CIRCULARITY BY DESIGN GUIDELINE FOR FIBRE-BASED PACKAGING

VERSION 3

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4ever green

Table of contents

Introduction

Fibre-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 fibre-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 transportation of the packed product.

Depending on the packaging and end use, different combinations of materials in fibre-based packaging can be utilised to achieve all of these performance criteria. The right combination of materials 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 fibre-based packaging solutions necessitates different recycling processes to ensure optimal material recovery. Additionally, as the amount and types of fibre-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 and paper packaging, recycling and sustainability experts from companies acting across the entire supply chain in the fibre-based packaging industry. The publication aims to help packaging designers and industry experts to design and specify fibre-based packaging that is recyclable at scale in Europe.

Therefore, the primary purpose of the document is to explain how different parameters, elements and materials of fibre-based packaging impact recycling processes and subsequent pulping reject recovery. The first version of the guideline document, issued in 2022, indicated whether the different parameters, elements and materials can be classified as "fully compatible with the standard recycling process", "conditionally compatible with the standard recycling process" or "not compatible with the standard recycling process". The second edition, published one year later, was an extended version which addressed the compatibility of certain fibre-based composite packaging formats (such as beverage cartons and paper cups) with the recycling process in specialised recycling mills, explicitly applicable for mills that treat used beverage cartons (UBC).

The current version of the document further provides general recommendations for recycling fibre-based composite packaging (FBCP) other than in specialist UBC and flotation-deinking mills.

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

Any fibre-based packaging that is not suitable for one dedicated recycling process (i.e. Recyclability Evaluation Protocol under PART I) could potentially be recycled in another type of mill. Thus, a negative compatibility assessment for a dedicated process does not suggest that the packaging is 'not' recyclable per se. The current version of this document includes a decision tree to support designers in determining the relevant mill where their packaging could be recycled in. 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 fibre-based packaging design with the particular recycling process and guide them to improve recyclability.

Scope of this document

This guideline document provides recommendations for the design of fibre-based packaging and it is recommended for all packaging designers along the entire value chain, from manufacturers to retailers. It addresses all types of fibre-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 fibre-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 fibre-based packaging in the recycling process depends on specific material grades/chemistry and the final composition of the converted packaging.
The ultimate aim is to provide a comprehensive and fact- based guideline, for standard, flotation-deinking and specialised recycling mill processes.
Therefore, certain recommendations, mainly for which the compatibility with the recycling process is unknown will be verified using the latest Cepi recyclability laboratory test method, and the 4evergreen Recyclability Evaluation Protocols.

Applicability

This document is intended to support the design of fibre-based packaging suitable for recycling in standard mill, flotation-deinking mill and specialised recycling mill processes. The guideline is therefore applicable to fibre-based packaging that is likely to be recycled in those types of mills, provided that product-specific regulations of the packaging are observed. The given recommendations in 7.2 PART III are explicitly applicable to fibre-based composite packaging recycling in specialised mills for used beverage cartons (UBCs). Recommendations for other types of fibre-based composite packaging (FBCPs) can be found in the Section 7.3.
Due to the lack of available information and the diversity of mills that treat only fibre-based composite packaging, 4evergreen has decided not to provide design recommendation tables and instead focus on general guidance for these types of packaging.

Innovations and future versions

This guideline is intended to support the use of fibre-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 that uses novel technologies requires testing to assess its compatibility with recycling processes. Relevant future innovations will be observed, evaluated and assessed by 4evergreen and the recommendations 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
COD	Ordinary Legislative Procedure previously Codecision procedure
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
FBB	Folding Boxboard
FBCP	Fibre-Based Composite Packaging
HDPE	High-Density Polyethylene
INGEDE	International Association of the Deinking Industry
INOX	Stainless Steel
ISO	International Organisation for Standardisation
LDPE/PE-LD	Low-Density Polyethylene
LLDPE	Linear Low-Density Polyethylene
LPB	Liquid Packaging Board
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 polyethylene and aluminium
PPWD	Packaging and Packaging Waste Directive
PPWR	Packaging and Packaging Waste Regulation
PS	Polystyrene
PVA	Polyvinyl Acetate
PVOH	Polyvinyl Alcohol
SB	Solvent-Based
SBB	Solid Bleached Board
SiOx	Silicon Oxide
UBC	Used Beverage Carton
UV	Ultraviolet
WB	Water-Based
w/w	Weight per Weight
WFD	Waste Framework Directive

GENERAL INFORMATION

1. REGULATORY BACKGROUND

The packaging industry is striving to improve recycling processes and more 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), published in July 2018, is a major driver of progress in environmental standards and actions. Among other things, it led to modifications of several regulations concerning packaging, including EU Directive 94/62/EC, also known as the Packaging and Packaging Waste Directive (PPWD), and the European Waste Directive 2008/98/EC (European Parliament, 2008).

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

As part of the European Green Deal and Circular Action Plan, the European Commission put forward a revised PPWD in November 2022, in the form of a regulation (Packaging and Packaging Waste Regulation, PPWR). Hence this legislation is directly binding and no adaption to national law is necessary (see Section 1.1. for more details).

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

Legislation	Abbreviations	Enforcement date	Implementation in national law	Content
Packaging and Packaging Waste Regulation	**2022/0396 (COD)**	Enforcement is expected for 2024/2025.[1] Different timelines per requirement.	Planned as a regulation; no transposition into national law required.	> 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)	**2008/98/EC**	December 2008	December 2010	> Definition of waste terms (recycling, waste, reuse) and waste hierarchy > Promotes separate collection and high-quality recycling
Amendment to WFD	**2018/851/EC**	July 2018	July 2020	> Recycling target for municipal waste > Mandatory separate collection > Eco-modulation of extended producer fees
Single Use Plastic Directive	**2019/904/EC**	June 2019	July 2021	> 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] Depending on the legislative procedure

1.1 Packaging and Packaging Waste Regulation

The 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 European Union and enter into force as applicable law on a set date in all Member States, whereas Directives leave more decision power for each country 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 in achieving compliance. The institutions reached a provisional political agreement in spring 2024, and the regulation is expected to enter into force by the end of 2024 or 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 on the EU market.
The Regulation addresses various topics such as substances in packaging, recyclability, recycled plastic content, compostability, reusability, packaging efficiency, extended producer responsibility including eco-modulation of EPR fees, packaging restrictions, packaging reusability and 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 seek to shave 5% of packaging waste by 2030, 10% by 2035 and 15% by 2040, all compared to a 2018 baseline. The Regulation also requires packaging weight and volume to be minimised 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 is prohibited, and the reusability of packaging must be considered.

Moreover, for e-commerce, transportation and grouped packaging, the empty space must be reduced to the bare 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) be reusable within a system for reuse.

Packaging placed on the EU market must be recyclable as of 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 implement this secondary legislation by early 2030. Criteria applied to the design for recycling and recyclability performance grades will be developed based on the ability of packaging waste to be separated into different material streams for recycling, and assurances that the resulting secondary material is of 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).

For fibre-based packaging, two categories have been introduced in the regulation (categorisation no., as per Table 1 in Annex II):

Paper/cardboard packaging
Category 2: Examples of this category are boxes, trays, grouped packaging, flexible paper packaging (e.g. films, sheets, pouches, lidding, cones, wrappers).

Composite packaging of which the majority is paper/cardboard
Category 3: Examples for category are liquid packaging board, and paper cups (i.e. laminated with polyolefin and with or without aluminium), trays, plates and cups, metallised or plastic laminated paper/cardboard, paper/cardboard with plastic liners/ windows.

For each category, separate design for recycling criteria are defined.

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

Furthermore, the design for recycling criteria and recyclability performance grades will be based on various parameters such as separability of components, efficiency of sorting (yield), but also on the presence of additives, labels, sleeves, closures, colours, characteristics of material composition, coatings, product residues, and ease of dismantling, according to Annex II Table 4 of PPWR. Further details on parameters will be defined by the Commission in delegated acts in 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 were provided for innovative packaging for a maximum for five years from 2030 and for special packaging (e.g. pharmaceutical and medicinal products) until 2035. Further secondary legislation will define the criteria and assessment methods, to calculate the recyclability of packaging, within the timeline of the delegated act on design for recycling and recyclability assessment, expected no later than 2028, with the implementing act on recycling at scale scheduled for 2030 (or two years after the delegated act).
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 ad 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, sales packaging and grouped and transport packaging.
Eco-modulation of the Extended Producer Responsibly (EPR) fees, with harmonised criteria based on recyclability performance grades achieved through packaging recyclability assessments, will be required. Producers will be charged differentiated fees according to recyclability, which will support upstream packaging changes to incentivise sustainably designed products. In the EPR system, producers pay fees to a 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 types 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 substantive recycling. In the case of fibre-based packaging that has been heavily 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[2] must be compatible with the composting standard for industrially controlled conditions. Members States may further demand that the packaging be compatible with the standards for home composting. It is crucial to note that only packaging categories specified in Art. 9 can be compostable. Apart from these specific applications, all other packaging types must adhere to the recyclability requirements outlined in the PPWR.

