assessment, and if so, in which type of processes and guidance to be followed.

In addition, a useful source is the guidance on the improved collection and sorting of paper-based packaging for recycling published by 4evergreen in December 2023, which includes more detailed information on sorting and collection of paper-based packaging.

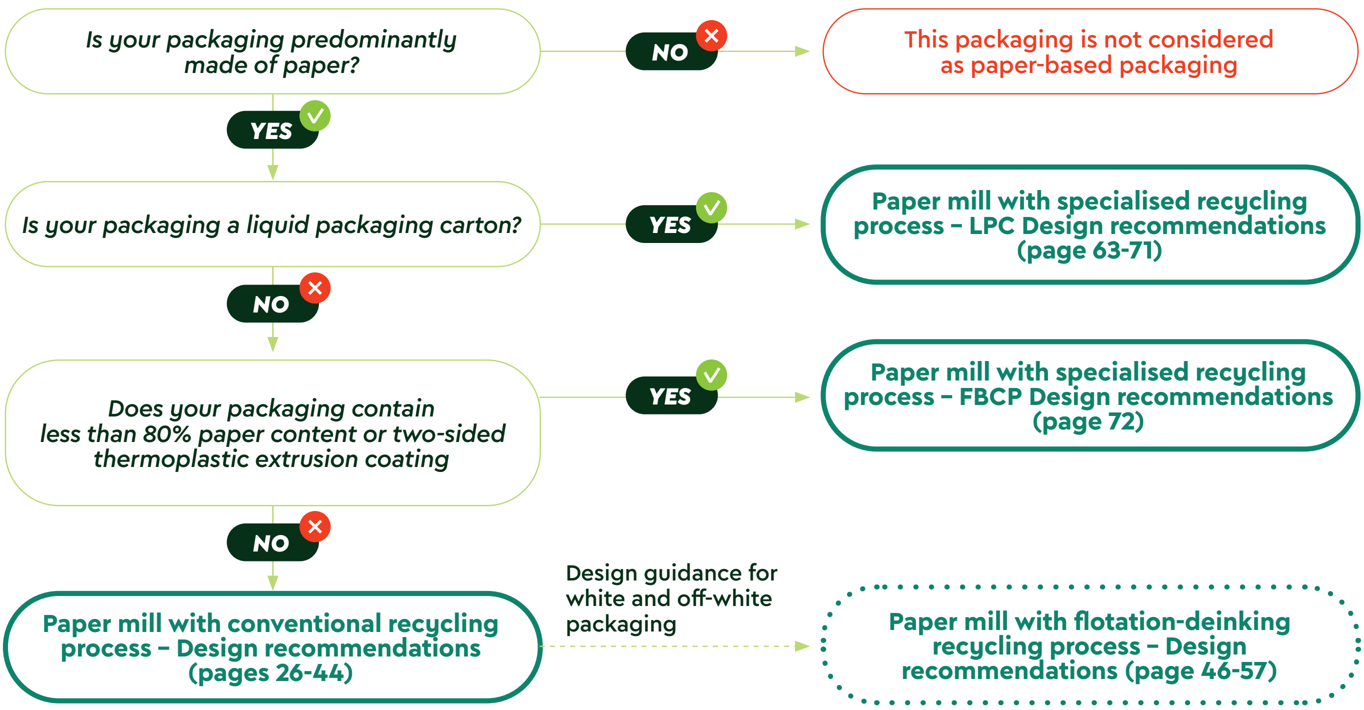


Figure 2. Decision tree

1| Paper consists mainly of natural fibres (both primary and secondary) and typically contains other ingredients such as filling materials, starch, different coating colorants including binders, as well as additives usually used in the paper industry, such as wet-strength agents, sizing agents, and water (Figure 1, p.16).

Nonetheless, greater paper content makes paper-based packaging more suitable for recycling. Consequently, the paper should be the predominant material in packaging to be considered as paper-based packaging[2] in this guideline.

2| Liquid packaging cartons are suitable for specialised mill processes (mills using these processes for food and beverage cartons are established across the EU). The term "beverage carton" does not fully reflect the range of filled products and can be misleading because these package formats also contain non-beverage products, such as tomato paste, therefore the term "liquid packaging carton" is used.

For such packaging, the relevant PolyAl DfR guidelines[3] must also be considered to ensure compatibility with the established subsequent recycling processes. To assess the recycling compatibility of composite paper/cardboard packaging with a material structure and composition corresponding to liquid packaging cartons (LPC), consult the LPC design guidance tables (see Chapter 7). Acceptance criteria include that the packaging: i) can be identified as LPC in NIR-sorting (PE or PP outer layer in combination with paperboard); ii) is made of paperboard corresponding to liquid packaging board (LPB) with barrier coatings predominantly made of polyolefins, with or without aluminium; and iii) is not used for the containment of hazardous substances or mixtures.

3| Based on 4evergreen Recyclability Evaluation Protocol, packaging should achieve a minimum Total Screening Yield (TSY) of 80% to proceed to further assessment under the conventional process. It is important to note, however, that TSY is not the sole criterion; other quantitative and qualitative metrics are also considered within the protocol that can disqualify the packaging. When reject levels cause the TSY to fall below 80%, the Technical Recyclability Score (TRS) drops below zero, resulting in a negative overall score. In such cases, the packaging is deemed not recyclable in paper mills with conventional recycling process. Consequently, the minimum paper content for designing packaging according to paper mill with conventional recycling process design tables is set at 80%, since packaging with less than 80% paper content would theoretically fail the evaluation protocol unless otherwise is proven for innovative structures.

At the same time, many composite paper packaging with relatively high paper content (80–95%) are currently processed in paper mills with conventional recycling process across the EU. It is therefore critical that these be better designed for recycling to ensure compatibility with this process. By contrast, packaging with less than 80% paper content, unless classified as a liquid packaging carton, should instead be designed for recycling in papers mill with specialised recycling process (FBCP).

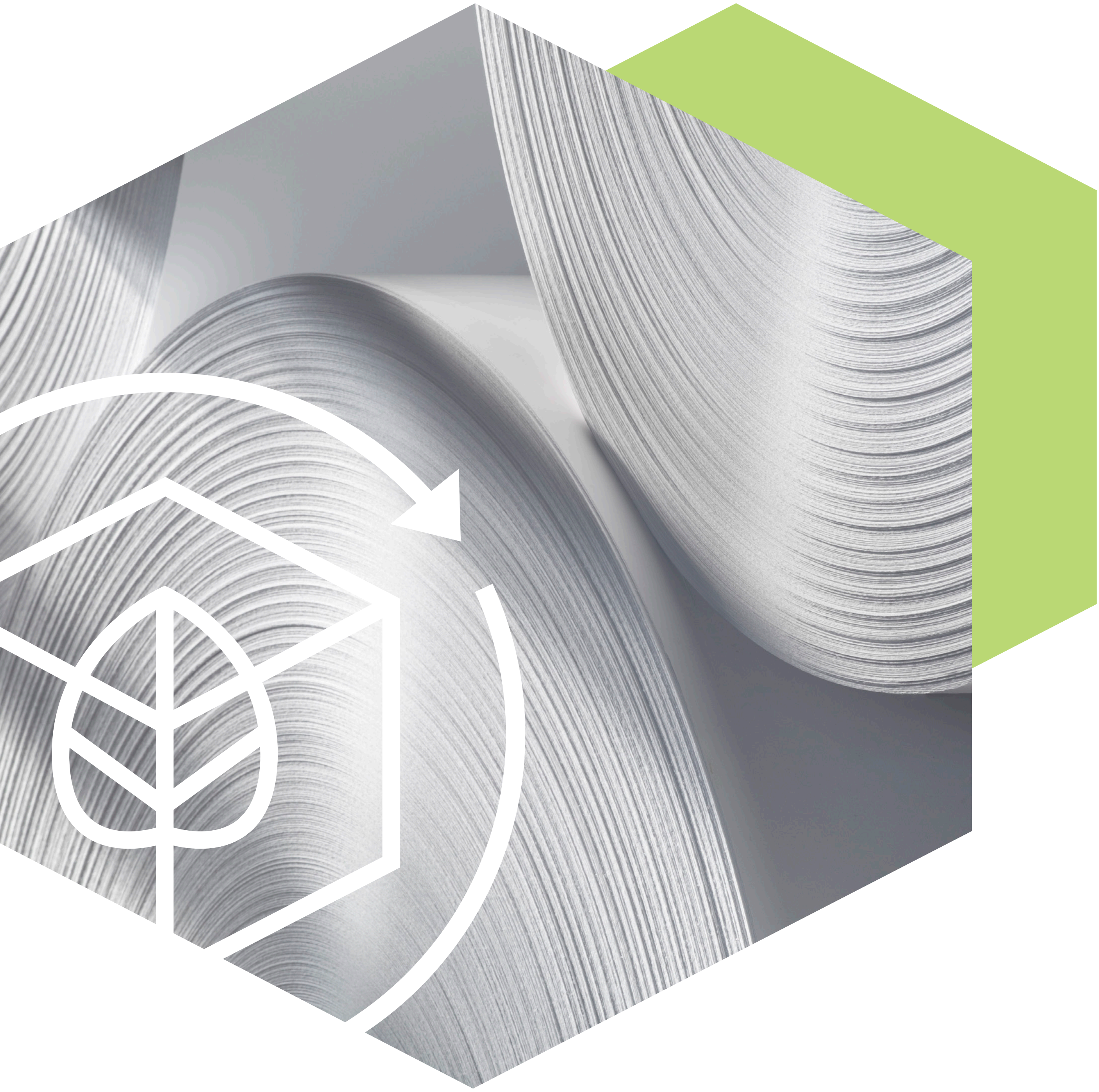
4| Thermoplastic extrusion coating on two sides of the paper packaging requires more repulping time and is a common form of coating. For paper mills with conventional recycling process, it is deemed unsuitable (Table 5). Referring to the particular coating is preferable to using terms such as "two-side coated" which do not reflect the individual structure of the packaging (solid or corrugated) nor the type of coating (mineral or pigment) involved. As newer coatings enabling easier repulping are available on the market, the term "two-side plastic coated" is also obsolete because it does not reflect state-of-the-art recycling and coating technologies.

---

[2] 'Composite packaging' means a unit of packaging made of two or more different materials which are part of the weight of the main packaging material and cannot be separated manually and therefore form a single integral unit, unless one of the materials constitutes an insignificant part of the packaging unit and in any event no more than 5 % of the total mass of the packaging unit and excluding labels, varnishes, paints, inks, adhesives and lacquers; this is without prejudice to Directive (EU) 2019/904; It is important to clarify that the de-facto 5% threshold is neither an ultimate recyclability metric nor a basis for Design for Recycling.

[3] Design for Recycling Guidelines, FBCA

5. PART I — PAPER MILLS WITH CONVENTIONAL RECYCLING PROCESS



5.1 Recycling in paper mills with conventional recycling process

Most paper mills with conventional recycling process typically utilise the EN 643 grades group 1-4. The paper-based packaging recycling process typically includes the following steps:

Repulping

The purpose of pulping is to disintegrate the paper and separate fibres from other materials contained in constituents and integrated components. In this step, the paper for recycling is blended with water, the temperature is typically around 40°C and the pH value is typically close to 7 (usually not regulated) by addition of acids or alkaline). Paper mills with conventional recycling process typically have a low-consistency pulper (<5% fibre concentration). The aim of this first step is to disintegrate and separate fibres from other materials.

Coarse and fine screening

Screening is the process of removing impurities from the pulp and separating the fibres from contaminants. It is based on particle size and shape differences between fibre and non-fibre constituents and integrated components or non-fully dispersed fibre flakes. It can be divided into coarse and fine screening. Coarse screening (often combined with de-flaking) is performed after the pulping step at a medium concentration (2.5-4.0%). The fibre suspension flows through screening holes where large contaminants are retained (holes and slots typically ranging from 2 to 10mm) while fibres can flow through freely. The objective of the fine screening is to remove smaller-sized particles (e.g. adhesives, smaller particles) from the stock. Fine screening is generally done at medium or low concentration (1-2.5%) through slotted baskets (typical slot size 0.15-0.4mm). Screening is often operated in cascaded systems, and paper mills with conventional recycling process may have one or more steps of coarse and fine screening in accordance with the process efficiency and target quality of recycled paper.

Cleaning

After pulping, the fibre slurry can be fed into hydrocyclones to separate impurities that have different densities from fibres. In general, paper mills with conventional recycling process have higher concentration (3-4%) hydro-cyclones to separate the bigger, heavier contaminants such as staples and small stones. Heavy contaminants of a smaller size (e.g. sand) are taken out by low-concentration hydro-cyclones (0.5-1.5%). In many cases the low-density debris (e.g. expanded polystyrene) are also separated in these hydro-cyclones.

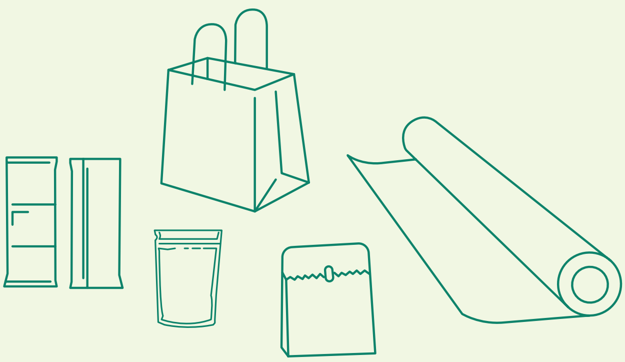
Papermaking

After the screening and cleaning steps, the recovered pulp is mixed with additives to form a papermaking furnish which is fed into a paper machine to produce recycled paper.

Packaging examples likely to be recycled in paper mills with conventional recycling process

Rigid paper packaging

- ✓ boxes, folding cartons, paper tubes, corrugated boxes, single-side coated paper cups, etc.
- ✓ with minimal or no proportions of non-paper material
- ✓ not printed or using inks non-compliant with EUPIA exclusion policy



Flexible paper packaging

- ✓ paper shopping bags, wrappers, sheets, pouches, etc.
- ✓ with minimal or no proportions of non-paper material
- ✓ not printed or using inks non-compliant with EUPIA exclusion policy

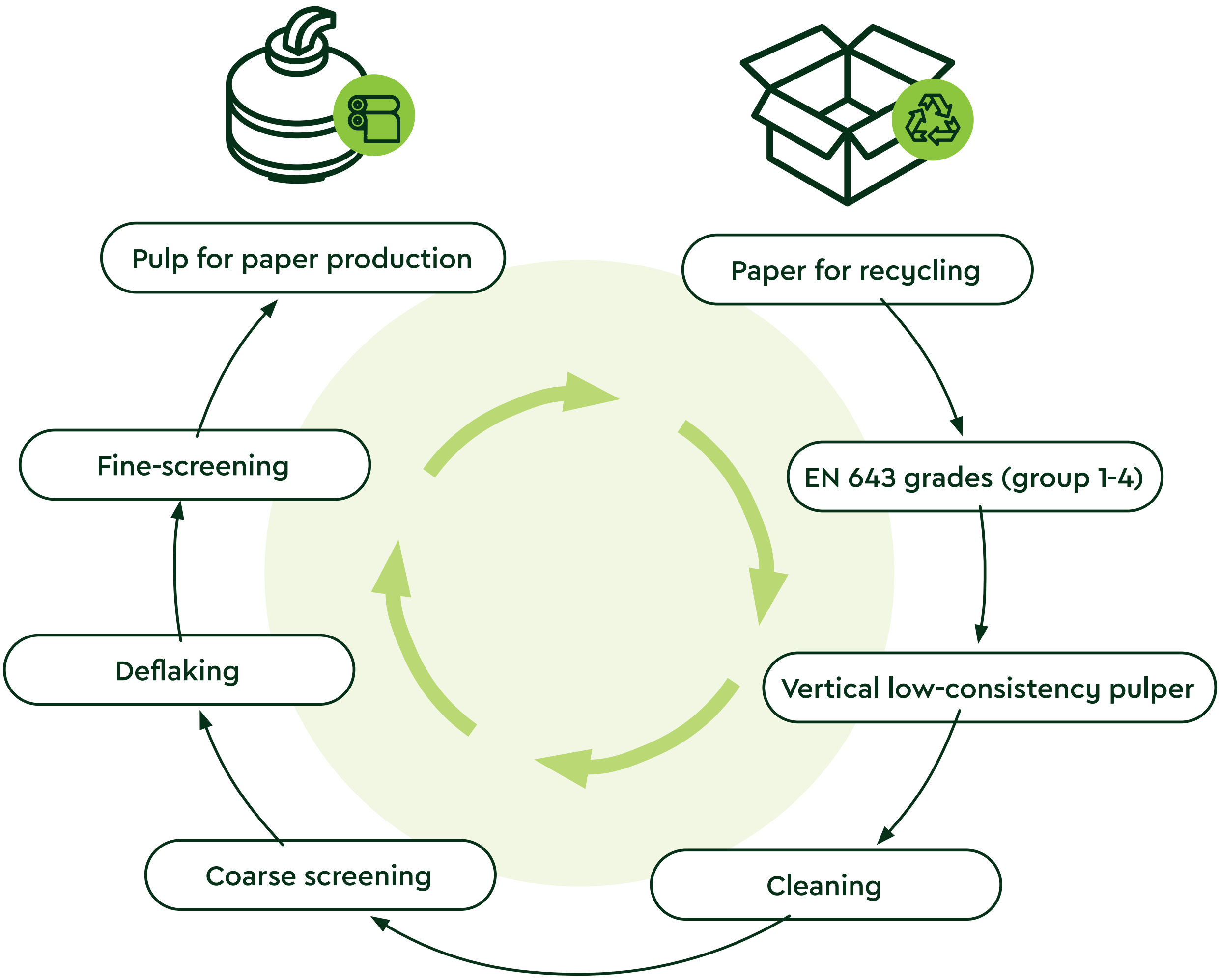


Figure 3. Recycling in paper mills with conventional recycling process

5.2 Design recommendations (PART I)

The sustainability and circularity of paper-based packaging is improved by increasing recycling rates. The design recommendations given in this chapter serve as guidance for choosing suitable constituents and integrated components for paper-based packaging and processes to assure the quality of the recycled fibre.