Additional resources, such as the recently launched Compostability by Design Platform[3], can provide further guidance on compostable packaging.

4evergreen advocates mechanical recycling of fibre-based packaging and provides detailed design recommendations, as outlined in Chapters 5.2, 6.2, and 7.2

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

[2] 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 intended for use and disposal with the product.
[3] 4evergreen and Compostability by Design Platform share a number of mutual participants. Further information is available here: https://compostablebydesign.com

Terminology differences between PPWR and 4evergreen

Composite packaging
4evergreen's Circularity by Design guideline is based on the principle of assessing the suitability of fibre-based packaging for a specific mill type (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 as 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, which it defines as *ackaging composed of paper and a considerable share of non-paper elements that by design are not separated after use"*.

Considering that packaging recyclability 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 also be recycled effectively in a standard mill, should it be designed for that mill type.

Parameter and component
Table 4 in Annex II of the PPWR presents a non-exhaustive list of parameters for defining recycling criteria. These parameters serve as a definition for the development of design for recycling criteria. It should be noted that not all elements listed correspond to components but rather to parameters.

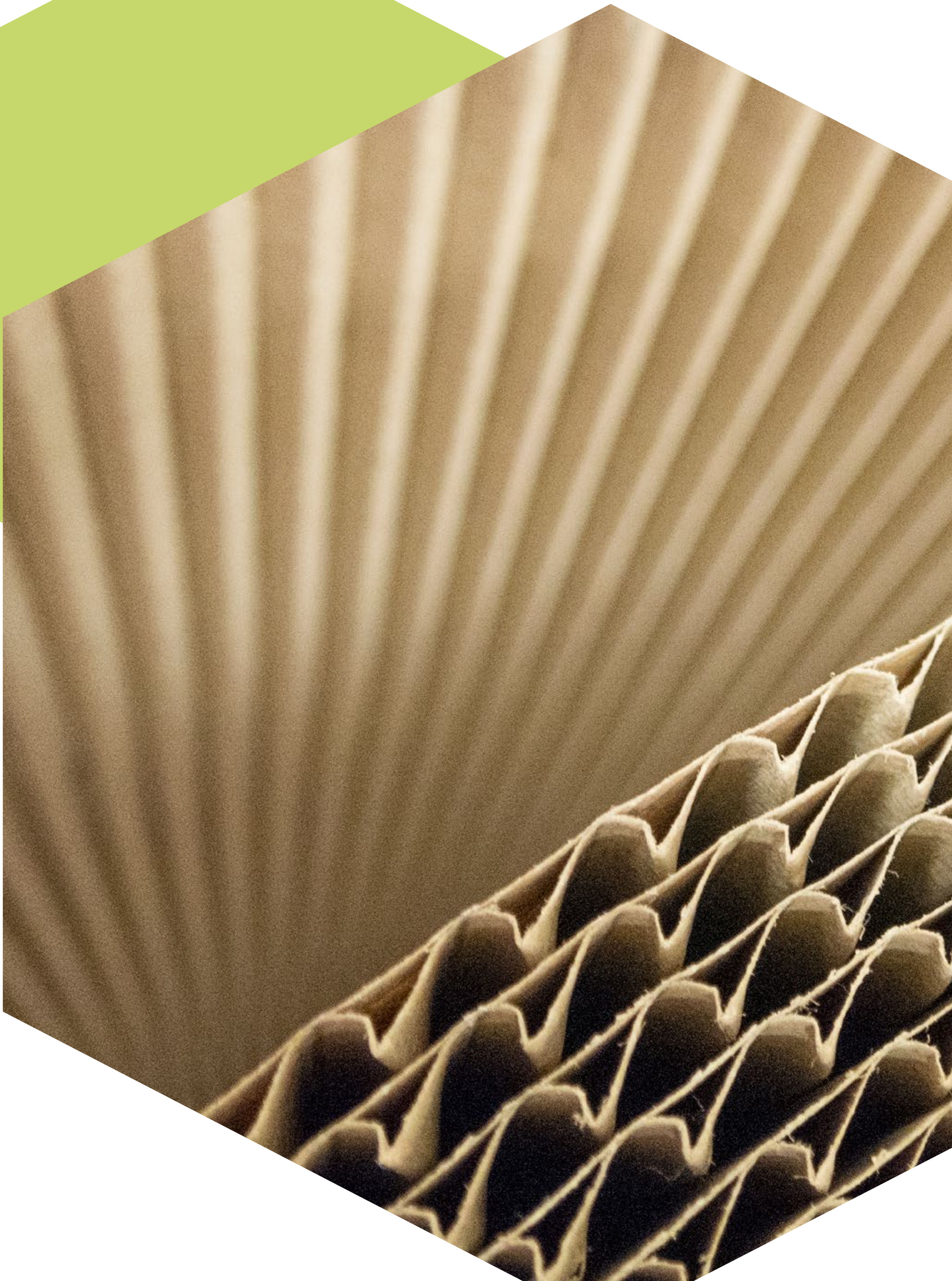
To prevent any misunderstandings, Version 3 of 4evergreen's Design for Circularity Guideline has adopted the terminology of "parameter" and "sub-parameter" to replace the terms "component" and "sub-category". The design recommendations tables for "Additional components" continue to fulfil the definition of components and, therefore, have not been modified.

1.2 Food contact materials

The main target of 4evergreen, therefore, is to improve the compatibility-for-recycling process of on-the-go and household packaging. Food packaging makes up a large part of this sector. Besides the above-described legislation concerning the recycling and circular design of materials, because food packaging is in direct contact with food it also needs to fulfil certain safety requirements.

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 meets 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 fibre-based packaging by classifying the parameters according to their compatibility with:

- Standard recycling processes (PART I)
- Flotation-deinking recycling processes (PART II)
- Specialised recycling processes (PART III – UBC)
- Specialised recycling processes (PART III – FBCP)

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

Fully compatible with dedicated process	Conditionally compatible with dedicated process	Not compatible with dedicated process	Compatibility with recycling 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 for target product > **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 and assessment of recyclability referring to different dedicated recycling processes (standard mill, deinking-flotation mill, or specialised mill) can be different. **4evergreen's current testing and assessment is expected to provide more detailed guidance in future.**

2.1 Pre-requisite for fibre-based packaging

Definition of paper and fibre-based packaging in this guideline

Paper consists mainly of natural fibres (both primary and secondary source) 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.

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

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

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

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

Parameters to avoid in fibre-based packaging

The presence of certain elements 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 packaging or packaging component.

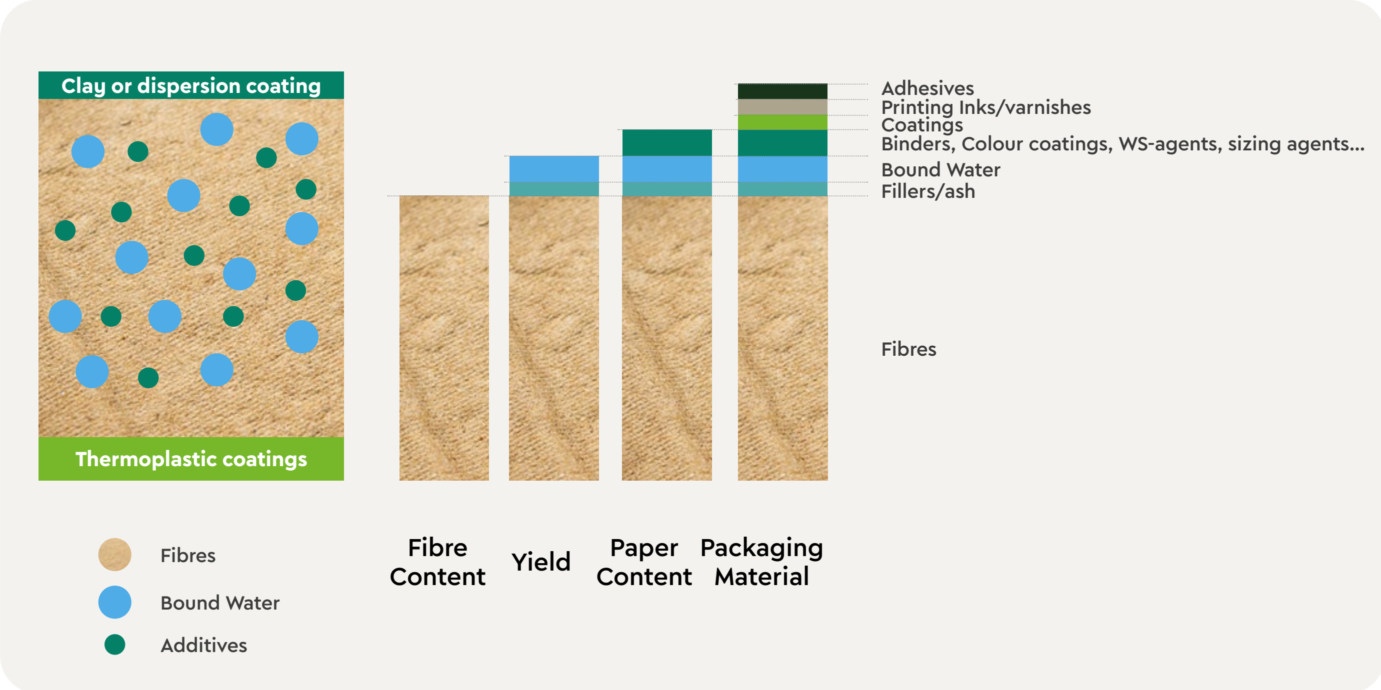


Figure 1. Distinction of fibre-content, yield, paper-content and packaging material

2.2 Recyclability definitions

Recyclability by design

Recyclability by design 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 recyclable by design. If not, it can still be proven recyclable with the Cepi laboratory test method and the 4evergreen Fibre-based Packaging 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 at-scale recycling 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 (38)) an annual quantity of recycled material under each packaging category equal to 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 recyclability under the PPWR.