The key is to explain why and how different constituents and integrated components affect the recycling process. Following a "design for recycling" approach helps packaging designers learn which constituents and integrated components might have a negative impact on the recycling process, already in the design phase of packaging.

This guideline provides specific design recommendations for certain packaging constituent and integrated component groups, to help designers refine their designs. The recommendations are presented in a compact design table, for the following constituents and integrated components, and their compatibility with the conventional recycling process:

- 5.2.1 Fillers, additives, and agents
- 5.2.2 Barrier coatings and treatments
- 5.2.3 Adhesives
- 5.2.4 Inks and varnishes
- 5.2.5 Decorative metallic constituents and integrated components
- 5.2.6 Other integrated components

The guideline also gives some more general advice on designing packaging to minimise the residual product content in packaging.

The design tables in chapter 5.2 refer to single constituents or integrated components categorised as:

- Fully compatible with the conventional recycling process
- Limited compatibility with the conventional recycling process
- Not compatible with the conventional recycling process
- Compatibility with the conventional recycling process unknown

NOTE: The given design recommendations are widely based on the expert opinion of the entire value chain represented in 4evergreen, and are valid for recycling in paper mills with conventional recycling process. Actual testing prevails over the given recommendations in the guideline; therefore the guideline will be updated in line with recyclability lab test results and the corresponding 4evergreen Recyclability Evaluation Protocol (PART I).

5.2.1 Fillers, additives and agents

Paper and board used in paper-based packaging mainly consists of virgin materials from wood pulp and fibres extracted from paper recycling. A certain amount of so-called "processing and functional" chemicals used to achieve different specifications are also present. Some paper (mainly Paper for Recycling, PfR) can contain mineral-based additives like fillers or pigments such as calcium carbonate or clay. Other chemical additives are used as sizing agents, strengthening additives, binders, and other functional additives. The design table below provides a compact overview of fillers, additives and agents used in paper production, and their compatibility with the conventional recycling process.

NOTE: The given design recommendations are based on expert opinion, and valid for recycling in paper mills with conventional recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents and integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Conventional recycling process (Part I)

Constituent or integrated component		Fully compatible with conventional recycling process	Limited compatibility with conventional recycling process	Not compatible with conventional recycling process	Compatibility with conventional recycling process unknown	Comment
Filler/ inorganic pigments	Clay (kaolin)	⊗				High ash content may have a negative impact on mechanical strength depending on the relative amount in the paper for recycling stream.
	CaCO3	⊗				
	Talc	⊗				
	Titanium dioxide	⊗				
Binder	S/B latex	⊗				
	S/A latex	⊗				Depending on amount, adhesive strength, etc.
	Starch-biobinder	⊗				
Sizing, wet end	AKD	⊗				
	ASA	⊗				
	Rosin	⊗				
Dry strength	Starch	⊗				
	CMC	⊗				
	Polyacrylamide	⊗				
	Guar gum	⊗				
Wet strength	PAE		⊗			Recyclability depends on several factors, such as relative wet-strength (WS) level, amount of WS agent, etc. Repulpability can be improved by increased pulping temperature and time, chemicals, high consistency pulping, etc.
	Urea/ formaldehyde				⊗	Recyclability depends on a number of factors such as relative wet strength level, amount of WS agent etc. Repulpability can be improved by e.g. increased pulping temperature and time, chemicals, high consistency pulping etc.
	Urea/melamine				⊗	
	Glyoxylated polyacrylamide (GPAM)	⊗				
	Polyvinylamine (PVAm)	⊗				
Sizing, surface	Starch	⊗				

Conventional recycling process (Part I)

Constituent or integrated component		Fully compatible with conventional recycling process	Limited compatibility with conventional recycling process	Not compatible with conventional recycling process	Compatibility with conventional recycling process unknown	Comment
Others	Colorants/dye for shading	⊗				Physically recyclable but certain dyes are not approved for food packaging applications and such dyes should be avoided.
	Colorants/ pigments	⊗				
	Polyvinyl alcohol	⊗				
	PAC	⊗				
	Retention polymers	⊗				
	Siliconising agents			⊗		Used, for example, in release papers for labels. Siliconised papers can be recycled in paper mills with specialised recycling processes yielding high value fibres.

Table 5. PART I – Design recommendations additives, fillers and agents

5.2.1.1 Fillers, additives and agents used in paper-based packaging

Retention agents
Retention agents are those added in the wet-end of the paper machine that improve the retention of fine fibre particles, fillers and other additives, while increasing the "runability" of the paper machine. They are not intended to have any impact on the paper and board properties.

Fillers
Fillers are used to improve the optical properties, such as opacity, printability and brightness, but can also be used as volume filler in terms of hydrous kaolin (Gliese and Kleemann, 2013; McLain and Ingle, 2009). However, there are normally processes, additives and equipment in place to reduce potential strength-loss effects, e.g. screening and chemicals can be used to compensate for the strength loss.

OBAs and colorants
Optical brightening agents (OBA) absorb and emit light in the visible spectrum, which makes paper appear whiter (Gliese and Kleeman, 2013). Soluble colourants (dyes) can also be used to give paper a certain shade and colour effect. Colourants for light shading and OBAs do not have any significant negative effect on the technical recyclability, but their fitness for use in food packaging needs to be reviewed in light of the prevailing regulations and research.

Dry strength additives
Various strength additives are added to paper and board to improve the mechanical properties of the paper in its dry state such as tensile, burst and compression strength.

Wet-strength agents
Wet-strength agents are used to enhance the strength of paper and board in wet/humid conditions. Technically, a distinction needs to be made between temporary and permanent wet-strength agents. Temporary wet-strength paper loses some of its strength after a certain period in wet conditions. Permanent wet-strength paper retains its strength over time.

Sizing agents
Sizing agents are used to give temporary hydrophobic properties to the fibres resulting in an even and controlled absorption of liquids. This is important for further converting processes such as printing and barrier coating. Sizing can have short-term positive effects on the water resistance of the paper as it decreases/delays water absorbing into the fibre structure.

Grease resistance agents
For grease resistant/greaseproof paper and board a barrier or treatment can be applied to allow greasy, fatty and oily food to be packed in direct contact with paper. Common chemicals used as surface treatment for greaseproof paper are starch and carboxymethyl cellulose (CMC) which can be applied at the wet-end of the paper machine.

Silicone treatment agents

For siliconised paper there are two main types of silicone treatment on the market; glassine paper which is "super-calendered" and "uncalendered" types like clay coated or machine-glazed (MG) paper. The silicone used for these paper types is present as a solid and insoluble with high thermal stability. Siliconised paper is used as "release paper" and also for grease-proofing.

Binders in dispersion coatings

Binders are usually used in pigment dispersion coatings applied in the papermaking process, as they bind pigments together and fix them on the base paper. The binders ensure that the coating withstands the stress during production, converting, and use. Commonly used materials are latex, starch, polyvinyl alcohol, and carboxymethyl cellulose (CMC) (Sangl, 2013).

Pigments in dispersion coatings

Pigments are often used in coatings and should meet further treatment and printing process requirements. The use of dispersion pigment coatings improves the optical properties, such as opacity and brightness, as well as the printability of paper and board (Gliese and Kleemann, 2013).

5.2.1.2 Effect on the recycling process and general recommendation for recyclable design

The combination of paper and board with fillers and chemical additives must be implemented in a way that does not hamper recycling while ensuring that the expected functionality of packaging is fulfilled.

Most fillers, additives, and agents are fully compatible with existing recycling technologies, but outside that, the key is to give preference to packaging materials that do not limit future or end uses of the recycled fibre. This means, they don't contain substances considered by the EU's REACH regulation to be of "very high concern", for example, rendering them unsuitable for food contact, and/ or accumulating over several cycles.

Use only the required quantity of wet-strength agents to fulfil the expected functions of the packaging. Consider replacing fluorochemicals with greener alternatives. Use special paper and board treatments only for applications where such functionality is absolutely necessary. That way, it increases the probability that conventional recycling paper processes can still be used.

For paper-based packaging constituents and integrated components that have no (or low) compatibility with conventional processes, there are potentially EN 643 grades defined (grades 5 XX), which enable recycling in paper mills with specialised recycling processes with dedicated processing setups.

5.2.2 Barrier coatings and polymer content

Paper-based packaging including paper and paperboard do not have intrinsic barrier properties. Barriers are required to provide adequate protection to food and non-food goods from external factors, such as moisture caused by high relative humidity, oxidation, contamination introduced through mineral oils, and other substances that can also be hazardous under certain circumstances. To ensure an appropriate level of protection, minimising food loss and ensuring the safety of the packed product, paper-based packaging is "functionalised" – which means treatments like coatings and lamination (polymeric barrier layers) are applied. Typical examples include but are not limited to polyethylene (PE) extrusion coating, polyester (PET) and metallised polyester (mPET), adhesive lamination, and dispersion coating (using different polymers and formulated latexes).

The following design table aims to give a compact overview of typical barrier coatings and treatments used in industry and their compatibility with conventional recycling processes.

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with conventional recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and types of the constituents or integrated components; thus, the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Conventional recycling process (Part I)

Constituent or integrated component		Fully compatible with conventional recycling process	Limited compatibility with conventional recycling process	Not compatible with conventional recycling process	Compatibility with conventional recycling process unknown	Comment
Extrusion barrier coating	**Thermoplastic (one side coated, inside the pack only)**	⊗	⊗			The outside lamination will predominantly affect the sorting process (as it is detected by NIR), in very few cases is the inside lamination detected by NIR. The method is considered fully or limited compatibility with recycling, until further information from the Cepi recyclability laboratory test method is available.
	Thermoplastics (two sides coated)			⊗		This is considered as not compatible with the conventional recycling process until further information from Cepi recyclability laboratory test method is available. It can only be recycled in paper mills with specialised recycling processes and with a dedicated pulper.
Adhesive barrier film	**Adhesive lamination with water-soluble adhesives (among others some types of PVOH, starch, etc.)**	⊗				Needs thorough cleaning in the milling to prevent issues like foam forming. The COD load will be higher for soluble polymers.
	Adhesive lamination (inside of pack) of PET, mPET, PET/PE etc.		⊗			This is more challenging than extrusion barrier solutions: the polymer will penetrate more deeply into the fibre and have an effect on fibre yield. The thickness and strength of the lamination foil are difficult to ascertain; some adhesives tend to increase the potential of stickies.
	Lamination with Alu containing film (6 micron +) (Alu/PE or PET/Alu/PE) etc.		⊗			Alu may impact on induction-based flowmeters and lead to metal being detected in the finished product.
	Lamination that is designed to be peeled easily by consumer	⊗				Considered to have no impact on recycling if separated by consumer, though not the same as one-sided extrusion coating.
Wet-barrier coatings	**Aqueous polymer dispersions (among others some types of acrylics, EEA, SB, ABS, PVDC, etc.)**	⊗	⊗			Testing required, as properties of polymer dispersion coatings depend on the amount and strength of the polymeric binder and the presence of fillers.
	Solvent-based coatings	⊗	⊗			Testing required.
	Wax dispersion (incl. microcrystalline waxes)		⊗			This is expected to have a potential impact on stickies.
	Water soluble coatings (among others some types of PVOH, EVOH EVA Biobased, etc.)	⊗	⊗			High amounts demand thorough cleaning in milling to prevent issues like foam forming. The COD load will be higher for soluble polymers.

Conventional recycling process (Part I)

Constituent or integrated component		Fully compatible with conventional recycling process	Limited compatibility with conventional recycling process	Not compatible with conventional recycling process	Compatibility with conventional recycling process unknown	Comment
Wax coatings	Dipping of paper in molten wax (two sided)		⊗			May impact on stickiness and cause screen clogging.
Barrier metallisa-tion	Direct metallisation (Primer, Alu nanoscale, Protective coating) – inside		⊗			May have a "stardust" effect in visual appearance, plus potential stickiness issues and yield impact, which depends also on the overall amount (testing required).
	Transfer metallisation (adhesive + transfer metallisation) – inside		⊗			May have a "stardust" effect in visual appearance, potential stickiness issues and yield impact, which depends also on the overall amount (testing required).

Table 6. PART I – Design recommendations barrier coatings and polymer content

5.2.2.1 Barrier applications used in paper-based packaging

There is no widely adopted or standardised classification of polymeric treatments, coatings, and laminations used to create barrier properties on paper, thus the classification below has been put forward and validated by experts acting in 4evergreen:

- Extrusion barrier coatings
- Adhesive barrier film lamination
- Wet (water-based and solvent-based dispersions and solutions) polymeric coatings
- Wax coatings
- Barrier metallisation treatments
- Fluorinated barrier/repellent coatings (not a polymer per se, but allocated to this group on the basis of their function)

These coatings can be applied in line with the papermaking process using blade, rod, curtain, or similar applications, offline at the paper mill using dedicated coating assets, or offline using typical converting equipment and processes such as extruders, gravure coating, lamination, etc.

Extrusion and co-extrusion barrier coatings

Extrusion is the process of applying molten polymer (LDPE, LLDPE, PLA, etc.) or polymers (PE-EVOH-PE, etc.) to paper or paperboard where adhesion between two layers is achieved via mechanical interlocking and the formation of hydrogen and covalent bonds between polymer and cellulosic fibres. The typical thickness of the polymeric layer, as applied, ranges from 8 to 40 microns.

Extrusion coatings in this guideline are classified as follows:

- One-sided thermoplastic film extrusion coating of paper and board
- Two-sided thermoplastic film extrusion coating of paper and board
- Water-soluble extruded coatings (among others some types of PVOH, EVOH, EVA, Biobased, etc.)

Adhesive lamination with barrier films

Paper and board can be laminated with blown or cast polymeric films such as PET, OPP, Cellophane, etc. using water-based, solvent-based, or solventless adhesives, such as polyurethane, polyvinyl alcohol, polyvinyl acetate, and ethylene vinyl acetate, to create a barrier and sealing functionality.

Adhesive lamination with barrier films in this guideline are classified as follows:

- Adhesive lamination with water-soluble adhesives (PVOH, starch, etc.)
- Adhesive lamination (inside of pack) of PET, mPET, PET/PE, etc.
- Lamination with aluminium-containing film (6 microns+) (Alu/PE or PET/Alu/PE)
- Lamination that is designed to be peeled by consumers

Peelable and tear-off solutions are recommended for the packaging formats where contamination with the food residuals is inevitable (chilled and frozen ready meals, rigid containers for pet food, etc.) and where plastic films are used as windows and cannot be replaced by alternative materials. In this case, contaminated plastic liner and residual paper or paperboard structure shall be disposed of separately. Peelable solutions can only be used where clear instructions on how to dispose of the materials are communicated on the pack.

Wet-barrier coatings
Wet-barrier coatings can be either water-based or solvent-based and represented either by polymer particle dispersions (also known as latexes or binders), colloidal and real solutions of polymer in water or organic solvents, and can include pigments. Water-based coatings include polymers like polyvinylidene chloride (PVDC), acrylics, styrene butadiene copolymers, vinyls, etc. The typical coating amount can vary between 5 and 20g/m². Solvent-based coatings include polyesters, polyurethanes, polyvinyl alcohol and nitrocellulose which typically dissolve in ethyl acetate. Typically, these coatings can be applied to a substrate using different technologies like curtain coating, printing or spraying the coating onto the surface. Wet coatings allow film formation of as little as 1-2 micron thickness, and so are easier to separate from fibre, which makes recycling easier compared to laminated materials.

Wet-barrier coatings in this guideline are classified as follows:

- Aqueous polymer dispersions (among others some types of acrylics, EEA, SB, ABS, PVDC, PVOH etc.)
- Solvent-based coatings
- Wax dispersion coating (incl. microcrystalline waxes)
- Water-soluble coatings (among others some types of PVOH, EVOH, EVA Biobased, etc.)

Wax coating (dipping paper in a molten wax bath)
Waxing paper is a traditional process where paper is given waterproofing properties ("hydrophobised") by passing it through a bath of melted wax. This process was used before the introduction of new methods such as extrusion coating with PE. It typically utilises paraffin wax, which is blended with PE or EVA.

Barrier metallisation
Metallisation has been traditionally used for decorative effects on paper. Recently, however, direct and transfer metallisation processes have been explored as a method of inducing effects or properties on paper, such as light, water vapor and oxygen barriers. For barrier-direct metallised paper, the metallisation is usually applied on the inside of the pack and composed of aqueous dispersion coating combined with an approximately 50nm-thick (ca. 0.14g/m²) aluminium layer that is applied in a vacuum deposition process. The metallisation is transferred on paper surface using adhesive (acrylic, polyurethane, EVA, etc.) courtesy of a release-coated PET film. The overall polymer thickness and protective layers, along with metallisation, is usually not more than 5µm.

Barrier metallisation coatings in this guideline are classified as follows:

- Direct metallisation (primer, Alu nanoscale, protective coating)
- Transfer metallisation (adhesive and transfer metallisation)

Fluorinated barrier/repellent coatings (wet end or surface application)
Per- and polyfluoroalkyl substances (PFAS) are applied in the wet-end of the paper machine as well as on the surface of the substrate. Though fluorinated coatings are fully compatible with recycling, it is recommended to avoid their usage due to the potential food safety and environmental (bio-persistence) concerns. Fluorine content in the wastewater and sludge may be controlled more stringently in the future, which may lead to challenges for paper mills.

5.2.2.3 Effect on the recycling process and general recommendation for recyclable design

The introduction of barriers in paper-based packaging may have negative impacts on recyclability, for example:

- Decrease recycling yield of paper-based packaging by reducing the share of the recoverable fibres in the overall weight of the packaging
- Increase in the repulping time and decrease in fibre yield due to the complicated separation of fibres from the polymeric matrix
- Reduction in coarse- and fine-screening capacity, and impact on wastewater quality (COD, BOD, etc.)
- Sticky deposits which may lead to increased paper machine breakdowns (downtime)
- Impact on the visual appearance of the finished recycled paper product
- Interference with magnetic induction-based flowmeters and web visual inspection devices

The extent of these impacts defines whether the paper-based packaging material is considered compatible with a conventional recycling process. This process typically operates with OCC and mixed paper (from separate collection) paper grades. Otherwise, the material would need to be recycled at a paper mill with specialised recycling processes.