As described in Section 1.1, the 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 PROCESS OF FIBRE-BASED PACKAGING

Recycling of fibre-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 the 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 fibre-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 fibre-based packaging, the process needs to be carefully set up and calibrated to handle the different parameters from the packaging conversion process. Recycling facilities (mills) for fibre-based packaging diverge from each other in how they handle different types of fibre-based packaging.

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

a) Standard mills typically treat Old Corrugated Containers (OCC) and/or mixed paper and mainly remove non-paper parameters and the foreign parts. The output is a brownish pulp.
b) Flotation-deinking mills 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) Specialised mills are using further process steps or different conditions, which are not part of the setup of standard mills, to recycle fibre-based composite packaging. One well-established recycling method used for liquid packaging carton (typically with two-sided lamination) requires enhanced pulping action and a process step to prepare the non-fibre fraction for its recycling at a PolyAl recycler. Similar processes can be adapted and optimised for wet-strength products and those with high non-paper content'; they 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 Fibre-based Packaging Recyclability Evaluation Protocols listed in Table 4.

Part	Scope	Release (*expected)
Part I	Standard recycling mill	Q4. 2022
Part II	Flotation-deinking mill	2024*
Part III	Specialised recycling mill	2024*

Table 4. 4evergreen Fibre-based Packaging Recyclability Evaluation Protocol

4. DECISION TREE

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

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 mills. 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 facility 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 fibre-base packaging and should be viewed as recommended rather than a strict protocol. In addition, a useful source is the Guidance on the improved collection and sorting of fibre-basedpackaging for recycling published by 4evergreen in December 2023, which includes more detailed information.

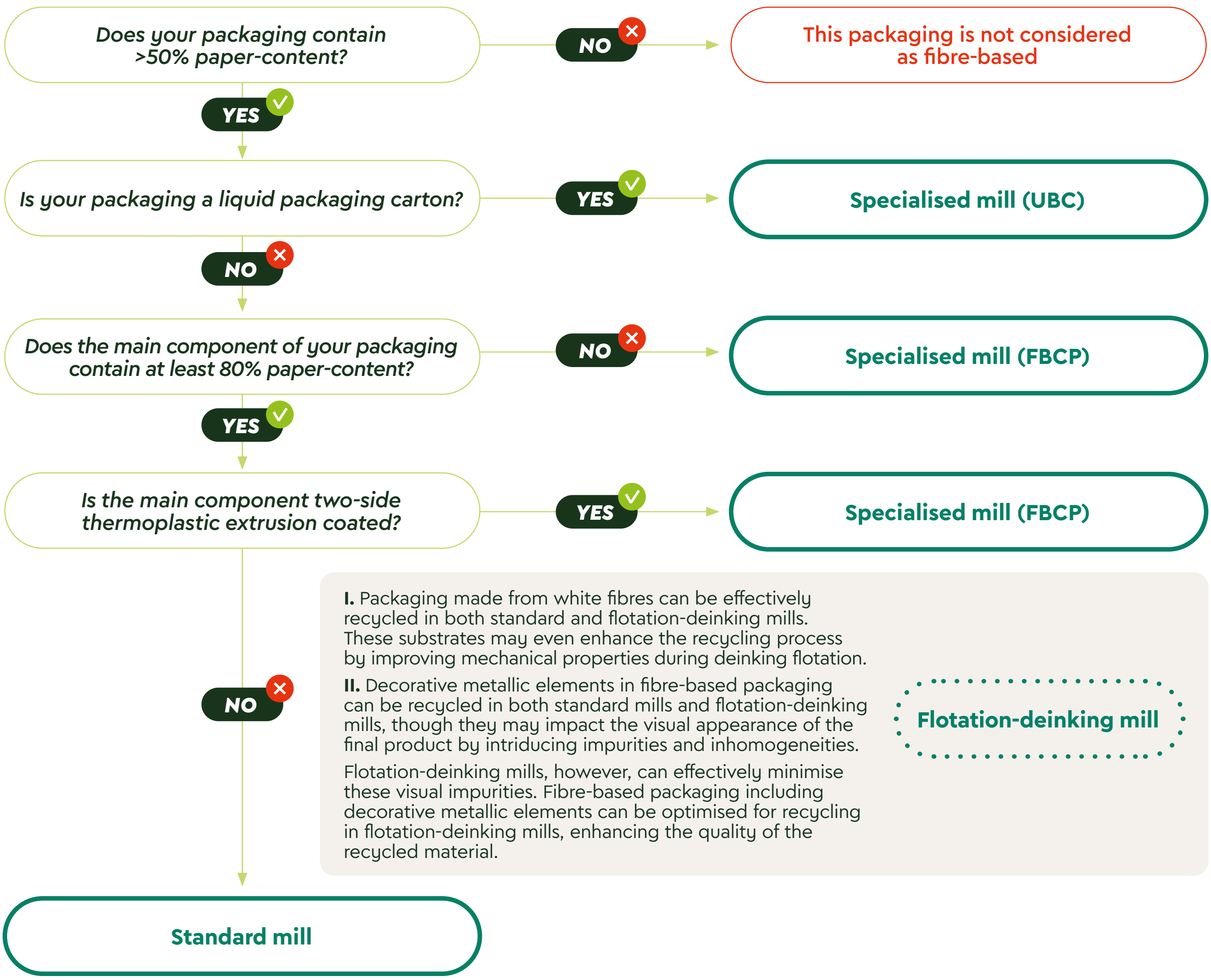


Figure 2. Decision tree

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.

Nonetheless, greater fibre content makes paper more suitable for paper recycling. Consequently, the paper content of the packaging should be at least 50% to be considered as fibre-based packaging in this guideline.

2 | Liquid packaging cartons are suitable for specialised mill processing (mills using these processes for UBC are established across the EU). The term "beverage carton" does not fully reflect the end uses 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".

3 | Based on 4evergreen Fibre-based Packaging Recyclability Evaluation Protocol it is evident that the standard mill process can tolerate a maximum rejection rate of 20%. When the reject levels exceed this rate, the protocol scores become negative, rendering the packaging under consideration unsuitable for recycling using the standard mill process. As the packaging is not a liquid packaging carton (because of condition 2 above), it can be recycled in a specialised mill for processing fibre-based composite packaging.