5.2.3 Inks and varnishes

Printing inks are used to colour the substrate surface to produce an image, text or design. They are composed of colorants, binders, additives and diluents (i.e. substances used for dilution). Colorants are responsible for the colour impression and consist mostly of organic or inorganic pigments. Binders contain polymers, which wrap and stabilise the pigment particles in the ink mixture and fix the pigment on the substrate. They determine the ink properties depending on packaging application, printing technology and ink chemistry. Additives are used to fine-tune the ink properties towards the desired application. The diluent dissolves the binder and determines the flow properties of the ink in order to ensure a good transfer to the substrate. Typical diluents are water, oil and organic solvents.

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with conventional recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Conventional recycling process (Part I)

Constituent or integrated component		Fully compatible with conventional recycling process	Limited compatibility with conventional recycling process	Not compatible with conventional recycling process	Compatibility with conventional recycling process unknown	Comment
Offset	Oil-based (mineral)	⊗				Inks based on mineral oils are fully compatible with the conventional recycling process. Due to legal restrictions, the use of the recovered fibres **can be limited** to certain applications. Therefore, the use of mineral oil-based inks is not recommended for food-applications and **should be avoided where alternatives are available for other end uses**.
	Oil-based (vegetable)	⊗				
	Ultra-violet cured/EB-cured	⊗				
Flexo	Solvent-based	⊗				
	Water-based	⊗				
	Ultra-violet cured	⊗				
Gravure	Solvent-based	⊗				
	Water-based	⊗				
	Ultra-violet cured	⊗				
Varnish	Solvent-based	⊗				
	Water-based	⊗				
	Ultra-violet cured	⊗				
	Two component	⊗				
Digital	Water-based	⊗				Digital printing technologies emerging; continuous surveillance required.
	Ultra-violet cured	⊗				
	Liquid toner	⊗				
	Solid toner	⊗				
	Hot melt				⊗	Testing is required.
Screen	Ultra-violet cured	⊗				

Table 7. PART I – Design recommendations inks and varnishes

Varnishes are unpigmented systems and contain binders, additives and solvents. They have a variety of functions. As a medium, varnishes are added to the ink during printing to adjust the pigment concentration. Applied as a primer, varnishes help to improve the printout behaviour of inks. The most common application of varnishes is their use as overprint varnishes (OPVs). OPVs have a huge variety of functions, including protection against mechanical and environmental factors and decorative finishes to printed surfaces (gloss, matt, haptic, etc.). If varnishes have a barrier function they are treated as barriers, as described in chapter Barrier coatings and polymer content.

The following design table aims to give a compact overview of typically used inks and varnishes in the industry and their compatibility for the conventional recycling process. The design areas with high share of carbon black-based inks or metallic inks might cause problems in the sorting process. Sorting tests are thus needed to define the exact threshold for each individual packaging.

5.2.3.1 Inks and varnishes used in paper-based packaging

Oil-based
Oil-based inks and varnishes contain either mineral or vegetable oils or vegetable esters as solvent. Used mainly in offset printing, these inks and varnishes dry either physically by the solvent evaporating or by oxidation using dryers.

Solvent-based
Solvent-based inks and varnishes use organic solvents (alcohols, esters, etc.) and are used in gravure and flexographic printing. Solvent-based systems dry physically by the solvent evaporating.

Water-based
Water-based inks and varnishes use water as a solvent and are applied in gravure, flexographic and digital printing. Water-based systems dry physically by the solvent evaporating.

UV-curing
UV-curing inks and varnishes are solvent-free systems. They use monomers (acrylates) as a diluent, which polymerise with the aid of photo initiators and under irradiation (UV-light).

EB-curing
As with UV-curing systems, EB-curing inks and varnishes are solvent-free and contain monomers. EB-systems do not contain any photo initiators. The polymerisation is initiated using a high-energy electron beam.

2K-varnishes
These systems consist of the varnish itself formulated with a special binder and a hardener. The hardener is added to the varnish prior to printing to set off the polymerisation process.

Liquid and dry toner
Liquid and dry toners are used in electrophotographic digital printing and are composed of pigments, resins, and various additives. For dry toner, magnetisable metal oxides may also be present. In contrast to dry toners, liquid toners use a carrier liquid to disperse the pigments and resins. The toner is transferred from a photoconductor to the substrate and then fixed by applying heat and/or pressure.

5.2.3.2 Effect on the recycling process and general recommendation for recyclable design

Printing inks and varnishes can be subject to two different recycling processes: (1) recycling including a flotation-deinking process to separate ink particles from the paper fibres (recycling process with flotation-deinking); and (2) recycling in the conventional process, where the ink particles remain in the pulp.

In previous versions of the guideline, only the compatibility of inks and varnishes for the conventional recycling process and specialised processes was considered. However, in this guideline, recommendations are included for the compatibility with recycling in paper mills with flotation-deinking recycling process.

Based on industry feedback, inks and varnishes as classified in Table 7 typically do not cause problems in recycling. This is confirmed by a study conducted by FFI/PTS, Recyclability of Folding Cartons and Material Combinations (October 2020).

5.2.4 Adhesives

In today's packaging industry, a wide range of adhesives is used to form, seal and close paper-based packaging. As adhesives fulfil many different needs in modern packaging, multiple chemistries and application technologies have been developed.

The following design table aims to give a compact overview of the most typically used adhesives in the industry. However, other applications/chemistries exist that also fulfil the technical and recyclability requirements.

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with conventional recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Conventional recycling process (Part I)

Constituent or integrated component		Fully compatible with conventional recycling process	Limited compatibility with conventional recycling process	Not compatible with conventional recycling process	Compatibility with conventional recycling process unknown	Comment
Corrugated board-making	Starch-based	⊗				# For hotmelts with suitable softening point (higher than 68°C according to DIN EN 1427:2015) and applied larger than 2mm in diameter (see EPRC scorecard for the removability of adhesives). * Only valid for materials with a positive rating according to Cepi recyclability laboratory test method, 2022. Existing positive results obtained until 2030 according to the legacy methods such as but not limited to Aticelca MC501:2019, Cyclos-HTP CHI-PTS-C6/2.0, INGEDE 12 and PTS-RH:021/97 should also be accepted.
	PVA	⊗				
Window patching	Hotmelt	⊗ #				
Box-making	Hotmelt	⊗ #				
	Protein Glues				⊗	
Side seaming	Starch-based	⊗				
Box closing/ end-of-line	Hotmelt	⊗ #				
Palletising	Pressure sensitive hotmelt	⊗ *	⊗			
Cross-pasting (sacs)	Starch-based	⊗				
	PVA	⊗				
Bottom pasting (sacs)	Starch-based	⊗				
	PVA	⊗				
Handle-making and patching (bags)	PVA	⊗				
Lamination	Starch-based	⊗				
	Protein glues, acrylic, other dispersions, UV curing acrylics, polyurethanes				⊗	

Conventional recycling process (Part I)

Constituent or integrated component		Fully compatible with conventional recycling process	Limited compatibility with conventional recycling process	Not compatible with conventional recycling process	Compatibility with conventional recycling process unknown	Comment
Litho-lamination	PVA	⊗				**Please note** that the adhesives design table should be considered 'non-exhaustive' and does not cover all potential options or market solutions. This section will be further developed and an extended version will be provided in the next issue of the guideline.
Cold seal	Natural rubber latex	⊗ *				
Heat seal	PVA	⊗ *				
	Acrylic	⊗ *				
	Hotmelt				⊗	
Water-based labelling	Protein Glues				⊗	
	Acrylic				⊗	
Pressure sensitive applications (self-adhesive labels, tapes)	Pressure sensitive emulsion acrylics	⊗ *				
	Pressure sensitive hotmelt	⊗ *	⊗			
	Pressure sensitive UV-curable acrylic adhesives	⊗ *	⊗			
	Water-based adhesives	⊗ *				
Pressure sensitive closures	Pressure sensitive hotmelt	⊗ *				
	Pressure sensitive UV-curable acrylic adhesives	⊗ *				
	Water-based adhesives	⊗ *				
Bonding of supple-ments	Hotmelt	⊗ #				
	Polyurethane hotmelt	⊗ #				
Multipack attachment	Hotmelt	⊗ #				# For hotmelts with suitable softening point (higher than 68°C according to DIN EN 1427:2015) and applied larger than 2mm in diameter (see EPRC scorecard for the removability of adhesives). * Only valid for materials with a positive rating according to Cepi recyclability laboratory test method, 2022. Existing positive results obtained until 2030 according to the legacy methods such as but not limited to Aticelca MC501:2019, Cyclos-HTP CHI-PTS-C6/2.0, INGEDE 12 and PTS-RH:021/97 should also be accepted.
	Pressure sensitive hotmelt	⊗ *			⊗	
	Water-based adhesives	⊗ *				
	Pressure sensitive acrylic adhesive	⊗ *				
	UV-curable acrylic adhesives	⊗ *				

Table 8. PART I – Design recommendations adhesives

5.2.4.1 Adhesives used in paper-based packaging

The following section aims to provide a simple classification of the different adhesive types based on whether they are cold-applied water-based adhesives, hotmelt adhesives, or reactive adhesives.

Water-based adhesives
Water-based adhesives can be solutions or dispersions. They are applied as liquids at room temperature or slightly elevated temperature to the paper substrates. These adhesives set when the water evaporates and/or it is absorbed (penetrates) into the substrate. Dispersion adhesives therefore usually require at least one porous, water-absorbent surface but no additional drying. Unless they are used for pressure sensitive applications, they are not sticky after drying.

Water-based adhesives in this guideline are classified as follows:
- Water-based adhesives based on natural polymers
- Water-based adhesives based on synthetic polymers
- Acrylics

Hotmelt adhesives
Hotmelt adhesives are heated before their application to form a "melt", typically at temperatures well above 100°C. The adhesive is then applied in liquid (molten) form to the substrate(s). A physical setting or hardening takes place during cooling and converts the liquid hotmelt back into a solid.

Hotmelt adhesives in this guideline are classified as follows:
- (Non-pressure sensitive) hotmelts
- Pressure sensitive hotmelts

Reactive adhesives
Reactive adhesives, as their name suggests, do not rely on a purely physical setting process. They contain substances that react chemically within the adhesive itself and in certain cases also with the substrate surface.

The chemical reaction leads to very resistant final adhesive applications. Once cured, reactive adhesives can generally not be dissolved in water or softened by temperatures that are encountered during the paper recycling process.

Reactive adhesives in this guideline are classified as follows:
- UV-curing adhesives
- Polyurethanes

5.2.4.2 Effect on the recycling process and general recommendations for recyclable design

As they make up only a small weight percentage of any given item they are used in, adhesives themselves are today not the target of any recycling process and they are therefore not as such considered "recyclable". At the same time, adhesives can impact the yield and quality of the recycling processes of their substrates, such as paper and paperboard. Consequently, adhesives should be suitably compatible with these processes to allow successful and effective recycling of the predominant materials. Compatibility refers to adhesive applications being designed in such a way that they neither cause unacceptable impacts on the recycling process nor unacceptably deteriorate the quality of the output.

As a general principle, as for all materials which are not the predominant material of the packaging unit, the amount of adhesives used in a given paper or paperboard item should be optimised to the minimum amount required to achieve its function. Doing so will minimise the amount of adhesive that the recycling process needs to handle. To facilitate easy removal of adhesive applications, they should, where technically possible, be made large enough to be screened out effectively. Very thin film applications should be avoided because they could be less resistant to shear forces introduced in pulping, resulting in very small particles that can't be removed by screening.

5.2.5 Decorative metallic constituents and integrated components

In order to increase the functionality and visual appearance of paper, decorative metallisation is a suitable method to achieve various paper properties. Metallised paper is widely used in food packaging, tobacco packaging, and labelling. As demand for flexible packaging is constantly increasing, the use of metallised fibre-based products is growing as well (Dahlgren et al., 2015).

The following design table aims to give a compact overview of typically decorative metallic constituents and integrated components used in the industry and their compatibility with the conventional recycling process.

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with conventional recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Conventional recycling process (Part I)

Constituent or integrated component		Fully compatible with conventional recycling process	Limited compatibility with conventional recycling process	Not compatible with conventional recycling process	Compatibility with conventional recycling process unknown	Comment
Decorative metallic constituents and integrated components	Hot and cold transfer	⊗				Designers should not cover the surface of paper-based packaging fully with metallisation, as this could cause issues regarding the detection as a paper-based packaging.
	PP/PET metallised laminates			⊗		In the case the metallised film is covering the full surface, as this could affect the sorting process (if NIR is used for detecting the metallised side).
	PET metallised film			⊗		In the case the metallised film is covering the full surface, as this could affect the sorting process (if NIR is used for detecting the metallised side).
	Direct Vacuum Metallised Paper		⊗			The outside metallisation could affect the sorting process (if NIR is used for detecting the metallised side).
	Direct metallisation		⊗			Designers should not cover the surface of paper-based packaging fully with metallisation, as the outside metallisation could affect the sorting process (only if NIR detection will detect the metallised side).

Table 9. PART I – Design recommendations decorative metallic components and constituents

5.2.5.1 Decorative metallic constituents and integrated components used in paper-based packaging

The following methods are used to metallise papers, after the papermaking process:

- Direct metallisation
- Hot and cold foil stamping
- Printing (see chapter 5.2.3 Inks and varnishes)

5.2.5.2 Effect on the recycling process and general recommendation for recyclable design

Metallic constituents and integrated components with a thickness lower than 1 µm do not cause any issue during the recycling process, but the recognition of these papers during the sorting process is crucial. If the paper's surface is not fully covered with metallic decoration, it will not cause major issues regarding detection as a paper-based packaging and will end up in the right recycling stream. If the surface is covered with a very high share of metallisation, it may cause detection issues, as the metallic effect reflects the NIR light, and the paper-based packaging may end up in the wrong recycling stream during sensor-based sorting.

To mitigate this issue, it is recommended to:

- Minimise the percentage of plastic used; it is recommended to use hot stamping or cold transfer instead of lamination
- Designers should not fully cover the paper-based packaging with metallisation to avoid problems during the sorting process.

5.2.6 Other integrated components

The following design table aims to provide a compact overview of other integrated components used to improve the functionality of paper-based packaging.

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with conventional recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.

Please be aware that the recommendations in the design tables only refer to the compatibility with recyclability of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Conventional recycling process (Part I)

Integrated component		Fully compatible with conventional recycling process	Limited compatibility with conventional recycling process	Not compatible with conventional recycling process	Compatibility with conventional recycling process unknown	Comment
Security label	Fibre-based	⊗				
	Polyolefins		⊗			
	PET		⊗			
Pull strip	Fibre-based	⊗				
Windows	Regenerated cellulose		⊗			Strongly attached windows should be avoided; it is recommended to consider easily detachable, thin, lightweight solutions.[4]
	Fibre-based		⊗			
	Polyolefins		⊗			
	PET		⊗			
Carrying handle	Fibre-based	⊗				
	Polyolefins		⊗			
	PET		⊗			
	Metal			⊗		
Zipper	Polyolefins		⊗			
	PET		⊗			

Table 10. PART I – Design recommendations other integrated components

[4] https://thecpi.org.uk/library/PDF/Public/Publications/Guidance%20Documents/Recyclability-Guidelines-2024.pdf

5.2.7 Base material and alternative fibres

Wood-based fibres (chemical and mechanical pulp fibres) are traditionally the primary or dominant resource for paper-based packaging in Europe, hence the majority of mills have been designed and are optimised to handle wood-based fibres. The structure and composition of wood fibre is especially suitable for the production of paper and board. Both hardwood (aspen, birch, eucalyptus) and softwood (pine, spruce) types are utilised to give paper-based packaging various properties (Holik, 2013).

Alternatives to wood-based fibres can be sourced mainly from bagasse, bamboo, straw, grass and other plant fibres. The compatibility with the recycling process of the various alternative fibres is the subject of ongoing investigation.

5.2.7.1 Effect on the recycling process and general recommendation for recyclable design

Most paper mills are set up to reprocess wood-based fibres, hence manufacturers are encouraged to use wood fibres. The multitude of existing and alternative fibres as well as newly evolving materials requires further recyclability testing for the individual packaging.

5.2.8 Product contamination (residual content)

Product residues (food and non-food) present in the packaging at the moment of disposal may result in contamination of the recovered fibres, which potentially affects the recycling process and pulp quality. The main reason for concerns regarding contamination of the recovered fibres, especially when it comes to food safety issues, are:

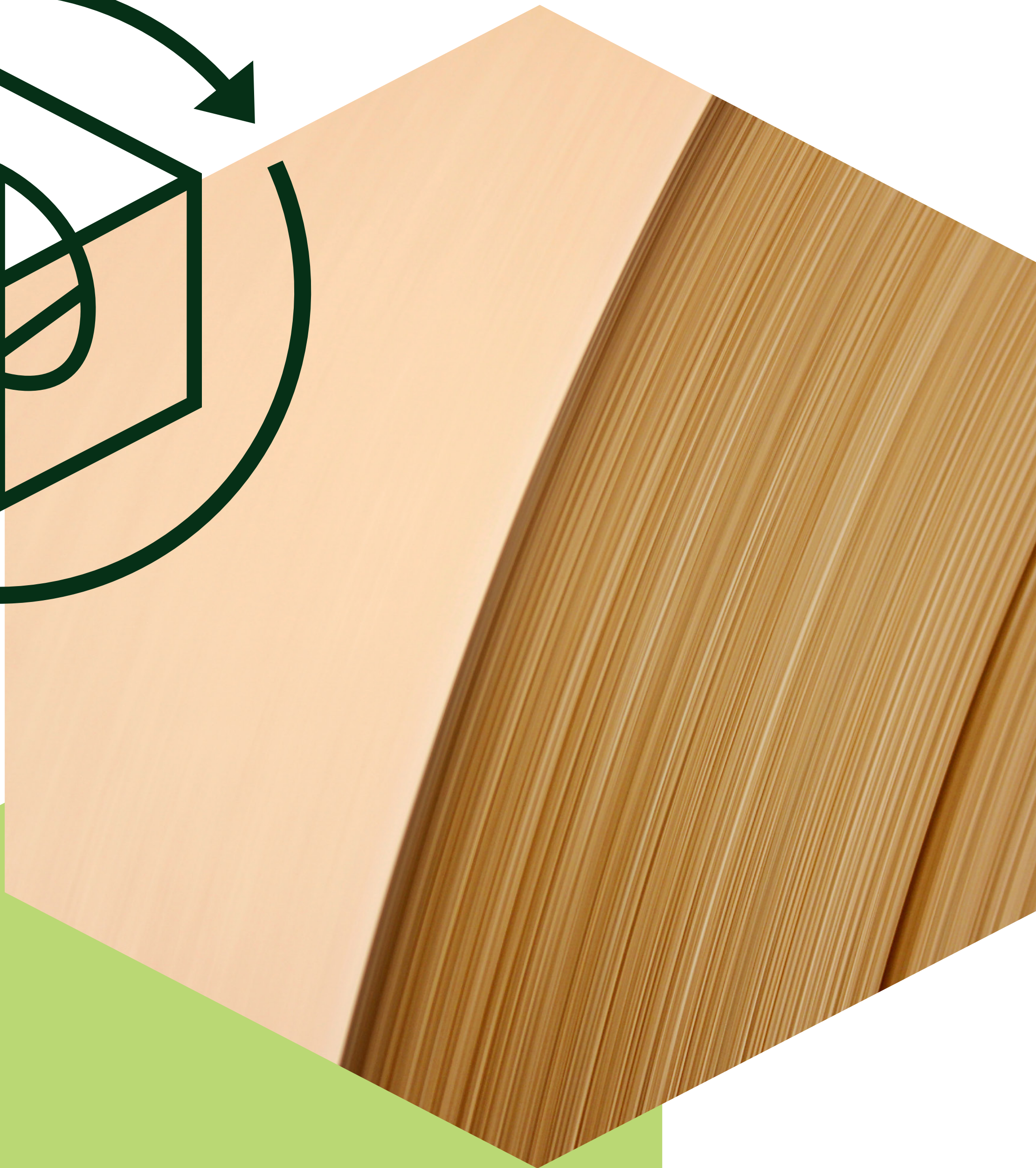
- Excessive microbial growth leading to contamination of the finished paper product
- Increased risks of infestation with insects and rodents
- Increased load on wastewater treatment plants due to increased soluble matter

Even though various well-proven and effective techniques are available for reducing the contaminant, it is impossible to completely eliminate the presence of product residuals in paper-based packaging. Minor contamination and/or staining are tolerated by most paper mills as long as it does not cause severe microbial growth in collected paper material.