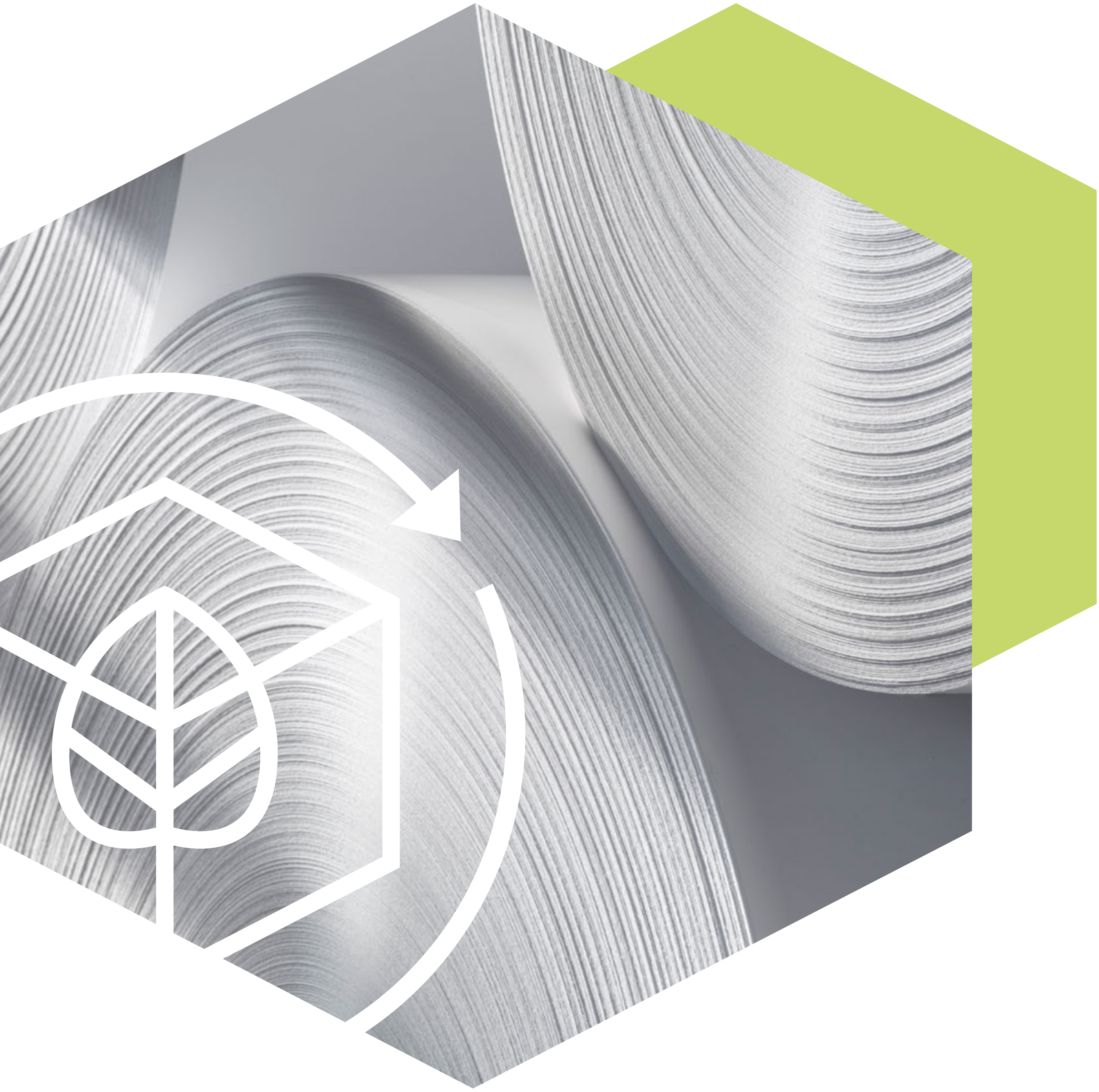
4| Thermoplastic extrusion coating on two-sided paper packaging requires more repulping time and is a conventional form of coating. As for standard recycling mills, it is deemed unsuitable (Table 5).
Referring to the particular coating is preferable to using terms such as "two-side coated" which do not 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.

Flotation-deinking mills

There are different factors that may influence the collection and sorting of paper-based packaging in a flotation-deinking mill – the most prominent being the sorting dynamics of the system deployed at scale and the available capacity. Because standard mill recycling is possible on a larger scale for packaging materials, it is highly likely that packaging suitable for flotation deinking processes may end up in a standard recycling mill. Packaging involving decorative metallic elements can essentially be recycled in both standard and flotation-deinking mills. However, there are fewer visual impurities resulting from paper processed in flotation-deinking mills, which thereby increases the quality of the recycled material produced.

Given that flotation-deinking mills enhance the visual quality of the output material, packaging containing such elements can be designed to be processed by these mills rather than in standard recycling mills. However, as mentioned earlier, designing packaging for standard mills would not hinder its possibility of being recycled in a flotation-deinking mill, given that ink type and other parameters are suitable for the flotation-deinking mills recycling process.

5. PART I — STANDARD RECYCLING MILLS



5.1 Recycling in standard recycling mills

Most standard mills typically utilise the EN 643 paper grades (groups 1-4). The fibre-based packaging recycling process typically includes the following steps:

Repulping

The purpose of pulping is to disintegrate the paper and separate fibres from other parameters. In this step, the paper for recycling is blended with water, the temperature is typically around 40°C and the pH value is maintained at around (though usually not regulated) 7 by adding acids or alkaline. These mills typically have a low consistency pulper (<5% fibre concentration). The aim of this first step is to break down 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 difference between fibre and non-fibre components or non-fully dispersed fibre flakes. It can be divided into coarse- and fine-screening stages. 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 2-10mm) while fibres can flow through freely. The objective of the fine-screening is to remove smaller-sized particles (e.g. adhesives) 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 the recycling mill 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 hydro-cyclones to separate impurities that have different densities from fibres. In general, standard mills 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.

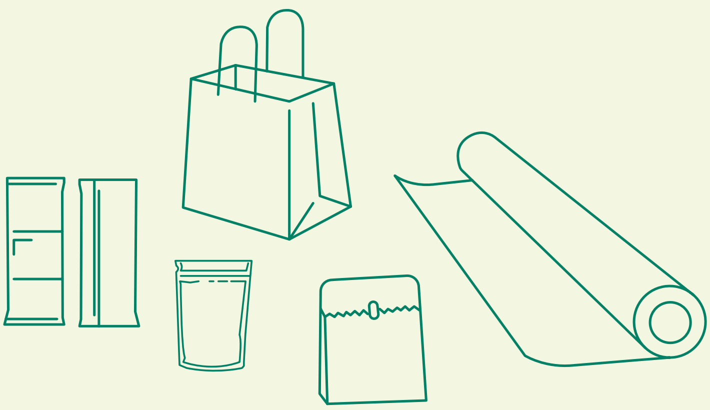
Papermaking

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 standard mills

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 not listed in 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 not listed in EUPIA exclusion policy

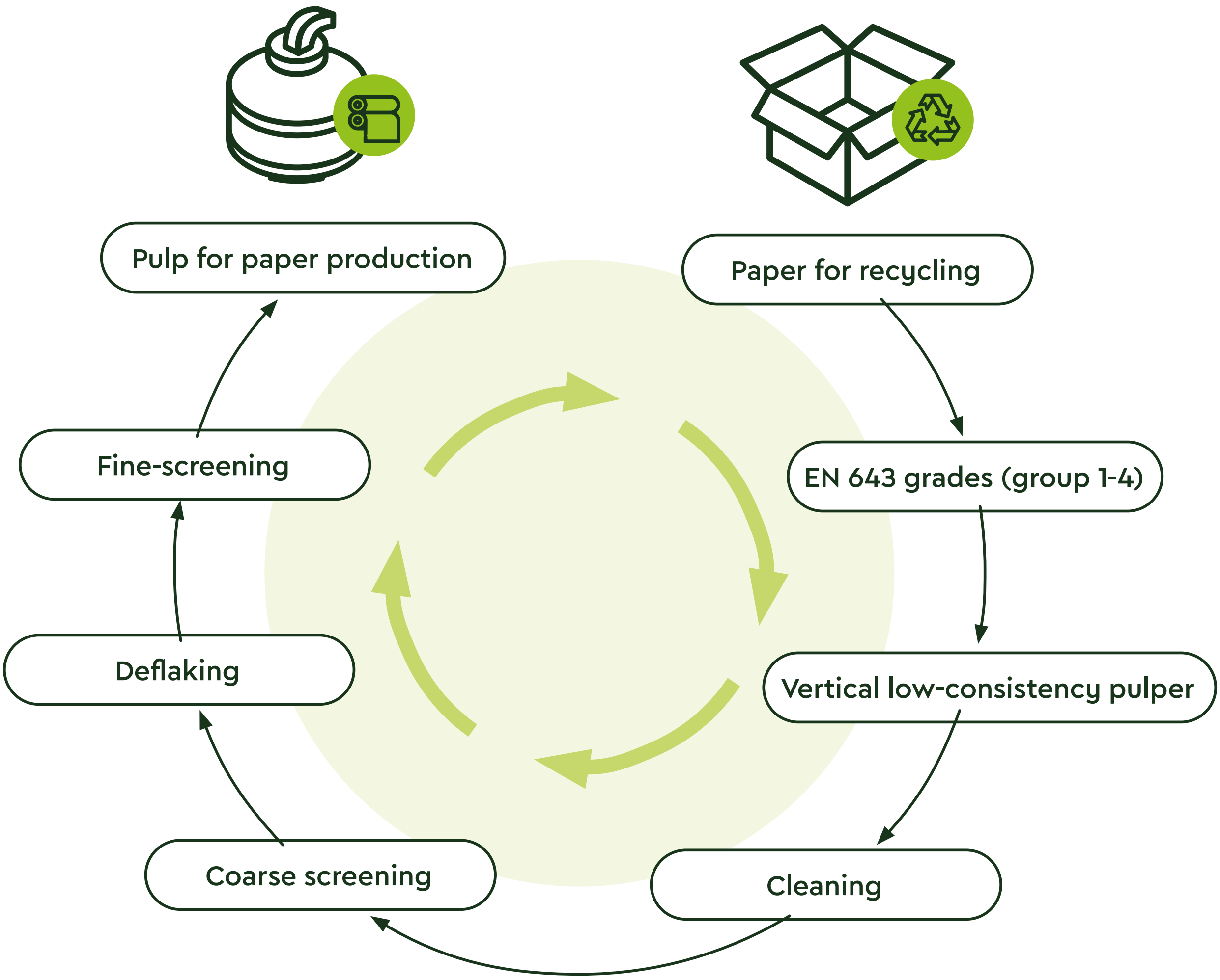


Figure 3. Recycling in standard recycling mills

5.2 Design recommendations (PART I)

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

The key is to explain why and how different parameters affect the recycling process. Following a "design for recycling" approach helps packaging designers learn which parameters 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 groups, to help designers refine their work. The recommendations are presented in a compact design table, for the following materials and parameters, and their compatibility with the standard 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 elements
- 5.2.6 Additional components

The guideline also gives some more general advice on choosing the right base material and design packaging to minimise the residual product content in packaging.

The design tables in Chapter 5.2 refer to single parameters categorised as:

- Fully compatible with standard recycling process
- Conditionally compatible with standard recycling process
- Not compatible with standard recycling process
- Compatibility with standard recycling process unknown

In this Version 3 of the Circularity by Design Guideline the terminology for "component" and "sub-category" have been changed to "parameter" and "sub-parameter", as mentioned in a previous chapter (Terminology differentiation between PPWR and 4evergreen).

NOTE: The given design recommendations are widely based on expert opinion covering the entire value chain represented in 4evergreen, and they are valid for recycling in standard recycling mills. Should future recyclability lab testing prove otherwise, the guideline will be updated in line those results alongside the corresponding 4evergreen Fibre-based Packaging Recyclability Evaluation Protocol (PART I).

5.2.1 Fillers, additives and agents

Paper and board used in fibre-based packaging mainly consists of virgin fibres 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 standard recycling process.

NOTE: The given design recommendations are based on expert opinion, and valid for recycling in standard recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Standard recycling (PART I)

Parameter	Sub-parameter	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with standard 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)	⊗				
Sizing, surface	Starch	⊗				

Standard recycling (PART I)

Parameter	Sub-parameter	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with standard 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 specialised mills yielding high value fibres.

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

5.2.1.1 Fillers, additives and agents used in fibre-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 grades 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 paper and board constituents 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 do not 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 other alternatives due to their environmental concerns. Use special paper and board treatments only for applications where such functionality is absolutely necessary. If no specialised process is required for recycling it increases the probability of being recycled in a standard mill.

For fibre-based packaging material that have no (or low) compatibility with standard processes there are potentially EN 643 grades defined which enable recycling in specialised mills with dedicated processing setups.

5.2.2 Barrier coatings and polymer content

Fibre-based packaging – including paper and paperboard – have no 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, fibre-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 standard recycling processes.

NOTE: The given design recommendations are based on expert opinion and valid for recycling in standard recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Standard recycling (PART I)

Parameter	Sub-parameter	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with standard 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 conditionally compatible 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 standard recycling process until further information from Cepi recyclability laboratory test method is available. It can only be recycled in specialised recycling mills with a dedicated pulper.
Adhesive barrier film	**Adhesive lamination with water-soluble adhesives (among others some grades 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 grades 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 grades 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.

Standard recycling (PART I)

Parameter	Sub-parameter	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with standard recycling process unknown	Comment
Wax coatings	Dipping of paper in molten wax (two sided)		⊗			May impact on stickiness and cause screen clogging.
Barrier metallization	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 fibre-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 grades 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 grades of acrylics, EEA, SB, ABS, PVDC, PVOH etc.)
- Solvent-based coatings
- Wax dispersion coating (incl. microcrystalline waxes)
- Water-soluble coatings (among others some grades 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 fibre-based packaging may have negative impacts on recyclability, for example:

- Decrease recycling yield of fibre-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 fibre-based packaging material is considered to be compatible with a standard recycling process. This is typically operating with OCC and mixed paper (from separate collection) paper grades. Otherwise, the material would need to be recycled at a specialised mill with dedicated equipment to mitigate the negative effects of barriers being present.

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

NOTE: The given design recommendations are based on expert opinion and valid for recycling in standard recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Standard recycling (PART I)

Parameter	Sub-parameter	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with standard recycling process unknown	Comment
Offset	Oil-based (mineral)	⊗				Inks based on mineral oils are fully compatible with the 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

of the ink in order to ensure a good transfer to the substrate. Typical diluents are water, oil, and organic solvents.

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 the relevant 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 standard 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 fibre-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 process to separate ink particles from the paper fibres (recycling process with deinking); and (2) recycling without a flotation process where the ink particles remain in the pulp (standard recycling process).

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

Based on industry feedback, inks and varnishes as classified in Table 6 typically do not cause problems in mechanical 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 are used to form, seal and close fibre-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 standard recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Standard recycling (PART I)

Parameter	Sub-parameter	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with standard 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 1.6mm 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				⊗	

Standard recycling (PART I)

Parameter	Sub-parameter	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with standard recycling process unknown	Comment
Litho-lamination	PVA	⊗				
Cold seal	Natural rubber latex	⊗ *				
Heat seal	PVA	⊗ *				
	Acrylic	⊗ *				
	Hotmelt				⊗	NOTE: 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
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).
	Pressure sensitive hotmelt	⊗ *			⊗	
	Water-based 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 acrylic adhesive	⊗ *				
	UV-curable acrylic adhesives	⊗ *				

Table 8. PART I – Design recommendations adhesives

5.2.4.1 Adhesives used in fibre-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 elements 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 base 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.

A general principle, as for all non-target materials of a recycling process, is that 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 cannot be removed by screening.

5.2.5 Decorative metallic elements

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 elements used in the industry and their compatibility with standard recycling process.

NOTE: The given design recommendations are based on expert opinion and valid for recycling in standard recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Standard recycling (PART I)

Parameter	Sub-parameter	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with standard recycling process unknown	Comment
Decorative metallic elements	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 9. PART I – Design recommendations decorative metallic elements

5.2.5.1 Decorative metallic elements used in fibre-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)

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

Metallic elements with a thickness lower than 1 micron do not cause any issue during the recycling process, but the recognition of these papers during the sorting process is crucial. If the papers' surface is not fully covered with metallic decoration, it will not cause major issues regarding detection as a fibre-based product and end up in the right recycling stream. If the surface is covered with a very high percentage of metallisation, it may cause detection issues, as the metallic effect reflects the NIR light, and the fibre-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 fibre-based packaging with metallisation to avoid problems during the sorting process

5.2.6 Additional components

The following design table aims to provide a compact overview of typical additional components used to improve the functionality of fibre-based packaging.

NOTE: The given design recommendations are based on expert opinion and valid for recycling in standard recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Standard recycling (PART I)

Parameter	Sub-parameter	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with standard 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 additional 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 fibre-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 fibre-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 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:

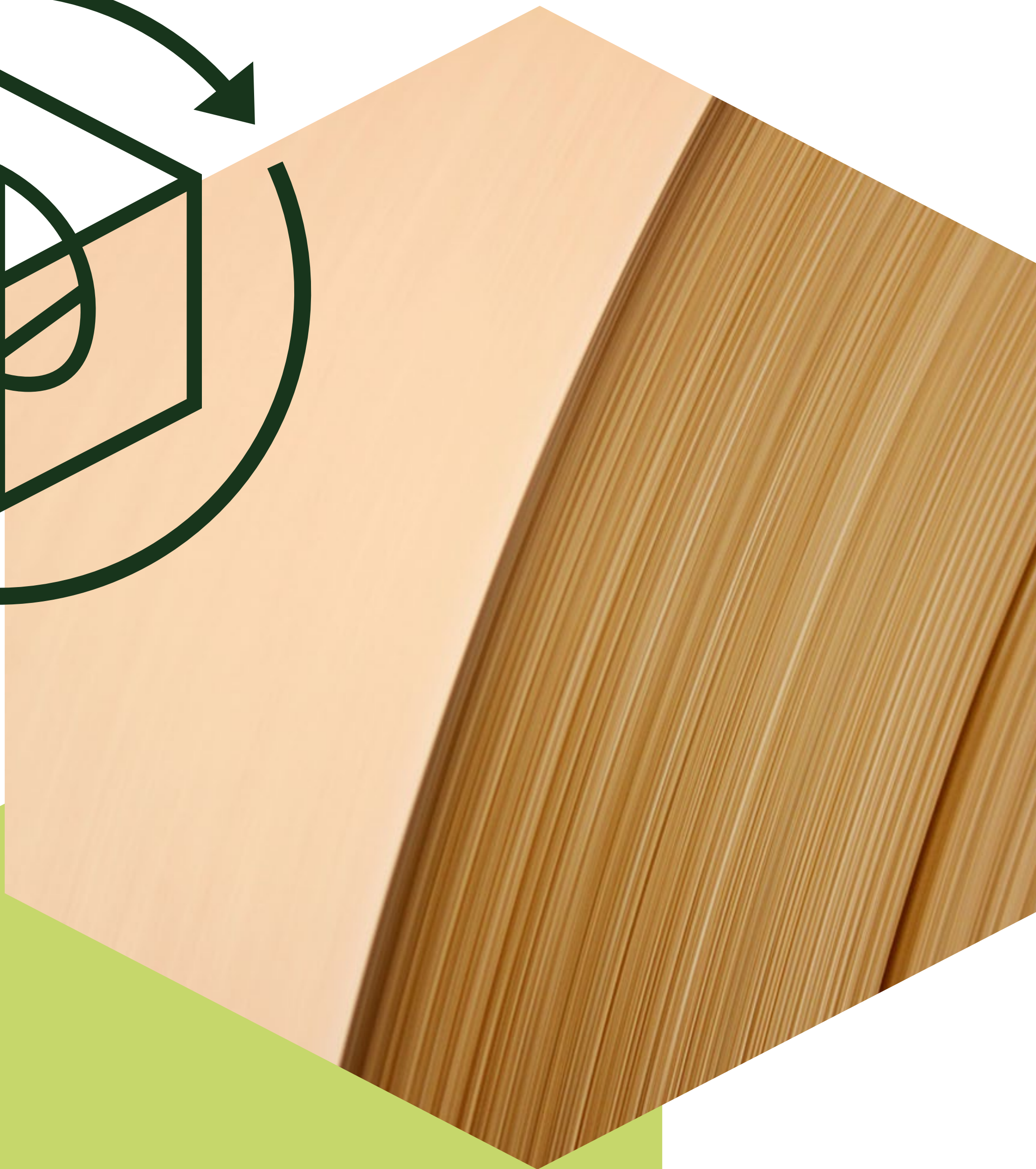
- Excessive microbial growth leading to contamination of the finished paper product
- Increased risks of infestation with insects and rodents
- Increased load on wastewater treatment plants due to increased soluble matter