5.2.8.1 Effect on the recycling process and general recommendation for recyclable design

To ensure that the residual content of the packaging does not hinder the recycling process, packaging design should make it as easy as possible to completely empty the contents. As such, the following aspects should be taken into consideration:

- If the packaging format allows, provide a tear-off or other facility to separate and remove the contaminated layer from the paper-based packaging after use.
- Design should enable cleaning of the surface in contact with food (when applicable, design the opening so that the surface in contact with food is accessible, allowing the food to be taken out as completely as possible).
- End-users should be informed to remove product residues from the packaging before disposal (i.e. producers or product distributors need to ensure that the packaging offers information on how to handle residues prior to disposal).



6. PART II — PAPER MILLS WITH FLOTATION-DEINKING RECYCLING PROCESS

6.1 Recycling in paper mills with flotation-deinking recycling process

Flotation-deinking is a process where inks are removed from collected paper for recycling to produce a clean white or off-white pulp. This happens in three technological steps – detachment of ink from the substrate, fragmentation of the ink particles into the proper size spectrum and removal from the pulp slurry.

Detachment and fragmentation usually happen during repulping, predominantly in an alkaline environment with the help of detergent-like substances.

In special cases, detachment is done by enzymes. Mostly flotation-deinking cells but also washers provide the removal. In addition, bleaching can be operated to enhance the pulp brightness further.

The focus of this part of the guideline is on the use of an alkaline flotation-deinking process in paper recycling mills. This process is most common in Europe and typically used for deinking of graphic papers such as newsprint and magazines, office papers and print house material, but also packaging on white substrates.

In general, flotation-deinking removes a wide range of hydrophobic particle sizes from 10 to 250 µm very efficiently with a high fibre yield, and in some systems even larger particles up to 500 µm with reasonable efficiency.

The flotation-deinking process is most commonly used for recycling printed products where the inks are water repellent. This type of inks and toners are used in the offset, rotogravure and dry toner printing processes. Other types of inks such as flexographic inks, UV inks, liquid toner inks, and inkjet inks in many cases cannot be processed in a deinking process with same efficiency but depending on the individual behaviour be compatible with the deinking process. For further guidance on the compatibility of different inks and varnishes type please see Table 14 Design recommendations for inks and varnishes.

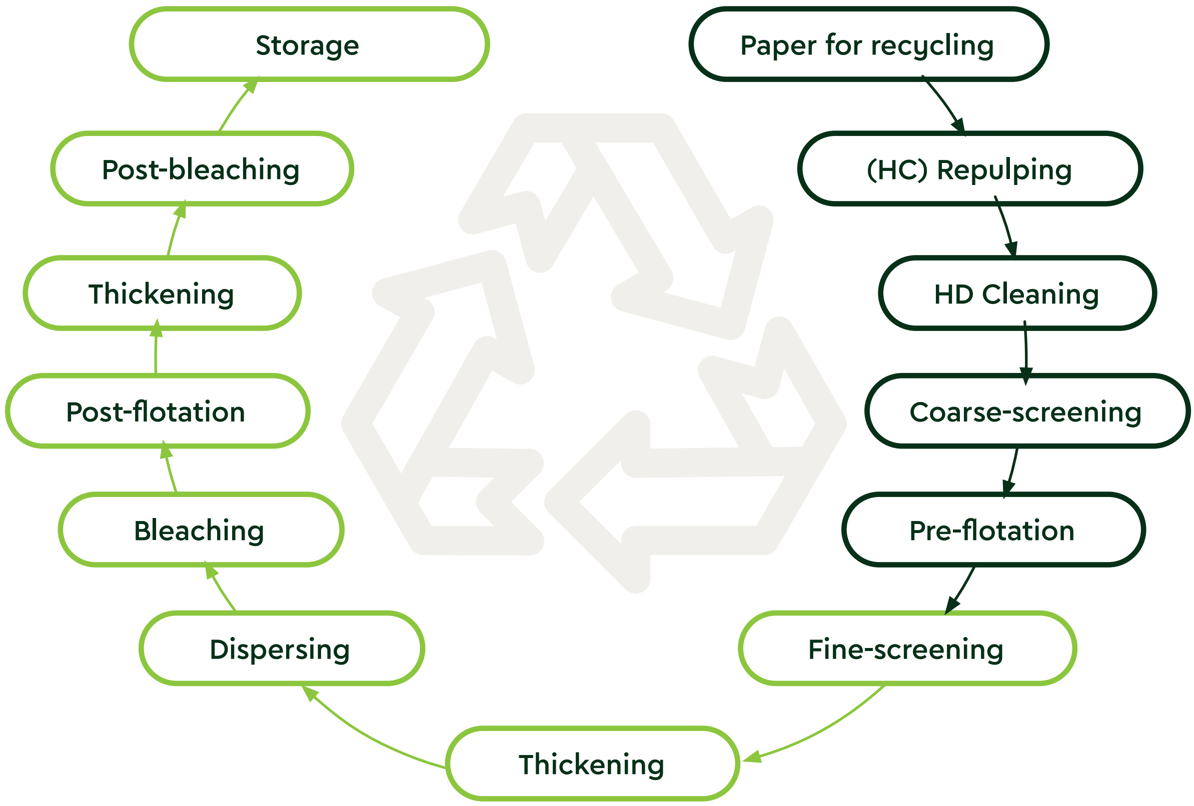


Figure 4. Example for recycling process in two-loop deinking-flotation recycling mills

Recycling process

Paper for recycling: The international standard EN 643 contains requirements for grades of paper for recycling that are specifically intended for deinking. EN 643 Grades that are intended for deinking include sub grades from group 1,2,3 and 5. These grades should only contain paper products which qualify for deinking according to 'Assessment of print product recyclability – deinkability score' in (www.paperforrecycling.eu).

The 4evergreen alliance has been working on a deinkability test method for paper-based packaging based on the well-established deinkability test method INGEDE Method 11. The alliance has published a test protocol that mimics the most relevant process stages of the deinking process at lab scale and is suitable for paper-based packaging. Beside the laboratory test method, the alliance has released the Recyclability Evaluation Protocol Version 1 which includes an evaluation scheme based on the obtained test results. The evaluation scheme includes the main elements of the EPRC score card (Assessment of Printed Product Recyclability – Deinkability Score) extended by additional parameters being relevant for paper-based packaging.

Current design recommendations in this guideline are based on expert opinion obtained from long term experience of graphic paper recycling. The European Recovered Paper Council (ERPC) recommends using its deinkability scorecard that assesses the deinkability of a printed product which is given in a range from -100 to +100, based on the results of the widely accepted INGEDE Method 11 laboratory deinking procedure, developed by the INGEDE. The scorecard is available at: http://www.paperforrecycling.eu/publications/erpc-publications

High-consistency repulping: This is specially designed for the deinking process where paper for recycling is introduced into the pulper with a large quantity of water. Horizontal drums or vertical vats equipped with a spiral rotor are used to break the input material under elevated temperatures into individual fibres, and to detach the inks from the fibres. Good paper disintegration and separation of fibres from contaminants is achieved here. Consistency in the pulp is relatively high at over 14% solids, before dumping into the next step.

High-density cleaning: In this stage, large and heavy impurities like staples, glass and stones are removed from the pulp slurry.

Coarse-screening: At this stage, the pulp slurry is forced through holes or slots so small that free fibres pass through them and the coarse particles like wood chips or medium-sized plastic particles do not pass through them. The result is a cleaner pulp while the coarse particles are rejected.

Pre-flotation: In this step detached inks are removed. Chemicals called surfactants are added to the pulp slurry, which is introduced into tanks known as flotation cells. The flotation cells are aerated to produce bubbles and eliminate the ink from the pulp. The hydrophobic ink particles become attached to the air bubbles and get separated from the hydrophilic fibres. These ink-laden bubbles stream upwards to the surface cell and accumulate in the froth where they are removed by overflow or suction.

Low-consistency cleaning: In this optional step fine hydro-cyclones remove sand and other small abrasive particles.

Fine-screening: By removing other impurities such as stickies which are mainly derived from seal and peel labels, envelopes and tapes, this step maximises the pulp quality for maximum runnability and further minimises the number of impurities.

Thickening: The deinked pulp is now thickened to remove the water content from the flotation process. The thickening process increases the pulp concentration to approximately 30% thus providing the pulp concentration to make it meet the requirements of for the next process.

Disperser: Dispersing is a high-speed kneading process at high consistency to reduce residual ink particles size. A disperser or a kneader can simultaneously be used for intense mixing of the bleaching agents with the fibres.

Bleaching: In this process, coloured substances and lignin are bleached to convert it into lighter colours or to enhance the brightness and the cleanliness of the pulp itself. This is performed because unbleached pulp is not suitable for manufacturing high grade of white paper. This is done through a series of oxidation and/or reduction reactions.

Post-flotation: In case of a second loop, a post-flotation is installed to remove additional dispersed inks, varnishes and the other non-fibrous parts. Some paper mills may add another bleaching section to further increase the brightness of the pulp.

Thickening: With the dewatering process, the stock consistency is increased from about 5 to 30% or more, to prepare the next process stage and for complete water-loop separation.

Post-bleaching: Some mills may use a post-bleaching stage with hydrogen peroxide or dithionite for higher brightness.

Storage: The cleaned fibres are placed in storage tanks and ready for use for the manufacture of new paper on the papermaking machine.

6.2 Design recommendations (PART II)

This chapter provides specific design recommendations for single packaging groups intended to be recycled in paper mills with flotation-deinking recycling process, to help designers refine their work.

The design recommendations tables in the sub-chapters 6.2.1 to 6.2.6 are applicable for the recycling process in paper mills with flotation-deinking recycling process.

The design tables provide information for the following constituents or integrated components:

- 6.2.1 Fillers, additives, and agents
- 6.2.2 Barrier coatings and treatments
- 6.2.3 Adhesives
- 6.2.4 Inks and varnishes
- 6.2.5 Decorative metallic constituents and integrated components
- 6.2.6 Other integrated components

The design tables in this chapter refer to single constituents or integrated components categorised as:

- Fully compatible with flotation-deinking recycling processes
- Limited compatibility with flotation-deinking recycling processes
- Not compatible with flotation-deinking recycling processes
- Compatibility with flotation-deinking recycling processes unknown

NOTE: The given design recommendations are widely based on the expert opinion of the entire value chain represented in 4evergreen and are valid for paper mills with flotation-deinking recycling process. Actual testing prevails over the given recommendations in the guideline; therefore the guideline will be updated in line with recyclability lab test results and the corresponding 4evergreen recyclability evaluation protocol (PART II).

6.2.1 Fillers, additives and agents

Flotation-deinking recycling process (PART II)

Constituent or integrated component		Fully compatible with flotation-deinking process	Limited compatibility with flotation-deinking recycling process	Not compatible with flotation-deinking recycling process	Compatibility with flotation-deinking recycling process unknown	Comment
Filler/ inorganic pigments	Clay (kaolin)	⊗				High ash content may have a negative impact on mechanical strength depending on the relative amount in the PfR stream.
	CaCO3	⊗				
	Talc	⊗				
	Titanium dioxide	⊗				
Binder	S/B latex		⊗			
	S/A latex		⊗			Depending on amount, adhesive strength, etc.
	Starch-biobinder		⊗			
Sizing, wet end	AKD	⊗				
	ASA	⊗				
	Rosin	⊗				
Dry strength	Starch	⊗				
	CMC		⊗			
	Polyacrylamide	⊗				
	Guar gum	⊗				

Flotation-deinking recycling process (PART II)

Constituent or integrated component		Fully compatible with flotation-deinking recycling process	Limited compatibility with flotation-deinking recycling process	Not compatible with flotation-deinking recycling process	Compatibility with flotation-deinking recycling process unknown	Comment
Wet strength	PAE		⊗			Recyclability depends on various factors, such as relative wet-strength (WS) level, amount of WS agent, etc. Recyclability can be improved by increased pulping temperature and time, chemicals, high consistency pulping, etc. Testing is needed to evaluate the recyclability and set thresholds for acceptable levels in the PfR stream.
	Urea/ Formaldehyde		⊗			
	Glyoxylated polyacrylamide (GPAM)		⊗			
Sizing, surface	Starch	⊗				
Other	Colorants/dye for shading		⊗			Physically recyclable but certain dyes are not approved for food packaging applications and such dyes should be avoided. Dyes may affect the optical properties of the deinked pulp negatively (discolouration) thus should be avoided or at least minimised.
	Colorants/ pigments		⊗			
	Polyvinyl alcohol		⊗			
	PAC	⊗				
	Retention polymers	⊗				
	Siliconising agents		⊗			

Table 11. PART II – Design recommendations additives, fillers and agents

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with flotation-deinking recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

6.2.2 Barriers, coatings and treatments

Flotation-deinking recycling process (PART II)

Constituent or integrated component		Fully compatible with flotation-deinking recycling process	Limited compatibility with flotation-deinking recycling process	Not compatible with flotation-deinking recycling process	Compatibility with flotation-deinking recycling process unknown	Comment
Extrusion barrier coating	Thermoplastic (one side coated, inside the pack only)				⊗	
	Thermoplastics (two sides coated)				⊗	
Adhesive barrier film	Adhesive lamination with water-soluble adhesives (some types of PVOH, starch, etc.)	⊗				
	Adhesive lamination (inside of pack) of PET, mPET, PET/PE etc.		⊗			
	Lamination with Alu containing film (Alu/PE)	⊗				
Wet-barrier coatings	Aqueous polymer dispersions (among others some types of acrylics, EEA, SB, ABS, PVDC, etc.)	⊗				
	Solvent-based coatings	⊗				
	Wax dispersion (incl. microcrystalline waxes)		⊗			Level of compatibility of wax-coated products should be determined with a recycling test evaluated with the 4evergreen protocol PART II on recyclability evaluation in paper mills with flotation-deinking recycling process.
	Water soluble coatings (among others some types of PVOH, EVOH EVA Biobased, etc.)	⊗				Needs thorough process water cleaning to prevent issues like problematic foam forming and process disturbances. The COD load will be higher for soluble polymers.
Wax coatings	Dipping of paper in molten wax (two-sided)				⊗	

Flotation-deinking recycling process (PART II)

Constituent or integrated component		Fully compatible with flotation-deinking recycling process	Limited compatibility with flotation-deinking recycling process	Not compatible with flotation-deinking recycling process	Compatibility with flotation-deinking recycling process unknown	Comment
Barrier metallisation	Direct metallisation on paper (primer, Alu nanoscale, protective coating) – inside	⊗				
	Transfer metallisation (adhesive + transfer metallisation) – inside	⊗				The visual impurities of paper processed in paper mills with flotation-deinking recycling process are minimised which thereby increases the quality of the recycled produced.

Table 12. PART II – Design recommendations barrier coatings and treatments

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with flotation-deinking recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.

The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.

Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

6.2.3 Adhesives

Flotation-deinking recycling process (PART II)

Constituent or integrated component		Fully compatible with flotation-deinking recycling process	Limited compatibility with flotation-deinking recycling process	Not compatible with flotation-deinking recycling process	Compatibility with flotation-deinking recycling process unknown	Comment
Bonding of supplements	Hotmelt	⊗ #				
	Polyurethane Hotmelt	⊗ #				# For hotmelts with suitable softening point (higher than 68°C according to DIN EN 1427:2015) and applied larger than 1.6mm in diameter (see EPRC scorecard for the removability of adhesives).
Cap/straw attachment for liquid packaging carton	Hotmelt	⊗ #				
Multipack attachment	Hotmelt	⊗ #			⊗	
	Pressure sensitive hotmelt	⊗ *			⊗	* Only valid for materials with a positive rating according to the 4evergreen recyclability evaluation protocol PART II. Existing positive results obtained until 2030 according to the legacy methods such as but not limited to INGEDE Method 12 and PTS-RH:021/97 should also be accepted.
	Pressure sensitive emulsion acrylics	⊗ *				
Pressure sensitive applications (self-adhesive labels)	Pressure sensitive emulsion acrylics	⊗ *				
	Pressure sensitive hotmelt	⊗ *				**Please note** that the adhesives design table should be considered 'non-exhaustive' and does not cover all potential options or market solutions.
	Pressure sensitive UV-curable acrylic adhesives	⊗ *				
	Water-based adhesives	⊗ *				This section will be further developed and extended version will be provided in the next issue of the guideline.
Water-based labelling	Protein glues				⊗	
	Acrylic				⊗	

Table 13. PART II – Design recommendations adhesives

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with flotation-deinking recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

6.2.4 Inks and varnishes

Flotation-deinking recycling process (PART II)

Constituent or integrated component		Fully compatible with flotation deinking process	Limited compatibility with flotation deinking process	Not compatible with flotation deinking process	Compatibility with recycling process unknown	Comment
Offset	**Oil-based (mineral)**	⊗				
	Oil-based (vegetable)		⊗			Deinkability dependent on ink formulation; deinkable and non-deinkable products commercially available.
	Ultra-violet cured/EB-cured		⊗			Deinkability dependent on ink formulation; deinkable and non-deinkable products commercially available.
Flexo	**Solvent-based**	⊗				
	Water-based		⊗			Ink is detachable from the paper fibres; by nature water-based inks decolourise the process water.
	Ultra-violet cured		⊗			Deinkability dependent on ink formulation; deinkable and non-deinkable products commercially available.
Gravure	**Solvent-based**	⊗				
	Water-based		⊗			Ink is detachable from the paper fibres; by nature water-based inks decolourise the process water.
	Ultra-violet cured				⊗	UV-curing inks are not common in gravure printing. Only UV-curing varnishes are used, e.g. Tobacco packaging (see below).
Varnish	**Solvent-based**				⊗	Deinkability of solvent- and water-based varnish is unknown as they are mostly used in combination with inks and not alone.
	Water-based				⊗	
	Ultra-violet cured		⊗			Deinkability dependent on coating formulation; deinkable and non-deinkable products commercially available.
	Two component				⊗	Deinkability of two component varnishes has to be tested.

Flotation-deinking recycling process (PART II)

Constituent or integrated component		Fully compatible with flotation deinking process	Limited compatibility with flotation deinking process	Not compatible with flotation deinking process	Compatibility with recycling process unknown	Comment
Digital	Water-based inkjet			⊗		
	Pigment-based inkjet		⊗			Deinkability dependent on ink formulation and/ or substrate properties; deinkable and non-deinkable products commercially available.
	Ultra-violet cured				⊗	
	Liquid toner			⊗		
	Solid toner	⊗				
	Hot melt				⊗	
Screen	Ultra-violet cured				⊗	

Table 14. PART II – Design recommendations inks and varnishes

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with flotation-deinking recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

6.2.5 Decorative metallic constituents and integrated components

Decorative metallisation is an effective method to enhance the functionality and visual appearance of paper, making it suitable for various applications. Metallised paper is extensively used in food packaging, tobacco packaging, and labelling. With the increasing demand for flexible packaging, the use of metallised fibre-based products is also on the rise (Dahlgren et al., 2015).

Packaging incorporating decorative metallic constituents and integrated components can be recycled efficiently at both paper mills with conventional recycling process and paper mills with flotation-deinking recycling process. The flotation-deinking process is particularly effective at minimising visual impurities, thereby improving the quality of the recycled product.

Given the capabilities of paper mills with flotation-deinking recycling process to effectively remove metallic constituents and integrated components, packaging designed with these processes in mind can achieve better visual quality.

Flotation-deinking recycling process (PART II)

Constituent or integrated component		Fully compatible with flotation-deinking recycling process	Limited compatibility with flotation-deinking recycling process	Not compatible with flotation-deinking recycling process	Compatibility with flotation-deinking recycling process unknown	Comment
Decorative metallic constituents and integrated components	Hot and cold transfer	⊗				Designers should not cover the surface of fibre-based products fully with metallisation, as this could cause issues regarding the detection as fibre product.
	PP/PET metallised laminates				⊗	In the case the metallised film is covering the full surface, as this could affect the sorting process (if NIR is used for detecting the metallised side).
	PET metallised film				⊗	In the case the metallised film is covering the full surface, as this could affect the sorting process (if NIR is used for detecting the metallised side).
	Direct vacuum metallised paper		⊗			The outside metallisation could affect the sorting process (if NIR is used for detecting the metallised side).
	Direct metallisation		⊗			Designers should not cover the surface of fibre-based products fully with metallisation, as the outside metallisation could affect the sorting process (if NIR is used for detecting the metallised side).

Table 15. PART II – Design recommendations decorative metallic constituents and integrated components

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with flotation-deinking recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

6.2.6 Other Integrated Components

Flotation-deinking recycling process (PART II)

Integrated Component		Fully compatible with flotation-deinking recycling process	Limited compatibility with flotation-deinking recycling process	Not compatible with flotation-deinking recycling process	Compatibility with flotation-deinking recycling process unknown	Comment
Security label	Fibre-based	⊗				
	Polyolefins		⊗			
	PET		⊗			
Pull strip	Fibre-based	⊗				
Windows	Regenerated cellulose		⊗			Strongly attached windows should be avoided; it is recommended to consider easily detachable, thin, lightweight solutions.
	Fibre-based		⊗			
	Polyolefins		⊗			
	PET		⊗			
Carrying handle	Fibre-based	⊗				
	Polyolefins		⊗			
	PET		⊗			
	Metal			⊗		
Zipper	Polyolefins		⊗			
	PET		⊗			

Table 16. Part III - Design recommendations other integrated components

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with flotation-deinking recycling process. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components; thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

7. PART III — PAPER MILLS WITH SPECIALISED RECYCLING PROCESSES

7.1 Recycling in paper mills with specialised recycling processes

A different recycling process is used for fibre-based composite packaging designed to meet more demanding performance criteria in the cases of liquid packaging cartons, and double-sided coated paper cups or when additional integrated components, or constituents, or higher pulp quality is required for the end product.

Paper mills with specialised recycling processes are able to process paper-based packaging structures that are different from the materials processed in paper mills with conventional recycling process. These types of paper mills with specialised recycling processes can recycle EN 643 Grade 5 papers, as well as some papers from Grades 1-4. In general, paper mills with specialised recycling processes are preferred for grades that benefit from longer pulping time and require gentle slushing conditions, to avoid cutting off the reject and/or have higher amounts of reject.

EN 643 defines a standard for paper grades including 5.03.00 used liquid packaging board and 5.14.00 used paper cups and other tableware. Other laminated or plastic-coated paper and board, especially the increasing types of new fibre-based composite packaging where plastic is being replaced by fibre-based solutions, are not always defined clearly under EN 643.

Non-paper components are typically a part of these innovative forms of packaging. The ability to recycle some of these materials depends on new or enhanced equipment. Input requirements will be based on the quality and type of the fibre and the amount of non-paper components that need to be removed. Although these paper mills have equipment to treat special grades, there are also limitations on the range of input material they can accept. Input will also depend on the end-market for recovered pulp and the quality requirements for end products. Paper mills evaluate the quality of the input based on the type of raw material, not the type of packaging. Also, for non-paper components, recycling mills clearly look at materials best suited to further paper and avoid those that are not recyclable in order to improve sustainability.

For this reason, paper mills with specialised recycling processes will apply specific input requirements beyond classification and descriptions in EN 643, establishing a de facto specification for sorting plants to produce these qualities.

Two product specifications describing specific input conditions have been developed for paper-based packaging fit for recycling in paper mills with specialised recycling processes. The first is product specification **No. 512/510** for liquid packaging board and the second is specification **No. 550** for other fibre-based composites (for example in Germany: PPK[5] from LWP). Different from EN 643, these specifications are not describing a dedicated fibre quality but are more an agreement between value chain partners on the acceptable composition of bales sent from sorting facilities to recyclers.

Although both qualities will go to paper mills with specialised recycling processes, not every paper mill with specialised recycling processes will be able or willing to recycle both qualities. This will depend on the available equipment and the quality of fibres needed for the paper end product and on other restrictions (e.g. food contact regulation) needed for the paper end product. Therefore, a paper mill with specialised recycling processes will require a choice to potentially use these materials as separate input qualities. It is therefore recommended to have these materials sorted into separated qualities under agreed rules, such as the mentioned standards No. 512 or 550 (or additional requirements to be defined by 4evergreen's Recyclability Evaluation Protocols).

The recycling path for used liquid packaging cartons is a European-wide well-defined stream. Currently, all collected and sorted packages are recycled by the existing paper mills, and the capacities will increase in line with the growing collection and sorting of liquid packaging cartons.

It should be noted that the available capacity to collect and recycle other fibre-based composite packaging remains still limited in certain parts of Europe.

Efforts to increase recycling capacity are still ongoing and setting clear industry standards sends a positive signal to paper mills with specialised recycling processes about the security and quality of future inputs, which is also needed to support investments in additional recycling capacity for these materials when sorted properly.

Across Europe, there are approximately 20 paper mills with specialised recycling process specifically dedicated to recovering this fibre-based composite packaging stream, and more reprocessing plants are in the planning stage (see figure below).

[5] PPK is the German acronym for paper/cardboard/board and LWP stands for lightweight packaging.

EUROPE HAS A WIDE NETWORK OF MILLS FOR RECYCLING PAPER-BASED PACKAGING

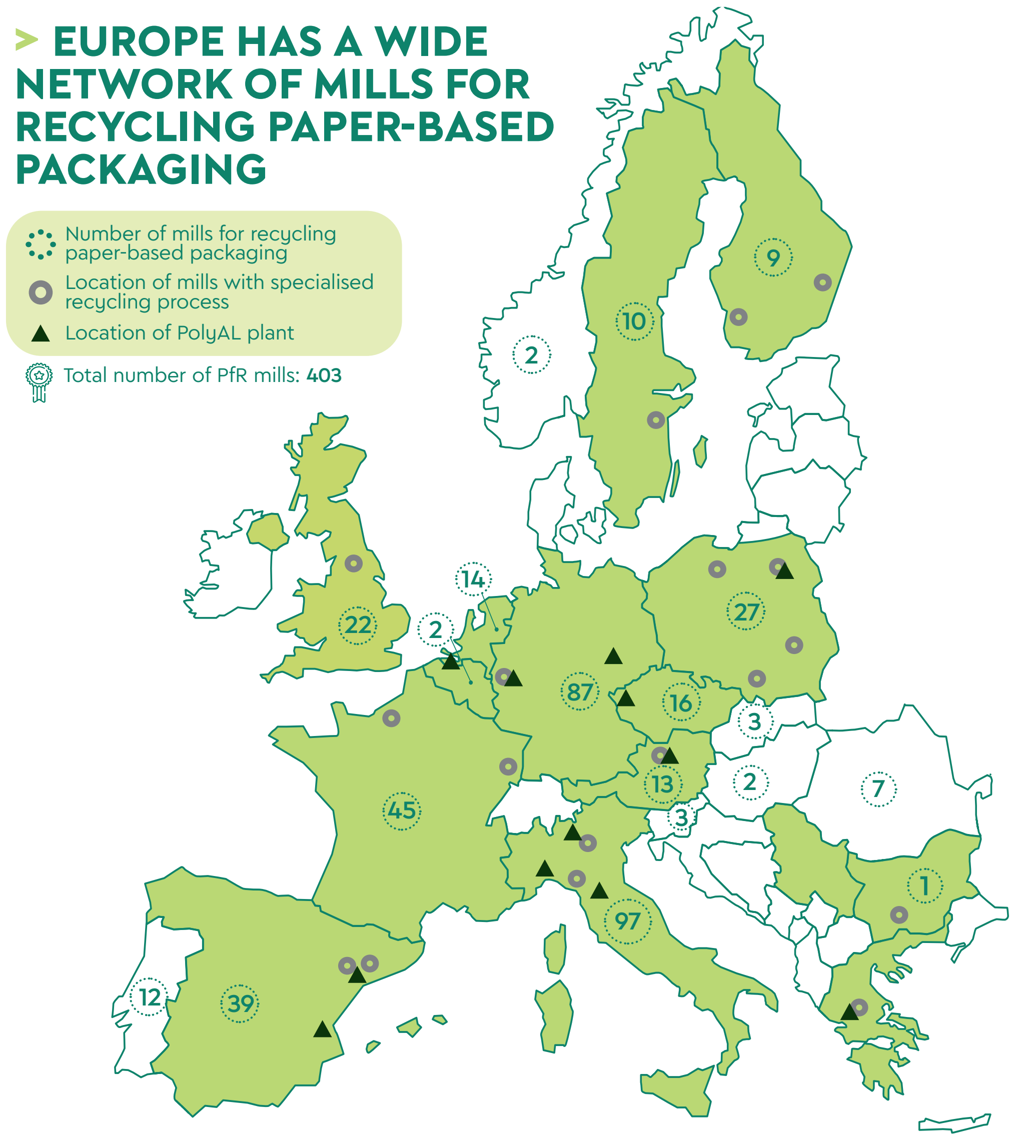


Figure 5. Paper mills for recycling paper-based packaging in Europe (Source: Cepi, 2022; FBCA, 2025)

The fibres are recovered from used liquid packaging cartons at paper mills with specialised recycling processes with dedicated processing equipment (see Figure 5).

Specific pulping conditions and process equipment are used in paper mills with specialised recycling processes, which use water and agitation processes to separate the paper fibres from the plastic and aluminium. Typically, this is achieved by incorporating a drum pulper or a vertical pulper – large cylindrical vessels with impellers (rotors) at the bottom which break paper fibres apart and produce a suspension that is further processed within a recycling line using cleaning and screening stages. The recovery of fibres can be performed in two processes, either as a batch or in continuous flow. In the pulper, the paper layer comes in contact with water, resulting in the paper layers separating from each other due to physical forces. To remove disturbing materials, pulpers are equipped with filter screens. Rejected caps, seals and closures, and other non-fibre layers of liquid packaging cartons will be further treated in the PolyAl recycling process.

Washing drums are used to further clean the PolyAl fraction, to accomplish additional fibre recovery and eliminate contamination for the PolyAl recycler.

The repulping process, e.g. the required dwell and pulping time in the pulper for recovering fibres from used liquid packaging cartons, primarily deviates from the repulping process in paper mills with conventional recycling process. A considerably longer repulping time is required for the fibre recovery from LPCs. Additionally, the capacity to remove and process the PolyAl fraction is better in a specialised process compared to the paper mill with conventional recycling process.

PolyAl process

In order to recover the polyolefin and aluminium components (PolyAl) from liquid packaging cartons a number of technologies are currently used. This process is only applied for materials originating from paper mills with specialised recycling process (LPC) recycling used liquid packaging cartons (EN 643 Grade 5.03.00/5.03.01).

Currently, all commercial technologies for recycling of the PolyAl fraction are preserving the molecular structure of the polymer after being mechanically pre-treated (e.g. shredding, washing, cleaning and/or drying) and transformed into the requested end product.

The available processes today treat and process the plastic layer, caps, closures and aluminium foil in the same facility. The available recycling technologies can be classified into two principal types of processes:

- Recycling that produces a composite of plastic and aluminium
- Recycling that produces separated fractions

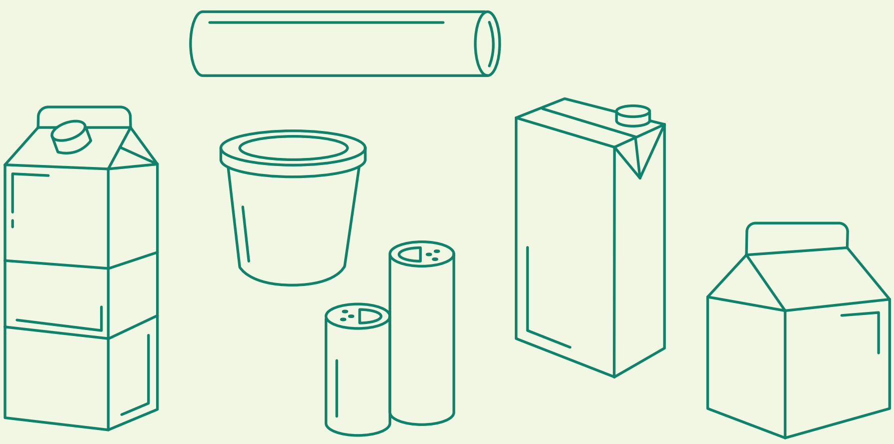
In both cases, it is common practice to separate the soft foil fraction (polymer film and aluminium barrier layers) from the hard plastic fraction (caps, closures, etc.), which is then processed separately into flakes as a mixed polyolefin stream. **The lower the residual fibre in the PolyAl stream, the better the quality of output material from the recycling process.**

In July 2025, the Food and Beverage Carton Alliance (FBCA) published Design for Recycling Guidelines Dedicated to Liquid Packaging Cartons. These guidelines provide well-defined and detailed information and recommendations for designing recyclable liquid packaging cartons, including the PolyAl recycling requirements, mostly for injection moulding applications. The FBCA guidelines therefore complement 4evergreen's own guideline recommendations.