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 fibre-based packaging. Minor contamination and/or staining are tolerated by most recyclers 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 fibre-based packaging after use
- Design should enable cleaning of the surface in contact with food (when applicable, design the opening in a way that the surface in contact with food is accessible, so the food can 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 — FLOTATION DEINKING RECYCLING MILLS

6.1 Recycling in flotation-deinking mills

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 perform 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 250µm very efficiently with a high fibre yield, and in some systems even larger particles up to 500µm with reasonable efficiency.

The flotation deinking process is most commonly used for recycling printed products where the inks are water repellent. These types of inks and toners are used in the offset, rotogravure and dry toner printing processes.

Other types 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 (depending on the individual behaviour, they may still be compatible with the deinking process). For further guidance on the compatibility of different inks and varnishes type please see Table 14.

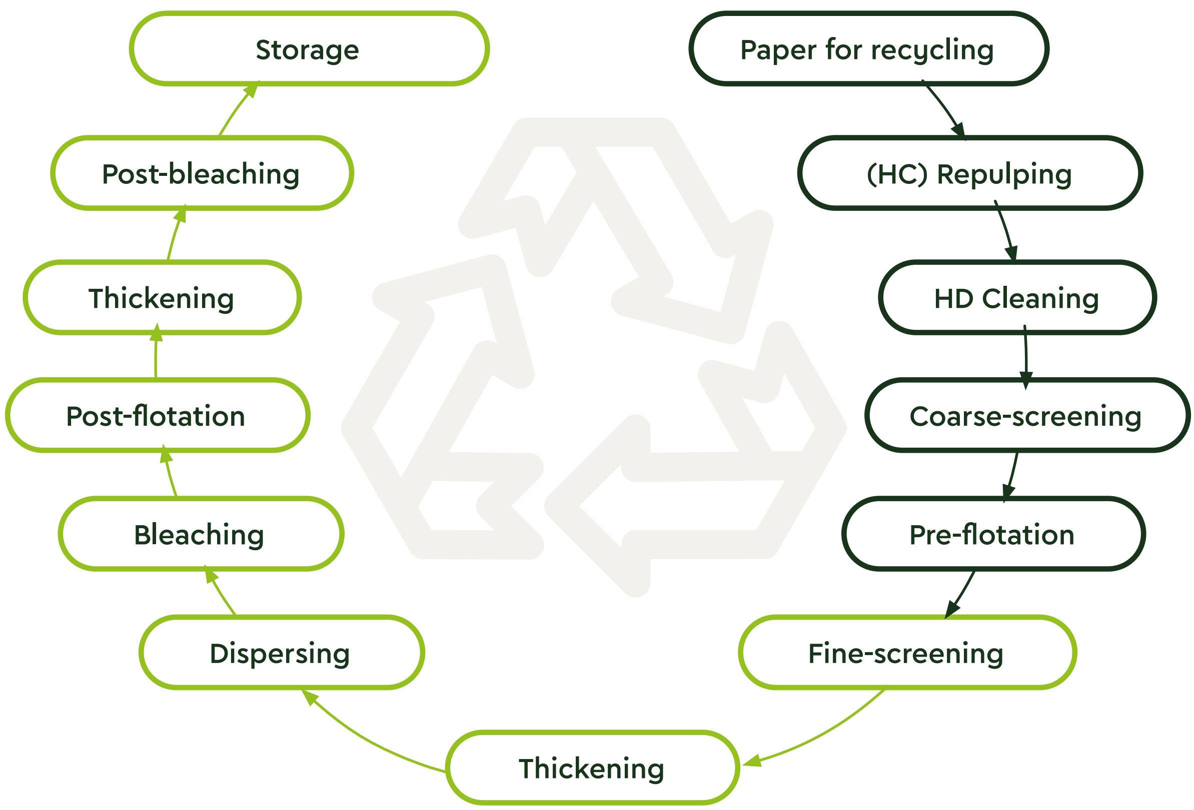


Figure 4. Example for recycling process in two-loop deinking-flotation recycling mills

Recycling process

Paper for recycling: The international standard EN 643 contains requirements for grades of paper for recycling that are specifically intended for deinking, and 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 fibre-based packaging based on the well-established deinkability test INGEDE Method 11. By the end of 2024 the alliance plans to publish a test protocol that mimics the most relevant process stages of the deinking process at lab scale and is suitable for fibre-based packaging. In addition to the laboratory test method, the alliance will also release the Recyclability Evaluation Protocol Version 1, including an evaluation scheme based on the obtained test results. The evaluation scheme will include the main elements of the EPRC score card (Assessment of Printed Product Recyclability – Deinkability Score) extended with additional parameters relevant to fibre-based packaging.

Current design recommendations in this guideline are based on expert opinion obtained thanks to long-term experience of graphic paper recycling. The European Recovered Paper Council (ERPC) recommends using its scorecard which assesses the deinkability of a printed product in a range from - 100 to +100, based on the results of the INGEDE Method 11 (see 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 transferring to 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 helping it meet the requirements of the next process.

Disperser: Dispersing is a consistent and high-speed kneading process to reduce residual ink particle size. A disperser or 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 grades of white paper. This is done through a series of oxidation and/or reduction reactions.

Post-flotation: In cases where a second loop is performed, 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 flotation-deinking mills, to help designers refine their work.
The design recommendations tables in the sections 6.2.1 to 6.2.6 are applicable for the recycling process in flotation-deinking mills.
The design tables provide information for the following parameters:

- 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 elements
- 6.2.6 Additional components

The design tables in this chapter refer to single parameters categorised as:

- Fully compatible with flotation-deinking recycling processes
- Conditionally compatible with flotation-deinking recycling processes
- Not compatible with flotation-deinking recycling processes
- Compatibility with flotation-deinking recycling processes unknown

Please note that in this version 03 of the Circularity by Design Guideline the terminology of “component” and “sub-category” has been changed to “parameter” and “sub-parameter” as mentioned in previous chapter (Terminology differentiation between PPWR and 4evergreen).

NOTE: The given design recommendations are widely based on the expert opinion of the entire value chain represented in 4evergreen and valid for flotation-deinking mills. Should future recyclability lab testing prove otherwise, the guideline will be updated in line those results alongside the corresponding 4evergreen Fibre-based Packaging Recyclability Evaluation Protocol (PART II).

6.2.1 Fillers, additives and agents

Flotation-deinking recycling (PART II)

Parameter	Sub-parameter	Fully compatible with flotation-deinking process	Conditionally compatible 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 (PART II)

Parameter	Sub-parameter	Fully compatible with flotation-deinking process	Conditionally compatible 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 flotation deinking recycling mills. 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 grades of the materials, 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 recyclability of the parameters. 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 (PART II)

Parameter	Sub-parameter	Fully compatible with flotation-deinking process	Conditionally compatible 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 grades 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 grades 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 flotation-deinking mills.
	Water soluble coatings (among others some grades 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 (PART II)

Parameter	Sub-parameter	Fully compatible with flotation-deinking process	Conditionally compatible 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 flotation-deinking mills 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 flotation deinking recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

6.2.3 Adhesives

Flotation-deinking recycling (PART II)

Parameter	Sub-parameter	Fully compatible with flotation-deinking process	Conditionally compatible with flotation-deinking recycling process	Not compatible with flotation-deinking recycling process	Compatibility with flotation-deinking recycling process 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 1.6mm in diameter (see EPRC scorecard for the removability of adhesives).
	Polyurethane Hotmelt	⊗ #				
Multipack attachment	Hotmelt	⊗ #			⊗	
	Pressure sensitive hotmelt	⊗ *			⊗	
	Pressure sensitive emulsion acrylics	⊗ *				* Only valid for materials with a positive rating according to 4evergreen 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. NOTE: 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
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 13. PART II – Design recommendations adhesives

NOTE: The given design recommendations are based on expert opinion and valid for recycling in flotation deinking recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

6.2.4 Inks and varnishes

Flotation-deinking recycling (PART II)

Parameter	Sub-parameter	Fully compatible with flotation-deinking process	Conditionally compatible with flotation-deinking recycling process	Not compatible with flotation-deinking recycling process	Compatibility with flotation-deinking 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 discolorise 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 discolorise 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-parameter varnishes has to be tested.

Flotation-deinking recycling (PART II)

Parameter	Sub-parameter	Fully compatible with flotation-deinking process	Conditionally compatible with flotation-deinking recycling process	Not compatible with flotation-deinking recycling process	Compatibility with flotation-deinking 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 flotation deinking recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

6.2.5 Decorative metallic 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 elements can be recycled efficiently at both standard recycling mills and flotation-deinking mills. The flotation-deinking process is particularly effective at minimising visual impurities, thereby improving the quality of the recycled product.

Given the capabilities of deinking mills to effectively remove metallic elements, packaging designed with these processes in mind can achieve superior visual quality.

Flotation-deinking recycling (PART II)

Parameter	Sub-parameter	Fully compatible with flotation-deinking process	Conditionally compatible with flotation-deinking recycling process	Not compatible with flotation-deinking recycling process	Compatibility with flotation-deinking recycling process unknown	Comment
Decorative metallic elements	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 elements

NOTE: The given design recommendations are based on expert opinion and valid for recycling in flotation-deinking recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

6.2.6 Additional components

Flotation-deinking recycling (PART II)

Parameter	Sub-parameter	Fully compatible with flotation-deinking process	Conditionally compatible 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 additional components

NOTE: The given design recommendations are based on expert opinion and valid for recycling in flotation deinking recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

7. PART III — SPECIALISED RECYCLING MILLS

7.1 Recycling in specialised mills

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

Mills with specialised operating conditions, additional equipment and using enhanced technology are able to process different fibre-based packaging raw materials than those in standard recycling mills. These types of specialised mills can recycle EN 643 grade 5 papers, as well as some from grades 1-4. In general, specialised mills are preferred for grades that benefit from longer pulping time and require gentle slushing conditions, to avoid cutting off the reject and/or with 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. Additional 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 parameters are typically a constituent part of these novel 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 parameters that need to be removed. Although these 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 these end products. Recycling mills evaluate the quality of the input based on the type of raw material, not the type of packaging. Also, for non-paper parameters, recycling mills clearly look at materials best suited to further recycling and avoid those that are not recyclable in order to improve sustainability.

For this reason, specialised recycling mills 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 fibre-based packaging fit for recycling in specialised mills. 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 from LWP[5]). 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 specialised mills, not every specialised mill 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) applied to the paper end product. Therefore, a specialised mill will potentially involve a choice to use these materials as separate input qualities. It is therefore recommended to have them sorted into separated qualities under agreed rules like the mentioned standards No. 512 or 550 (or additional requirements to be defined by 4evergreen's Fibre-based Packaging Recyclability Evaluation Protocols). The recycling path for used beverage cartons is a well-defined stream Europe wide. Currently, all collected and sorted packages are recycled by the existing mills and the capacities will increase in line with growing collection and sorting of UBC.

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

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

Across Europe, there are approximately 20 recycling facilities 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 FIBRE-BASED PACKAGING

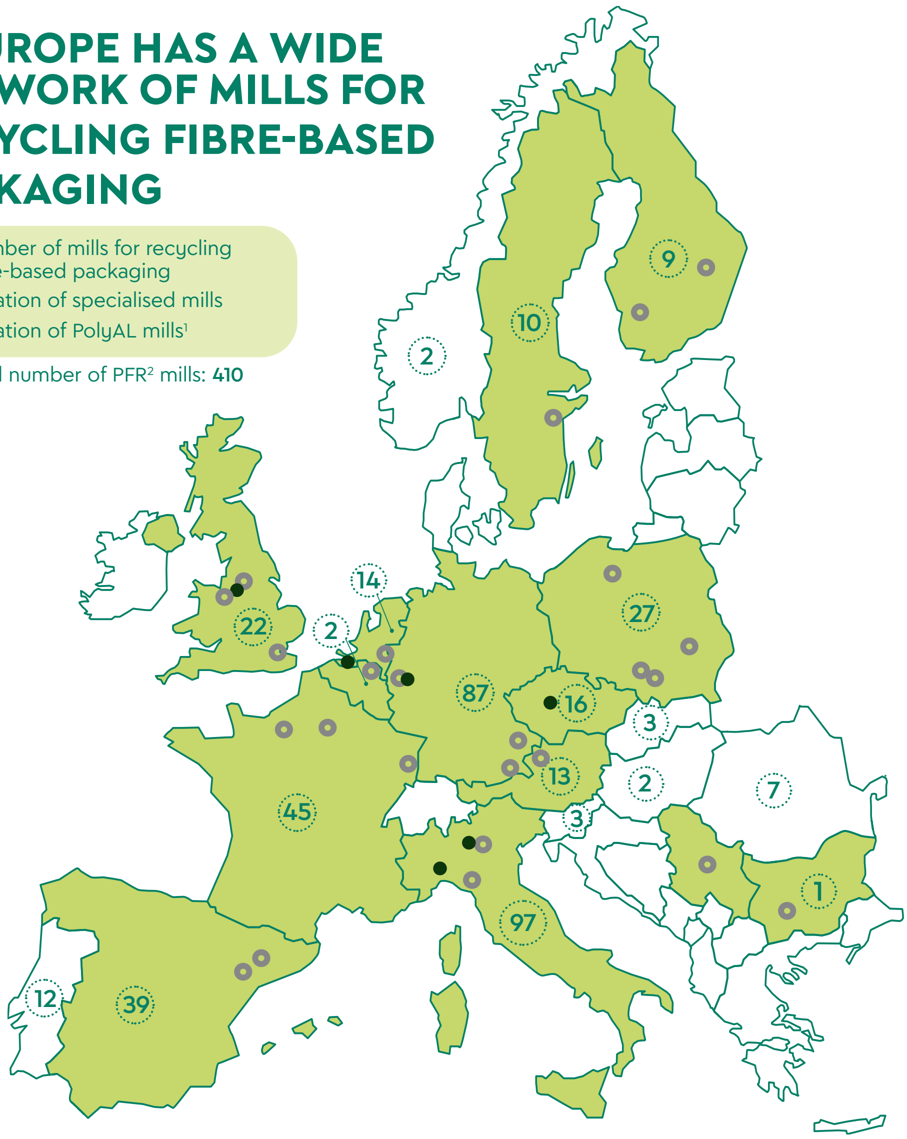


Figure 5. Recycling mills for fibre-based packaging in Europe (Source: Cepi, Extr:act 2022)

The fibres are recovered from UBCs at specialised recycling mills with dedicated processing equipment (see Figure 5).

Specific pulping conditions and equipment are used in specialised recycling facilities, 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 unwanted materials, pulpers are equipped with filter screens. Rejected caps, seals and closures, and other non-fibre layers of beverage 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 beverage cartons – primarily deviates from the repulping process in standard recycling mills. A considerably longer repulping time is required for the fibre recovery from UBCs. Additionally, the capacity to remove and process the PolyAl fraction is better in a specialised process compared to the standard recycling mill.

PolyAl process

In order to recover the polyolefin and aluminium parameters (PolyAl) from beverage cartons a number of technologies are currently used. This process is only applied for materials originating from UBC-mills recycling used beverage 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

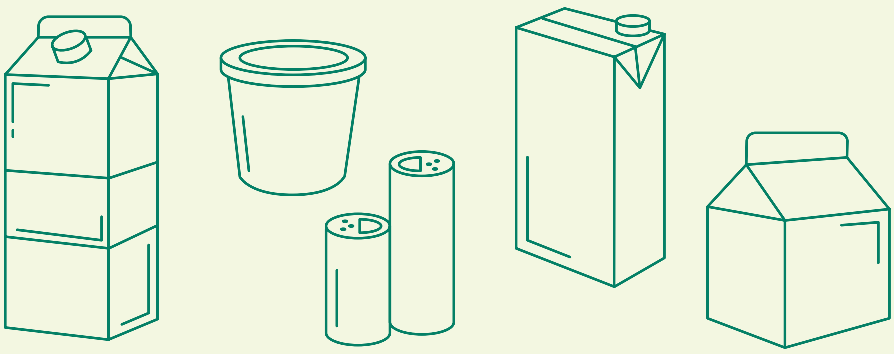
In both cases, it is common practice to separate the soft foil fraction (polymer film and aluminium barrier layers) from the hard plastic fraction (caps, closures, etc.), which is then processed separately into flakes as a mixed polyolefin stream. **The lower the residual fibre in the PolyAl stream,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

In 2022, the Alliance for Beverage Carton and the Environment (ACE) published Design for Recyclability Guidelines[6] dedicated to beverage cartons and specialised recycling mills. This publication provides well-defined and detailed information and recommendations for designing recyclable beverage cartons, including the PolyAl recycling requirements, mostly for injection moulding applications. The ACE guidelines therefore complement 4evergreen's own recommendations.