Packaging examples likely to be recycled in paper mills with specialised recycling processes

Rigid packaging

- ✓ Like food and liquid packaging cartons, double-sided coated paper cups
- ✓ Selection of non-fibre material that does not disturb the recovery processes



Flowchart (paper mills with specialised recycling process (LPC))

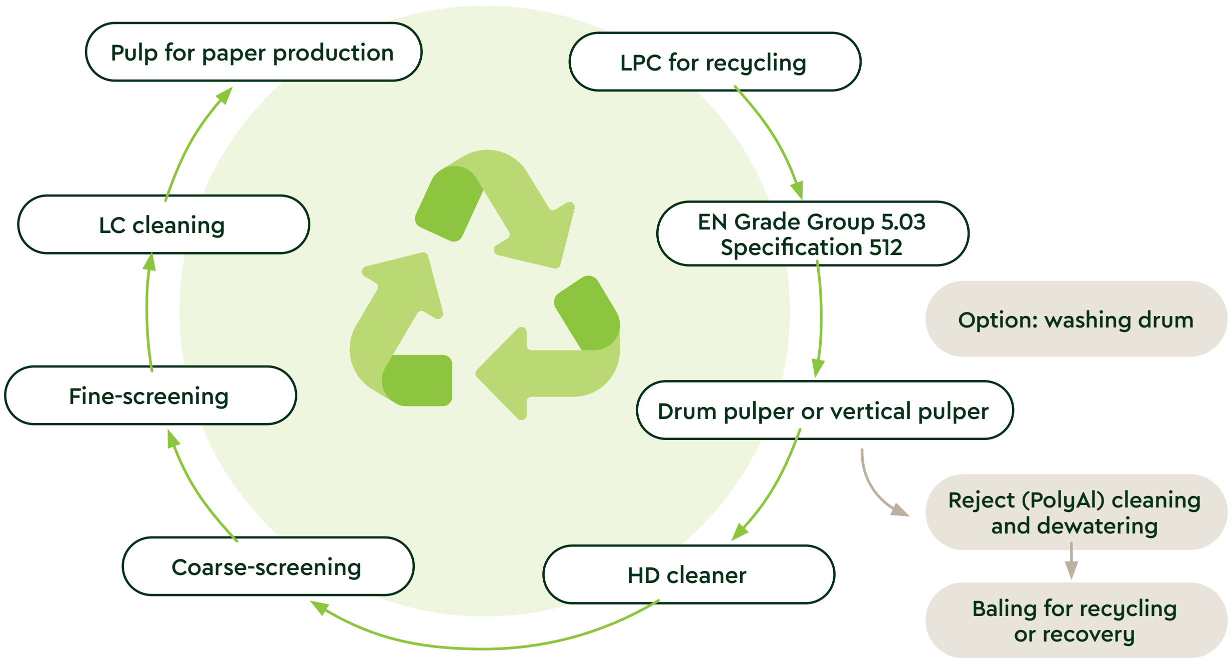


Figure 6. Recycling process in paper mills with specialised recycling process (LPC)

Flowchart recycling process (paper mills with specialised recycling process (FBCP))

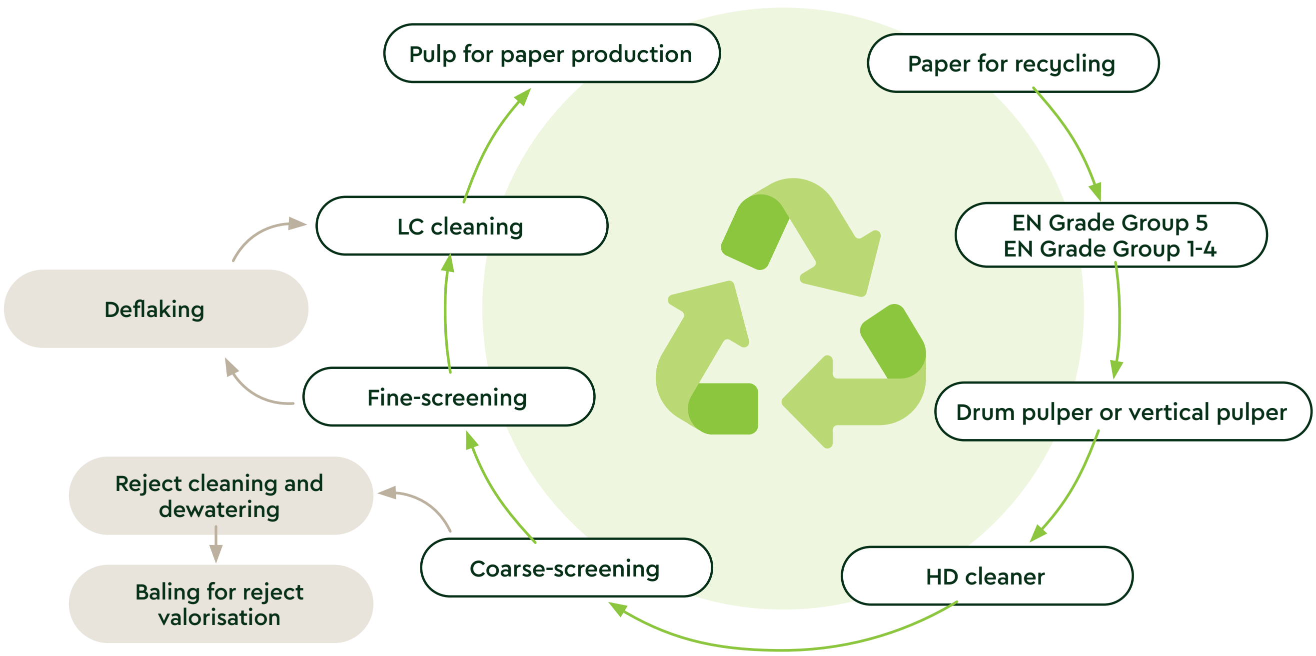


Figure 7. Recycling process in paper mills with specialised recycling process (FBCP)

7.2 Design recommendations (PART III – Paper mills with specialised recycling process (LPC))

This chapter provides specific design recommendations for single packaging groups intended to be recycled in paper mills with specialised recycling process (LPC), to help designers refine their work.

In July 2025, the Food and Beverage Carton Alliance (FBCA) published Design for Recycling Guidelines dedicated to Liquid Packaging Cartons. These guidelines provide well-defined and detailed information and recommendations for designing recyclable liquid packaging cartons, including the PolyAl recycling requirements, mostly for injection moulding applications. The FBCA guidelines therefore complement 4evergreen's own guideline recommendations.

The design recommendations tables in the sub-chapters 7.2.1 to 7.2.6 are applicable for the recycling process in paper mills with specialised recycling processes. The given tables are developed especially for conditions in paper mills with specialised recycling processes for used liquid packaging cartons. In future versions of the Circularity by Design Guideline further design tables will be incorporated, that focus on the paper mills with specialised recycling processes for other types of fibre-based composite packaging not mentioned here.

The design tables provide information for the following constituents or integrated components:

- 7.2.1 Fillers, additives, and agents
- 7.2.2 Barrier coatings and treatments
- 7.2.3 Adhesives
- 7.2.4 Inks and varnishes
- 7.2.5 Decorative Metallic constituents and integrated components
- 7.2.6 Other integrated components

The design tables in this chapter refer to single constituents or integrated components categorised as:

- Fully compatible with LPC recycling processes
- Limited compatibility with LPC recycling processes
- Not compatible with LPC recycling processes
- Compatibility with LPC recycling processes unknown

NOTE: The given design recommendations are widely based on the expert opinion of the entire value chain represented in 4evergreen and are valid for paper mills with specialised recycling processes. Actual testing prevails over the given recommendations in the guideline; therefore the guideline will be updated in line with recyclability lab test results and the corresponding 4evergreen recyclability evaluation protocol (PART III).

7.2.1 Fillers, additives and agents

Specialised recycling process (LPC) (PART III)

Constituent or integrated component		Fully compatible with LPC recycling process[6]	Limited compatibility with LPC recycling process[6]	Not compatible with LPC recycling process[6]	Compatibility with LPC recycling process unknown[6]	Comment
Filler/ Inorganic pigments	Clay (kaolin)	⊗				High ash content may have a negative impact on mechanical strength depending on the relative amount in the PfR stream.
	CaCO3	⊗				
	Talc	⊗				
	Titanium dioxide	⊗				
Binder	S/B latex	⊗				
	S/A latex	⊗				Depending on amount, adhesive strength, etc.
	Starch-biobinder	⊗				
Sizing, wet end	AKD	⊗				
	ASA	⊗				
	Rosin	⊗				
Dry strength	Starch	⊗				
	CMC	⊗				
	Polyacrylamide	⊗				
	Guar gum	⊗				

[6] Including PolyAl recycling.

Specialised recycling process (LPC) (PART III)

Constituent or integrated component		Fully compatible with LPC recycling process[6]	Limited compatibility with LPC recycling process[6]	Not compatible with LPC recycling process[6]	Compatibility with LPC recycling process unknown[6]	Comment
Wet strength	PAE	⊗				If relative wet strength is less than 15%, determined by ensuring dry tensile strength according to ISO 1924-2:2008 and wet tensile strength according to ISO 3781:2011.
	Urea/ Formaldehyde	⊗				Recyclability depends on various factors, such as relative wet-strength (WS) level, amount of WS agent, etc. Recyclability can be improved by increased pulping temperature and time, chemicals, high consistency pulping, etc. Testing is needed to evaluate the recyclability and set thresholds for acceptable levels in the PfR stream.
	Glyoxylated polyacrylamide (GPAM)	⊗				
	Polyvinylamine (PVAm)	⊗				
Sizing, surface	Starch	⊗				
Other	Colorants/dye for shading	⊗				Physically recyclable but certain dyes are not approved for food packaging applications and such dyes should be avoided.
	Colorants/ pigments	⊗				
	Polyvinyl alcohol (PVOH)	⊗				
	PAC	⊗				
	Retention polymers	⊗				
	Siliconising agents			⊗		

Table 17. PART III – Design recommendations fillers, additives and agents

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with specialised recycling processes. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

7.2.2 Barrier coatings and treatments

Barrier coatings and their placement on Liquid Packaging Board help ensure that packaging meets demanding performance criteria. They impact on the recycling process for liquid packaging cartons and also influence the compatibility with sorting technology in light-weight packaging stream and require enhanced technology and recycling equipment in order that they can processed in paper mills with specialised recycling processes. Furthermore, the material composition of barriers is also a deciding factor in how compatible the pulping reject material is with subsequent PolyAl recycling. The following design table covers these aspects, including subsequent PolyAl recycling. 4evergreen summarises industry expertise, in particular guidelines by FBCA for Liquid Packaging Board barrier coatings and their placement. More details, thresholds and information on Liquid Packaging Board, or beverage cartons, is available in the FBCA Design for Circularity Guidelines.

In general terms and for better overall recycling results, barrier content of liquid packaging board should be minimised, fibres should ideally be separable from barrier layers, and barrier material should be 'screenable', and compatible with PolyAl recycling.

Specialised recycling process (LPC) (PART III)

Constituent or integrated component		Fully compatible with LPC recycling process[7]	Limited compatible with LPC recycling process[7]	Not compatible with LPC recycling process[7]	Compatibility with LPC recycling process[7] unknown	Comment
Extrusion barrier coating	Thermoplastic (one side coated, inside the pack only)				⊗	Not relevant in LPC recycling. Packaging with coating only on the inside of the packaging would potentially not be recognised as LPC target material in sorting plants. Please refer to chapter 7.3 Design guidance (Part III - paper mills with specialised recycling process (FBCP))
	Thermoplastics (two sides coated)	⊗[8]				Paper mills with specialised recycling process (LPC) are designed to process two-sided barrier coated paper packaging. Barrier coating needs to be made predominantly of PE, with a possible limited share of PP or other polymers. Thresholds and material compatibility apply, as defined in FBCA Design for Recyclability Guidelines.
Adhesive barrier film	Adhesive lamination with water-soluble adhesives (some types of PVOH, starch, etc.)	⊗				Adhesive lamination with water-soluble adhesives is fully compatible with the LPC recycling process.
	Adhesive lamination (inside of pack) of PET, mPET, PET/PE etc.		⊗	⊗[8]		PET content with <5% share of weight relative to polymer structure is non-desirable but manageable. PET content with with a higher share than 5% relative to polymer structure is not compatible with current subsequent PolyAl recycling.
	Lamination with Alu containing film (Alu/PE)	⊗				Alu/PE lamination is compatible with LPC recycling process. For PET/Alu/PE barriers, please refer to guidance on adhesive lamination containing PET above.

[7] Including PolyAl recycling.
[8] Detailed information on material compatibilities and thresholds as defined in the FBCA Design for Recyclability Guidelines.

Specialised recycling process (LPC) (PART III)

Constituent or integrated component		Fully compatible with LPC recycling process[7]	Limited compatible with LPC recycling process[7]	Not compatible with LPC recycling process[7]	Compatibility with LPC recycling process[7] unknown	Comment
Wet-barrier coatings	Aqueous polymer dispersions (among others some types of acrylics, EEA, SB, ABS, PVDC, etc.)				⊗	Application of materials in LPB products and performance in LPC recycling process is unknown.
	Solvent-based coatings				⊗	Application of materials in LPB products and performance in LPC recycling process is unknown.
	Wax dispersion (incl. microcrystalline waxes)				⊗	Level of compatibility of wax-coated LPB products needs to be determined with a recycling test.
	Water soluble coatings (among others some types of PVOH, EVOH EVA Biobased, etc.)				⊗	Application of materials in LPB products and performance in LPC recycling process is unknown.
Wax coatings	Dipping of paper in molten wax (two-sided)				⊗	Not relevant in LPC recycling. Please refer to chapter 7.3 Design guidance (Part III – paper mills with specialised recycling process (FBCP)).
Barrier metallisation	Direct metallisation on paper (primer, Alu nanoscale, protective coating) – inside	⊗ [8]				Vapour deposition of thin-layer metallisation can be applied. Thresholds and material compatibility as defined in FBCA DfR Guidelines apply.
	Direct metallisation on polymer (Primer, Alu/AlOx/SiOx nanoscale, protective coating) – inside	⊗ [8]				Vapour deposition of thin layer metallisation can be applied. Thresholds and material compatibility as defined in FBCA DfR Guidelines apply.
	Transfer metallisation (adhesive + transfer metallisation) – inside				⊗	Not relevant in LPC recycling. Packaging with coating only on the inside of the packaging would potentially not be recognised as LPC target material in sorting plants. Please refer to chapter 7.3 Design guidance (Part III – paper mills with specialised recycling process (FBCP)).

Table 18. PART III – Design recommendations barrier coatings and polymer content

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with specialised recycling processes. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

[7] Including PolyAl recycling.
[8] Detailed information on material compatibilities and thresholds as defined in the FBCA Design for Recyclability Guidelines.

7.2.3 Adhesives

The following design table aims to give a compact overview of the most typically used adhesives in the industry. However, other applications / chemistries exist that also fulfil the technical and recyclability requirements.

Specialised recycling process (LPC) (PART III)

Constituent or integrated component		Fully compatible with LPC recycling process[9]	Limited compatible with LPC recycling process[9]	Not compatible with LPC recycling process[9]	Compatibility with LPC recycling process[9] unknown	Comment
Bonding of supplements	Hotmelt	⊗ #				# For hotmelts with suitable softening point (higher than 68°C according to DIN EN 1427:2015) and applied larger than 2mm in diameter (see EPRC scorecard for the removability of adhesives). § Polyurethane is not compatible with polyolefins and PolyAl recycling. Polyurethane Hotmelt should be limited. * Only valid for materials with a positive rating according to Cepi recyclability laboratory test method, 2022. Existing positive results obtained until 2030 according to the legacy methods such as but not limited to Aticelca MC501:2019, Cyclos-HTP CHI-PTS-C6/2.0, INGEDE 12 and PTS-RH:021/97 should also be accepted. **Please note** that the adhesives design table should be considered 'non-exhaustive' and does not cover all potential options or market solutions. This section will be further developed and extended version will be provided in the next issue of the guideline
	Polyurethane Hotmelt	⊗	⊗ §			
Cap/straw attachment for beverage cartons	Hotmelt	⊗ #				
Multipack attachment	Hotmelt	⊗ #			⊗	
	Pressure sensitive hotmelt				⊗	
	Pressure sensitive emulsion acrylics	⊗ *				
Pressure sensitive applications (self-adhesive labels)	Pressure sensitive emulsion acrylics	⊗ *				
	Pressure sensitive hotmelt	⊗ *				
	Pressure sensitive UV-curable acrylic adhesives	⊗ *				
	Water-based adhesives	⊗ *				
Water-based labelling	Protein glues				⊗	
	Acrylic				⊗	

Table 19. PART III – Design recommendations adhesives

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with specialised recycling processes. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

[9] Including PolyAl recycling.
[10] All beverage cartons in use and being recycled today employ hotmelts for cap and straw attachment.

7.2.4 Inks and varnishes

In order to assess the compatibility of inks and varnishes in paper mills with specialised recycling processes, two different cases in applying them on liquid packaging board have to be considered:

Case 1 – Inks and varnishes are applied to the board: The main technology used is water-based inks and varnishes for flexographic printing. As board is mechanically separated from other non-fibre constituents and integrated components in the recycling process the same recyclability evaluation applies as for paper mills with conventional recycling process.

Case 2 – Inks and varnishes are applied on outer PE-layer: The main technologies used are solvent-based inks and varnishes for gravure printing and radiation-curing inks and varnishes for offset and flexographic printing. Because of the mechanical separation of the PE-layer and board, ink and varnish particles remain in the reject mix. Therefore, a recyclability evaluation does not apply here. There is some probability that ink and varnish particles unintentionally detached from the PE-layer may be found in the pulp. In this case the recyclability evaluation for paper mills with conventional recycling process applies.

Specialised recycling process (LPC) (PART III)

Constituent or integrated component		Fully compatible with LPC recycling process[11]	Limited compatible with LPC recycling process[11]	Not compatible with LPC recycling process[11]	Compatibility with LPC recycling process[11] unknown	Comment
Offset	Oil-based (mineral)		⊗			Not relevant for LPC-recycling. Inks based on mineral oils are fully compatible with the recycling process. Due to legal restrictions, the use of the recovered fibres is limited to non-food applications. Therefore, the use of mineral oil-based inks is not recommended for food-applications.
	Oil-based (vegetable)	⊗				
	Ultra-violet cured/EB-cured		⊗			This printing technique and ink combination is fully compatible with fibre recovery processes, but its influence on some PolyAl recycling processes when print is applied directly to the outer LDPE layer may require further investigation.
Flexo	Solvent-based	⊗				
	Water-based	⊗				
	Ultra-violet cured		⊗			This printing technique and printing ink combination is fully compatible with fibre recovery processes, but its influence on some PolyAl recycling processes when print is applied directly to the outer LDPE layer may require further investigation.
Gravure	Solvent-based	⊗				
	Water-based	⊗				
	Ultra-violet cured				⊗	This printing technique and printing ink combination is fully compatible with fibre recovery processes, but its influence on some PolyAl recycling processes when print is applied directly to the outer LDPE layer may require further investigation.
Varnish	Solvent-based	⊗				
	Water-based	⊗				
	Ultra-violet cured		⊗			This printing technique and printing ink combination is fully compatible with fibre recovery processes, but its influence on some PolyAl recycling processes when print is applied directly to the outer LDPE layer may require further investigation.
	Two component	⊗				

[11] Including PolyAl recycling.

Specialised recycling process (LPC) (PART III)

Constituent or integrated component		Fully compatible with LPC recycling process[11]	Limited compatible with LPC recycling process[11]	Not compatible with LPC recycling process[11]	Compatibility with LPC recycling process[11] unknown	Comment
Digital[12]	Water-based	⊗				
	Ultra-violet cured				⊗	This printing technique and printing ink combination is fully compatible with fibre recovery processes, but its influence on some PolyAl recycling processes when print is applied directly to the outer LDPE layer may require further investigation.
	Liquid toner	⊗				
	Solid toner	⊗				
	Hotmelt				⊗	Testing is required.
Screen	Ultra-violet cured		⊗			This printing technique and printing ink combination is fully compatible with fibre recovery processes, but its influence on some PolyAl recycling processes when print is applied directly to the outer LDPE layer may require further investigation.
Binders in ink systems	Nitrocellulose (NC) based inks	⊗ #	⊗ *			# 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			⊗		
	Other chlorinated binders			⊗		

Table 20. PART III – Design recommendations inks and varnishes

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with specialised recycling processes. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

[12] Digital printing technologies emerging; continuous surveillance required.

7.2.5 Decorative metallic constituents and integrated components

Metallic integrated components and constituents with a thickness lower 1 micron are not causing any issue during the LPC recycling process, but the recognition of these papers during the sorting process could be impacted if only an NIR detection system is in place, as the metallic effect reflects the NIR light.

Paper fully printed with black inks containing carbon black pigments, may also impact the sorting, if only an NIR detection system is in place, as these pigment types adsorb the NIR light.

Paper laminated with metallised PET film has shown limited compatibility with the LPC recycling process. Moreover, if the surface is fully laminated to a metallised film, this may impact the sorting, if only an NIR detection system is in place.

To mitigate this issue, it is recommended to:

- Minimise the percentage of metallised PET film laminates used; it is recommended to use hot stamping or cold transfer or lamination of direct vacuum metallised paper.
- Minimise the use of carbon black pigments; it is recommended to use black inks not containing these pigments.

Specialised recycling process (LPC) (PART III)

Constituent or integrated component		Fully compatible with LPC recycling process[13]	Limited compatible with LPC recycling process[13]	Not compatible with LPC recycling process[13]	Compatibility with LPC recycling process[13] unknown	Comment
Decorative metallic constituents and integrated components	Hot and cold transfer	⊗				Designers should not cover the surface of fibre-based products fully with metallisation, as this could cause issues identifying or detecting fibre products.
	PP/PET metallised laminates			⊗		Since PET content share should be lower than 5% to be compatible with current PolyAl recycling, PET laminates for decorative purposes should be avoided.
	PET metallised film			⊗		Since PET content share should be lower than 5% to be compatible with current PolyAl recycling, PET laminates for decorative purposes should be avoided.
	Direct vacuum metallised paper		⊗			The outside metallisation could affect the sorting process (if NIR is used for detecting the metallised side).
	Direct metallisation		⊗			Designers should not cover the surface of fibre-based products fully with metallisation, as the outside metallisation could affect the sorting process (if NIR is used for detecting the metallised side).

Table 21. PART III – Design recommendations decorative metallic constituents and integrated components

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with specialised recycling processes. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

[13] Including PolyAl recycling.

7.2.6 Other Integrated Components

The following design table aims to provide a compact overview of typical components used to improve the functionality of paper-based packaging. The design is applicable for recycling in paper mills with specialised recycling processes, including the subsequent PolyAl procedure.

Specialised recycling process (LPC) (PART III)

Integrated Component		Fully compatible with LPC recycling process[14]	Limited compatibility with LPC recycling process[14]	Not compatible with LPC recycling process[14]	Compatibility with LPC recycling process[14] unknown	Comment
Caps and closures	PE	⊗ [15]				Thresholds and material compatibility apply, as defined in FBCA DfR Guidelines.
	PP	⊗ [14]				
	PET			⊗ [14]		
	Biodegradable polymers			⊗		
Spouts	PE	⊗ [14]				
	PP	⊗ [14]				
	Metal			⊗		
Straw	Fibre-based	⊗				Consumers should be encouraged to push the straw into the packaging, after consumption.
Protective wrapper	Fibre-based	⊗				
	PE (fossil-based and bio-based)	⊗				
	PP (fossil-based and bio-based)	⊗				Due to the low mass percentage of protective wrappers, it is not foreseen that PP has a negative impact on the PolyAl recycling process.
	PET			⊗		

Table 22. PART III – Design recommendations other integrated components

NOTE: The given design recommendations are based on expert opinion and valid for recycling in paper mills with specialised recycling processes. Ongoing testing (i.e. 4evergreen Recyclability Evaluation Protocol) is likely to supersede the present recommendations and inform a future update of the guideline.
The behaviour in the recycling process may depend on the chemistry and the formulation of the constituents or integrated components, thus the design recommendations given here cannot cover all existing possibilities of material types. A recyclability test is recommended to determine the exact behaviour of each material.
Please be aware that the recommendations in the design tables only refer to the compatibility with recycling of the constituents or integrated components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

[14] Including PolyAl recycling.
[15] Detailed information on material compatibilities and thresholds as defined in the FBCA Design for Recyclability Guidelines.

7.3 Design guidance (Part III – paper mills with specialised recycling process (FBCP))

Recycling in paper mills with specialised recycling process (FBCP)

The recycling of paper-based packaging would require a specialised fibre recycling process when the functionality and/or complexity of the packaging is increased by additional integrated components or constituents, or when higher pulp quality is required for the end product of the recycling process. Certain paper-based packaging would require a specialised recycling process when added functionality of packaging is required for the products to be contained, such as hygiene requirements and food safety measures that they are not suitable for processing in paper mills with conventional recycling process.

Paper mills with specialised recycling process (FBCP) can process EN 643 Grade 5 papers, and some from Grades 1-4.

These fractions include packaging that, due to their composition, are more suitable for re-processing in paper mills with specialised recycling processes, e.g. Kraft sacks with a plastic layer and polymer liner

These paper mills are designed to handle materials that need longer pulping times and gentle slushing to avoid cutting off the reject, or that have higher amounts of reject. These facilities employ advanced technology and equipment to process materials that paper mills with conventional recycling process cannot handle. This allows them to recycle packaging that includes other integrated components or requires higher pulp quality for the product.

EN 643 includes standards for various paper grades, such as 5.03.00 for used liquid packaging board and 5.14.00 for used paper cups. However, it does not always clearly define new fibre-based composite packaging, especially those replacing plastic.

These composite materials often contain non-paper components, and their recyclability depends on the presence of enhanced equipment. The input requirements for paper mills with specialised recycling processes focus on the quality and type of fibre and the quantity of non-paper integrated components needing removal. Despite their advanced capabilities, these mills have limitations on the range of input materials they can accept, influenced by the end-market needs for recovered pulp and the quality of end products produced with this pulp.

In the development of 4evergreen's deliverables (Circularity by Design Guideline and Recyclability Evaluation Protocol), it has been noticed that the specialised processes for FBCP varies significantly.

The processes of these mills highly depend on the incoming raw material and the targeted output quality after the recycling process.

Given this complexity, this chapter offers general design guidance for fibre-based composite packaging unlike detailed design recommendation tables provided in Chapter 7.2. Design Recommendation Tables (Part III-LPC).

To ensure that fibre-based composite packaging which cannot be handled in conventional processes or in paper mills with specialised recycling process (LPC), can be recycled effectively in paper mills with specialised recycling process for FBCP certain general rules apply:

- Design to increase the paper content
- Enhance the sorting efficiency by not using integrated components causing issues during the sorting process, to increase recycling effectiveness.

8. SORTING DISRUPTORS

Sorting disruptors in paper packaging

The sorting of household and similar packaging waste in the EU depends largely on the collection systems implemented in each Member State. In cases where post-consumer packaging is sent to materials recovery facilities (MRFs), a combination of mechanical and optical technologies separates mixed waste into distinct material streams. The output is typically compacted into bales for recycling.

However, the availability and sophistication of sorting technologies, both hardware and software, are not consistent across the EU. This means that not all household and similar paper-based packaging are treated in the same way.

Importance of designing for sortability

Despite these regional variations, designing packaging for sortability remains essential. Doing so ensures that paper-based packaging can be correctly recognised and separated where such systems are in place, while also reducing the risk of cross-contamination if misclassified in MRFs. Importantly, designing for sortability does not compromise recyclability in markets where certain sorting technologies are not yet used. By contrast, failing to design for sortability risks losing valuable recyclable material and contaminating other recycling streams, particularly in regions where sorting is critical to directing packaging to the appropriate stream. Therefore, paper-based packaging should be designed for sortability.

Common sorting challenges

Many paper-based packaging formats are already quite sortable within existing MRFs. However, when such packaging includes sorting disruptors, such as large integrated plastic components, NIR-reflective or absorbing inks, pigments or features such metallic coatings with high surface coverage, sortability may be compromised.

Numerous studies have investigated such sorting disruptors in packaging, with the majority focusing on plastic packaging due to its broader reliance on the sorting step. However, some of these studies yield varying thresholds and differing conclusions. Some of these factors may also apply to household paper-based packaging, but not all due to characteristic differences between materials such as translucency or sorting needs, where certain plastic types must be sorted based on colour, which is not the case for paper-based packaging.

To support robust recyclability assessments, there is a clear need to identify and evaluate disruptors that are specific to paper-based packaging. Establishing evidence-based thresholds will help ensure that packaging is both recyclable and compatible with state-of-the-art sorting technologies and practices.

Practical guidance

The following tables provide a first screening tool to highlight disruptors particularly relevant for paper packaging.

As a **general rule**, packaging that does not contain any of the listed disruptors can be considered *sortable*. Where disruptors are present, however, targeted testing is recommended to confirm compatibility with sorting systems.

Component/ constituent	Sorting disruptor	Note
Inks/pigments	Metal pigments applied over a large area on outer surface [1], [2]	If applied over a large surface, metallic coatings reflect or scatter the near-infrared light used by optical sorting systems, while carbon black absorbs it, preventing the sensors from detecting and correctly identifying. However, this shall be further investigated with a harmonised sorting protocol, where relevant. Several studies indicate >50% surface coverage or when printing small areas beneath each other a total area coverage of >50% can still be compatible with sorting.
	Carbon black inks that cover large portion of the surface area [1], [2]	
	Dark dyed pulp (including carbon black) [1], [2]	Black-dyed pulp is a sorting disruptor because the carbon black absorbs most of the near-infrared light used by optical sorting systems, leaving insufficient reflected signal for sensors to distinguish the pulp's material type, causing it to be misidentified or rejected during automated sorting. However, this shall be further investigated with harmonised sorting protocol, where relevant.
Ferromagnetic components	Integrated ferromagnetic component [1]	Integrated ferromagnetic components can trigger false metal detections or stick to magnetic separators. This can be considered relevant when weight of the component in relation to paper-based packaging is more than 5% as a preliminary guidance. However, this shall be further investigated with harmonised sorting protocol, where relevant.
Aluminium foil layer	Aluminium foil layer applied over a large area on outer surface [1], [2]	Both aluminium foil layers and vacuum metallisation applied to the outer surface of the paper-based packaging can be sorting disruptors if applied over a large surface because their highly reflective metallic surfaces scatter or reflect near-infrared and visible light, preventing optical sensors from detecting the underlying material and causing the item to be misclassified or rejected in automated sorting systems. However, this shall be further investigated with harmonised sorting protocol, where relevant. Several studies indicate >50% surface coverage.
Vacuum metallisation	Metallised paper surface applied over a large area on outer surface [3]	
Coatings	Thick outer surface plastic coatings [1], [2]	Thick outer-surface plastic coatings are sorting disruptors because they shield the underlying material from optical or NIR sensors, preventing the system from detecting the substrate's spectral signature and causing the item to be misidentified or rejected during automated sorting. Non-exhaustive studies highlight that up to 40 µm outer surface coating allows successful detection.[16] This shall be further investigated with harmonised sorting protocol, where relevant
	Inner plastic coatings when paper is too thin [1], [2]	Inner plastic coatings on very thin paper are sorting disruptors because the thin paper allows the sensor to detect the plastic layer rather than the paper substrate, causing optical or NIR systems to misclassify the material and sort it incorrectly. This shall be further investigated with harmonised sorting protocol, where relevant
Integrated components (such as window)	Non-paper based integrated components that cover a large area on outer surface [3]	Integrated components, such as plastic windows, are sorting disruptors because they introduce materials with different optical or physical properties than the main substrate, causing sensors to misread the packaging composition and leading to misclassification or rejection during automated sorting. This shall be further investigated with harmonised sorting protocol, where relevant.
Design	Liquid packaging cartons that have outer layer different than PE/paperboard combination or PP/paperboard combination [1], [2], [3]	When the outer layer of LPCs, or fibre-based composite packaging with material structure and composition corresponding to liquid packaging cartons that deviates from the standard PE/paperboard or PP/paperboard combinations, it can affect sorting in MRFs, as optical and NIR sensors rely on the characteristic spectral 'fingerprint' of these standard structures for accurate identification. LPCs with nonstandard outer layers may not produce the expected NIR signature, so their compatibility with sorting must be verified.

Table 23. Sorting disruptors

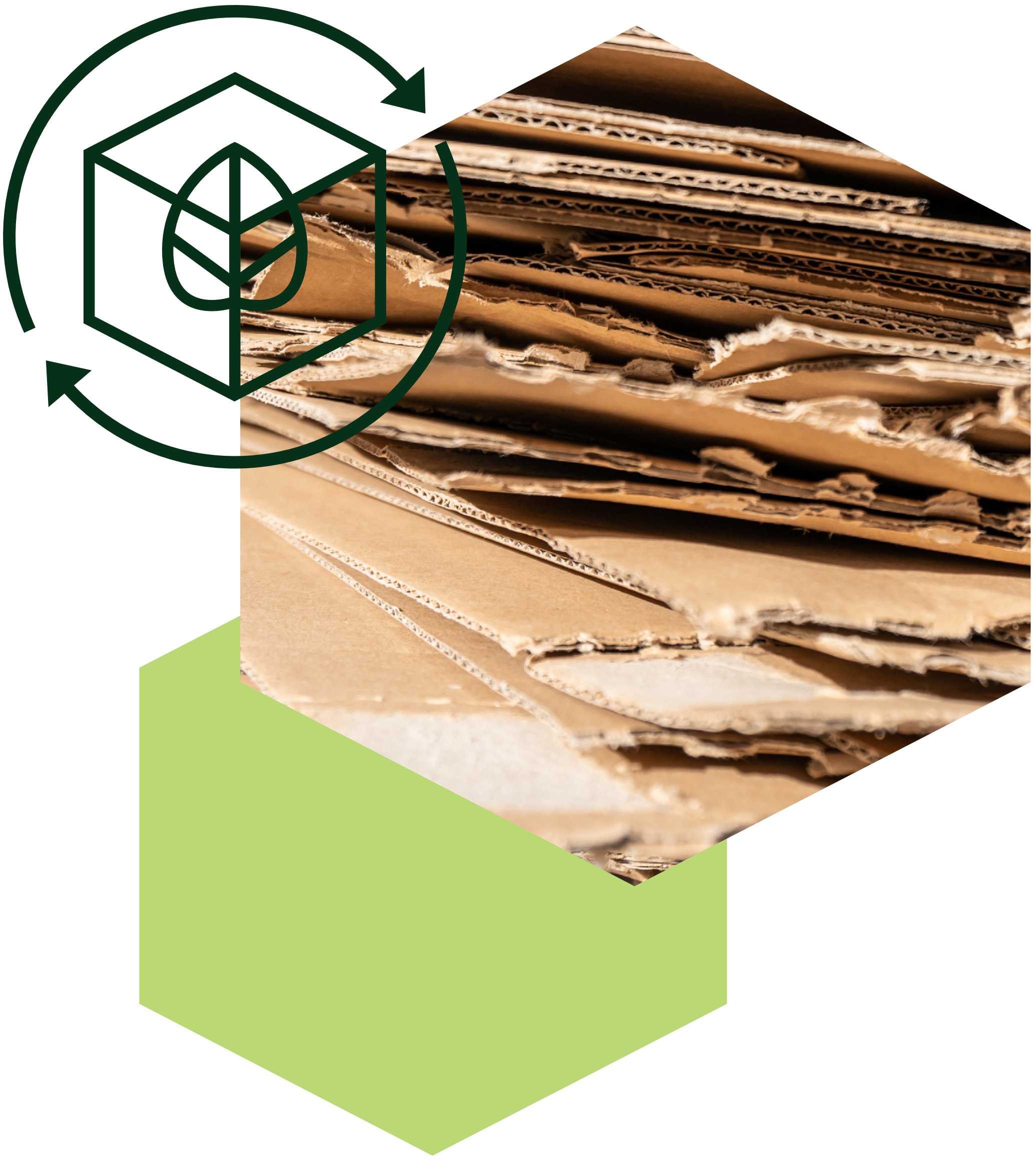
16 Typical protective and decorative lacquers, as they are applied in printing presses, are below this value.

The information provided herein is derived from non-exhaustive internal testing results and reflects the key insights of the referenced sources. It is important to note, however, that a harmonised sorting protocol is necessary to comprehensively evaluate the sorting disruptors identified above, with the objective of establishing more robust thresholds to guide designers. Currently, the protocols used across the industry may vary, resulting in minor differences in thresholds; notwithstanding, the general conclusions remain valid. Furthermore, as sorting is an inherently dynamic field, this information is intended to offer preliminary guidance to designers regarding sorting-relevant considerations. Updates shall be provided as appropriate, and further testing is recommended where necessary to ensure accuracy and applicability.

[1] *Minimum Standard for Determining the Recyclability of Packaging Subject to System Participation pursuant to Section 21 (3) VerpackG*, 2025.

[2] *Recyclability Guidelines and Assessment (CHI – cyclos-HTP Institute), Version 6.1.*

[3] *Circular Packaging Design Guideline: Design Recommendations for Recyclable Packaging,* FH Campus Wien, Version 6.



9. DESIGN FOR RECYCLING (D4R) CHECKLIST

The primary aim of this Design for Recycling Checklist is to offer a systematic, step-by-step approach to ensure thorough consideration and evaluation of all relevant variables in the design of recyclable packaging. The checklist helps to minimise the need for extensive testing especially for products that only include materials from the green column. streamlining the process and maximising efficiency.

It is important to acknowledge that while the D4R checklist in combination with the recommendations in the current document, provides guidance, it may not encompass all conceivable material types or scenarios. However, by adhering to its principles and adapting as necessary, designers can still achieve recyclability outcomes.

The D4R checklist will be updated with new results of the recyclability evaluation protocol and findings of the updated version of the guidance for improved collection and sorting.

Quick start: The step-by-step approach will lead users of the design guidelines to an estimation of whether the packaging can be considered designed for recycling by asking several questions regarding the composition of the packaging (based on the recommendations in the guideline). This decision tree is valid for all packaging that can be recycled in paper mills with conventional recycling process, paper mills with flotation-deinking recycling process, or paper mills with specialised recycling process.

Prerequisite for the use of the D4R checklist: To estimate the design for recycling compatibility of a packaging, indicate if the packaging design involves a separation of components. If so, consider each separate component as a separate item for the design for recycling check.

Separation of components involves packaging component that is distinct from the main body of the packaging unit and that is typically discarded prior to and separately from the packaging unit (Article 3(43)) and integrated component (Article 3(42)) that does not need to be separated from the main packaging unit in order to ensure its functionality and is typically discarded at the same time as the packaging unit, although not necessarily in the same disposal route.

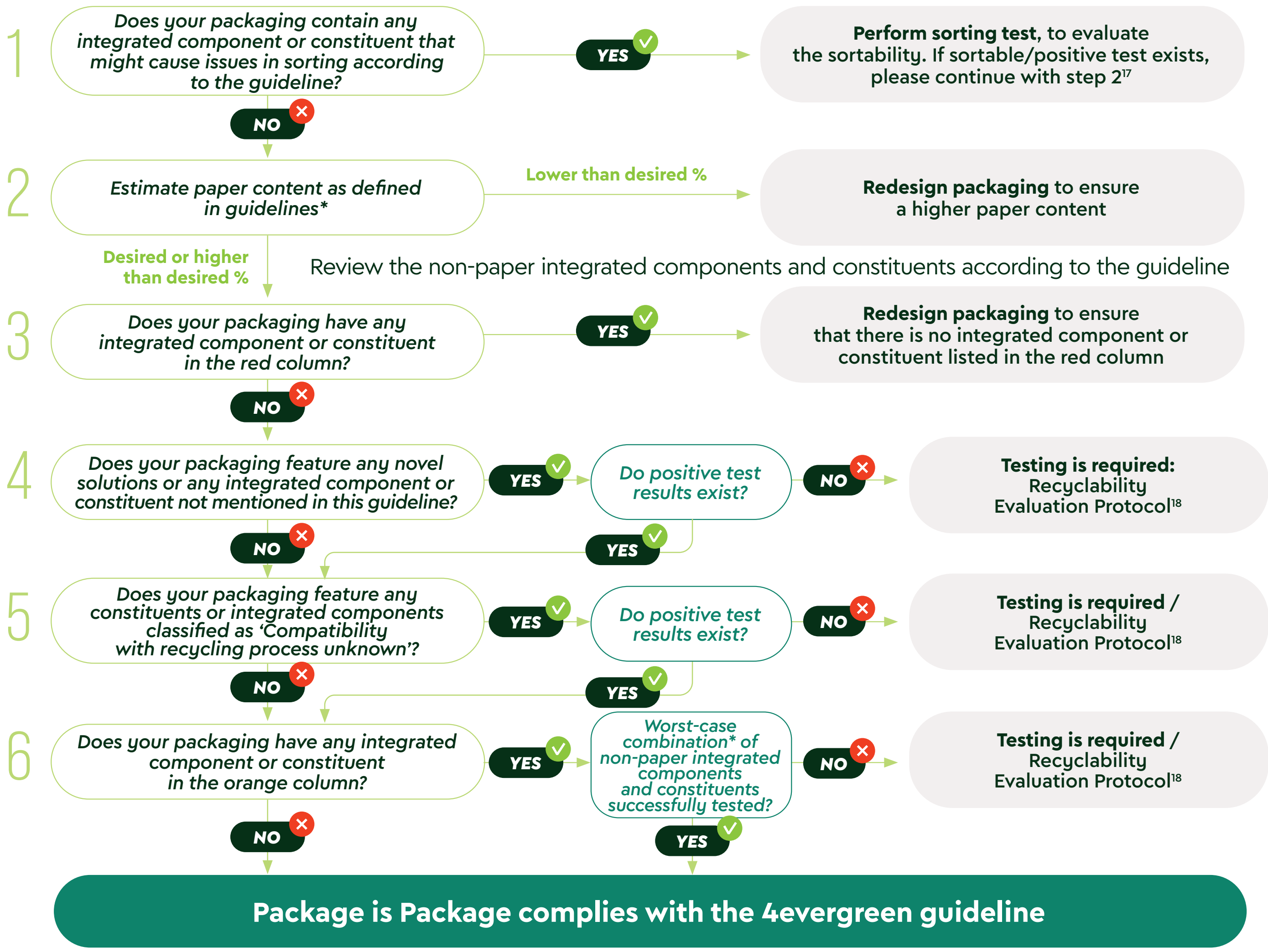


Figure 8. Design for Recycling Checklist

[17] As a 4evergreen specific sorting protocol for paper-based packaging is not available, existing sorting protocols could be utilised to determine whether similar effects are present in paper-based materials.

[18] Please refer to the current available test methods and recyclability evaluation protocols for the dedicated mill type provided by 4evergreen. The D4R checklist will be updated as soon as further methods become available.

1| When determining if paper-based packaging can be considered designed for recycling, the behaviour of the packaging in paper mills, as well as its sorting behaviour, must be considered. Hence, the D4R checklist aims to indicate if the packaging contains any constituents that could pose issues with regard to state-of-the-art sorting techniques (e.g. eddy-current or NIR).
Example: see 5.2.5 Decorative metallic constituents and integrated components

4evergreen is currently investigating the impact of various non-paper integrated components on the sorting process. As a 4evergreen-specific sorting protocol for paper-based packaging does not exist, existing sorting protocols could be utilised to determine whether similar effects are present in fibre-based materials.

2| To determine if the packaging can be recycled effectively in the dedicated paper mill type, a minimum (paper) content must be considered to guarantee sufficient volume for milling. According to 4evergreen's Recyclability Evaluation Protocol for paper mills with conventional recycling process, a minimum of 80% paper content must be ensured; any lower would theoretically fail to comply with the conventional recycling process evaluation. This question will be updated as soon as the testing methods and corresponding recyclability evaluation protocols from 4evergreen are available.

3| If packaging features any constituents or integrated components in the red category, it is not designed for recycling. Therefore, the D4R checklist advises redesigning the packaging to feature only constituents or integrated components listed in the green column or carefully considered constituents or integrated components from the 'limited compatibility' column.

4| The given design recommendations in the guideline are widely based on expert opinion of the entire value chain represented in 4evergreen and can only represent a picture of the status at the time of publication. Anything that might be classified as 'unknown' might be resolved by relevant testing.

5| It is important to acknowledge that this guideline may not encompass all conceivable constituent or integrated component types or scenarios, including those in development.

If positive recyclability evaluation test results for this type of constituent or integrated component combination already exist, proceed to the next question.

If there is no recyclability information available about the behaviour of such a constituent or integrated component combination, recyclability testing with the currently available test methods and recyclability evaluation protocols for the dedicated recycling process provided by 4evergreen is required.

6| This question aims to determine if the packaging design is likely to be recyclable by considering the worst-case scenario of a packaging combination (e.g. 20g non-paper-content and 80g paper content). If the worst-case combination is recyclable, then less stringent combinations of the same materials should be as well, thus reducing the need for extensive testing.

10. GLOSSARY

Chemical pulp
Pulp obtained by a chemical treatment in which a considerable part of non-carbohydrate (lignin and other plant extractives) is removed from the fibre matrix.

Collection
'Collection' means the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility (Source: Regulation (EU) 2025/40).

Composite packaging
A unit of packaging made of two or more different materials which are part of the weight of the main packaging material and cannot be separated manually and therefore form a single integral unit, unless one of the materials constitutes an insignificant part of the packaging unit and in any event no more than 5 % of the total mass of the packaging unit and excluding labels, varnishes, paints, inks, adhesives and lacquers; this is without prejudice to Directive (EU) 2019/904.

Compostable packaging
Packaging that biodegrades in industrially controlled conditions or that is capable of undergoing biological decomposition in such conditions, including through anaerobic digestion, but not necessarily in a home-composting environment, combined, if necessary, with physical treatment, resulting ultimately in the conversion of the packaging into carbon dioxide or, in the absence of oxygen, methane, and mineral salts, biomass and water, and that does not hinder or jeopardise the separate collection and the composting and anaerobic digestion process (Source: Regulation (EU) 2025/40).

Contact-sensitive packaging
packaging that is intended to be used for products falling within the scope of Regulations (EC) No 1831/2003 of the European Parliament and of the Council, (EC) No 1935/2004, (EC) No 767/2009 of the European Parliament and of the Council, (EC) No 1223/2009 of the European Parliament and of the Council, (EU) 2017/745, (EU) 2017/746, (EU) 2019/4 of the European Parliament and of the Council or (EU) 2019/6, or of Directives 2001/83/EC, 2002/46/EC of the European Parliament and of the Council or 2008/68/EC, or for products as defined in Articles 1 and 2 of Commission Decision (EU) 2023/1809) (Source: Regulation (EU) 2025/40).

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

Corrugated board
Board consisting of one or more plies of fluted paper glued to a flat board.

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

Design for recycling
The design of packaging, including individual components of packaging, that ensures the recyclability of the packaging with established collection, sorting and recycling processes proven in an operational environment (Source: Regulation (EU) 2025/40).

Fibre-based composite packaging (FBCP)
Packaging composed of paper and a considerable share of non-paper integrated components and constituents that by design are not separated after use.

High-quality recycling
Any recycling process which produces recycled materials that are of equivalent quality to the original materials, based on preserved technical characteristics, and that are used as a substitute to primary raw materials for packaging or other applications where the quality of the recycled material is retained (Source: Regulation (EU) 2025/40).

Innovative packaging
A form of packaging that is manufactured using new materials, resulting in a significant improvement in the functions of the packaging, such as the containment, protection, handling, or delivery of products, and in overall demonstrable environmental benefits, with the exception of packaging that is the result of modification to existing packaging for the main purpose of improving the presentation of products and marketing (Source: Regulation (EU) 2025/40).

Integrated component
A packaging component, whether or not of the same material as, or distinct from, the main body of the packaging unit, that is integral to the packaging unit and its functioning, that does not need to be separated from the main body of the packaging unit in order to ensure the functionality of the packaging unit and that is typically discarded at the same time as the main body of the packaging unit, although not necessarily via the same disposal route (Source: Regulation (EU) 2025/40).

Material recycling
Any recovery operation by which waste materials are reprocessed into materials or substances, whether for the original or other purposes, with the exception of

biological treatment of waste, reprocessing of organic material, energy recovery and reprocessing into materials that are to be used as fuels or for backfilling operations (Source: Regulation (EU) 2025/40).

Mechanical pulping
High-yield pulp in which defibration is achieved intentionally by means of mechanical energy. Among pulps of this category are refiner mechanical pulp, groundwood pulp, pressurised groundwood pulp, thermo-mechanical pulp, chemi-mechanical pulp, chemi-thermomechanical pulp and bleached chemi-thermomechanical pulp.

Multiply board
Paper or board consisting of more than three furnish layers combined together during manufacture (ISO 4046-3:2016).

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

Packaging
An item, irrespective of the materials from which it is made, that is intended to be used by an economic operator for the containment, protection, handling, delivery or presentation of products to another economic operator or to an end user, and that can be differentiated by packaging format based on its function, material and design, including:
(a) an item that is necessary to contain, support or preserve a product throughout its lifetime, without being an integral part of the product, and which is intended to be used, consumed or disposed of together with the product;
(b) a component of, and ancillary element to, an item referred to in point (a) that is integrated into the item;
(c) an ancillary element to an item referred to in point (a) that is hung directly on, or attached to, the product and that performs a packaging function, without being an integral part of the product, and which is intended to be used, consumed or disposed of together with the product;
(d) an item that is designed and intended to be filled at the point of sale in order to dispense the product, which is also referred to as 'service packaging';
(e) a disposable item that is sold and filled or designed and intended to be filled at the point of sale and which performs a packaging function;
(f) a permeable tea, coffee or other beverage bag, or soft after-use system single-serve unit that contains tea, coffee or another beverage, and which is intended to be used and disposed of together with the product;
(g) a non-permeable tea, coffee or other beverage system single-serve unit intended for use in a machine and which is used and disposed of together with the product
(Source: Regulation (EU) 2025/40).

Packaging minimisation
Packaging that is designed so that its weight and volume is reduced to the minimum necessary to ensure its functionality to protect the product and meet legal requirements, taking account of the shape and material from which the packaging is made.
Note: Packaging minimisation requirements are described in article 10 of the EU Packaging and Packaging Waste Regulation.

Packaging unit
A unit, including any integrated or separate components, which as a whole serves a packaging function, such as the containment, protection, handling, delivery, storage, transport or presentation of products, and includes independent units of grouped or transport packaging where they are discarded prior to the point of sale (Source: Regulation (EU) 2025/40).

Packaging waste
Any packaging or packaging material that is waste, with the exception of production residues (Source: Regulation (EU) 2025/40).

Paper
Range of materials in the form of a coherent sheet or web, made by deposition of pulp from a fluid suspension onto a suitable forming device. Pulp fibres are generally of vegetable origin, typically cellulose. For specialties, other origins are possible. In the generic sense, the term "paper" may be used to describe both paper and board as well as moulded pulp products. 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. Papers may be coated, impregnated or otherwise converted, during or after their manufacture, without necessarily losing their identity as paper. In conventional papermaking processes, the fluid medium is water; new developments, however, include the use of air and other fluids. Sheets or laps of pulp as commonly understood for paper making or dissolving purposes are excluded.

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

Paper mill with conventional recycling process
Paper mills with conventional recycling process typically produce high quality end-products based on EN 643 groups 1 to 4. In large paper mills, high consistency drum pulpers are common. Often such processes operate deflakers to separate fibre bundles into individual fibres, as well as coarse and fine screening cleaners. The aim is to separate the fibre from the other material. The final result is fibrous material suspended in water ready for papermaking (=recycled pulp).

Paper mill with specialised recycling process
Paper mills with specialised recycling processes treat a mix of special grades (group 5 of EN 643) and grades from other groups (1-4 from EN 643). Each paper mill determines the optimal mix and adds one or more piece of dedicated equipment, such as a horizontal high consistency drum pulper, a separate batch pulper with longer pulping time, de-inking, fine cleaners, hot dispersion, special process and waste water systems.

Paper mills with specialised recycling processes can treat paper-based packaging that has been coated with non-water soluble products such as wax, plastic film or other layers such as aluminium, polyester and polyethylene entering the recycling process in homogeneous lots. Some paper mills with specialised recycling processes can also treat wet-strength grades (labels).

In order to optimise the recycling process, fibre-based composite packaging, which cannot be handled in paper mills with conventional recycling process, should be delivered to specialised paper mills in EN 643 identified flows. As in paper mills with conventional recycling process, the result of the process is also very high quality fibrous material suspended in water ready for papermaking.

Paper for recycling (PfR)
Natural fibre-based paper and board suitable for recycling and consisting of products made predominantly of paper and board (of any shape), which may include other constituents that cannot be removed by dry sorting, such as coatings and laminates, spiral bindings, etc.

Packaging waste recycled at scale
Packaging waste which is collected separately, sorted and recycled in installed infrastructure, using established processes proven in an operational environment which ensure, at Union level, an annual quantity of recycled material under each packaging category listed in Table 2 of Annex II equal to or greater than 30% for wood and 55% for all other materials; it includes packaging waste that is exported from the Union for the purpose of waste management and which can be considered to meet the requirements of Article 53(11) (Source: Regulation (EU) 2025/40).

Recycling
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 for backfilling operations (Source: Regulation (EU) 2025/40).

Plastic
a material consisting of a polymer within the meaning of Article 3, point (5), of Regulation (EC) No 1907/2006, to which additives or other substances may have been added, and which is capable of functioning as a main structural component of packaging, with the exception of natural polymers that have not been chemically modified (Source: Regulation (EU) 2025/40).

Pulp
Fibrous material, generally of vegetable origin, obtained with various processes from raw materials in different forms and made ready for use in further manufacturing processes. Examples for raw materials are wood, wood chips, plants, paper and board for recycling, textiles, etc.

Pulping
The act of processing wood (or other plant and slushing paper and board for recycling to obtain the raw material for making paper and board. The fibres are separated from one another into a mass of individual fibres (see Pulp).

Separate component
A packaging component, whether or not from the same material as the main body of the packaging unit, that is distinct from the main body of the packaging unit, that needs to be disassembled completely and permanently from the main body of the packaging unit and that is typically discarded prior to and separately from the main body of the packaging unit, including packaging components that can be separated from each other simply through mechanical stress during transportation or sorting (Source: Regulation (EU) 2025/40).

Waste
waste as defined in Article 3, point (1), of Directive 2008/98/EC; reusable packaging sent to reconditioning is not considered to be waste (Source: Regulation (EU) 2025/40).

Terms and definitions from ISO standards can be looked up free-of-charge from the ISO website, using the OBP tool: https://www.iso.org/obp/ui

NOTES

NOTES

CIRCULARITY BY DESIGN GUIDELINE FOR PAPER-BASED PACKAGING

VERSION 4

February 2026

ABOUT 4EVERGREEN

4evergreen is a cross-industry alliance perfecting the circularity of paper-based packaging to contribute to a climate-neutral and sustainable society. Our goal is to raise the overall recycling rate of paper-based packaging to 90% by 2030. We bring a particular focus on packaging with a lower circularity performance today, namely the types used for household, out-of-home and on-the-go consumption.

The alliance brings together industry representatives from across the paper-based packaging value-chain, from pulp, paper and board manufacturers and recyclers to packaging producers and converters, including brand owners, retailers and waste management companies. It also comprises non-fibre material suppliers (e.g. adhesives, inks, coatings), technology providers (e.g. machinery, collection, and recycling solutions), and leading research institutes.

4ever
green

For general enquiries please contact 4evergreen@cepi.org