Packaging examples likely to be recycled in specialised recycling mills

Rigid packaging

- ✓ Food and beverage cartons, double-side coated paper cups, etc.
- ✓ Selection of non-fibre material that does not disturb the recovery processes



[6] ACE (2022), Design for Recyclability Guidelines.

Flowchart (UBC mills)

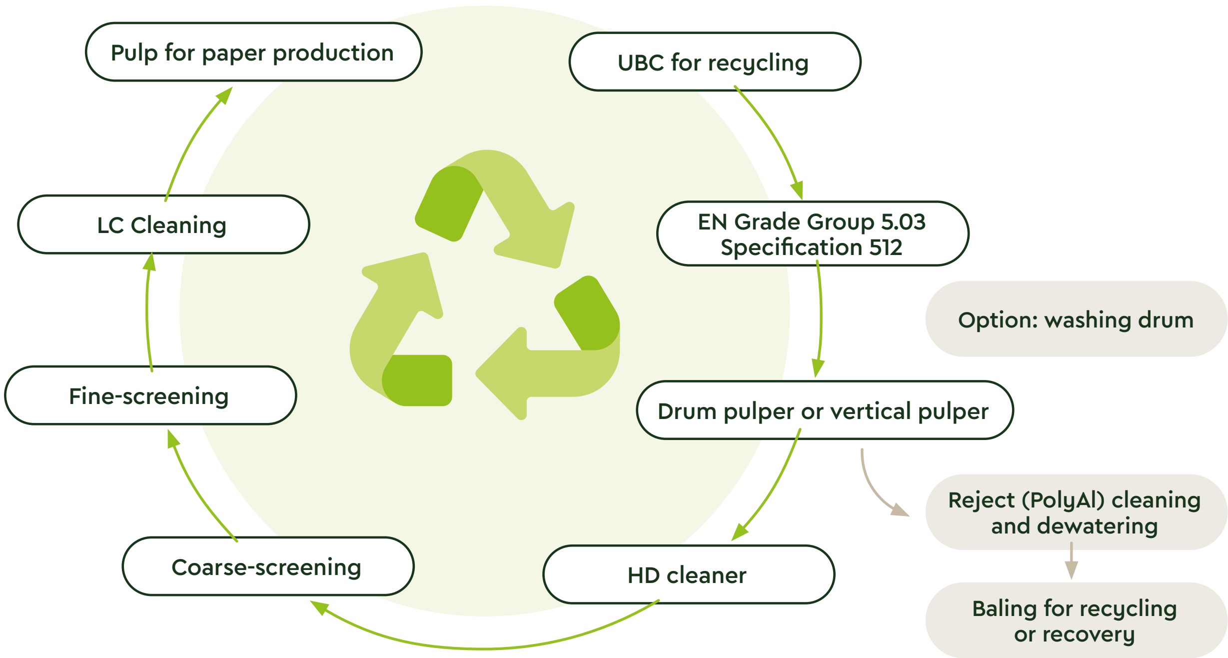


Figure 6. Recycling process in UBC-mills

Flowchart recycling process (FBCP mills)

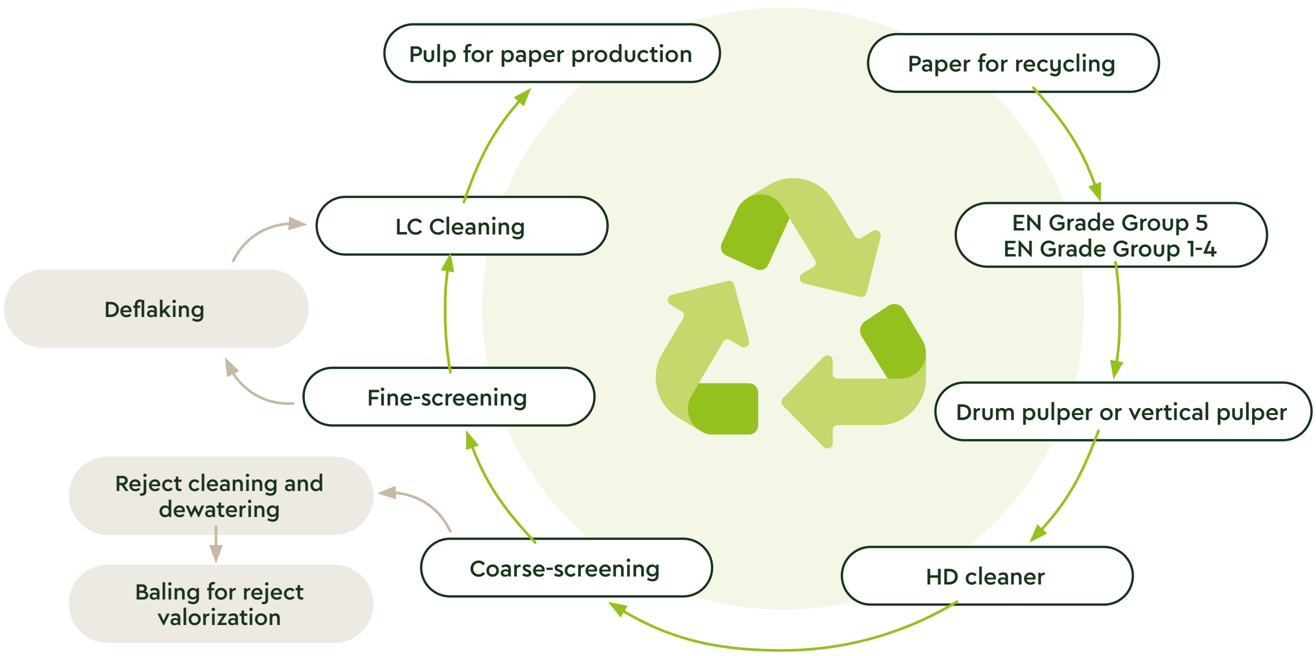


Figure 7. Recycling process in FBCP mills

7.2 Design recommendations (PART III – UBC mills)

This chapter provides specific design recommendations for single packaging groups intended to be recycled in UBC recycling mills, to help **designers refine their work**. As mentioned above, ACE published guidelines dedicated to beverage cartons and specialised recycling mills which should be viewed as complementary to 4evergreen's own recommendations.

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

The design tables provide information for the following parameters:

- 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 elements
- 7.2.6 Additional components

The design tables in this chapter refer to single parameters categorised as:

- Fully compatible with UBC recycling processes
- Conditionally compatible with UBC recycling processes
- Not compatible with UBC recycling processes
- Compatibility with UBC recycling processes unknown

Please note that in this version of the Circularity by Design Guideline the terminology of "component" and "sub-category" has been changed to "parameter" and "sub-parameter" as mentioned previously (see Terminology differentiation between PPWR and 4evergreen).

NOTE: The given design recommendations are widely based on expert opinion covering the entire value chain represented in 4evergreen and valid for specialised recycling mills. Should future recyclability lab testing prove otherwise, the guideline will be updated in line those results alongside the corresponding 4evergreen Fibre-based Packaging Recyclability Evaluation Protocol (PART III).

7.2.1 Fillers, additives and agents

Specialised recycling (PART III)

Parameter	Sub-parameter	Fully compatible with UBC recycling process[7]	Conditionally compatible with UBC recycling process[7]	Not compatible with UBC recycling process[7]	Compatibility with UBC recycling process unknown[7]	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	⊗				

[7] Including PolyAl recycling.

Specialised recycling (PART III)

Parameter	Sub-parameter	Fully compatible with UBC recycling process[7]	Conditionally compatible with UBC recycling process[7]	Not compatible with UBC recycling process[7]	Compatibility with UBC recycling process unknown[7]	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.
	Colorants/ pigments	⊗				
	Polyvinyl alcohol	⊗				
	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 specialised recycling mills. 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 grades of the materials, 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 recyclability of the parameters. 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 recycling process compatibility for used beverage 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 specialised mills. 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 ACE 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 ACE – Beverage Carton – Design for Recyclability 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 (PART III)

Parameter	Sub-parameter	Fully compatible with UBC recycling process[8]	Conditionally compatible with UBC recycling process[8]	Not compatible with UBC recycling process[8]	Compatibility with UBC recycling process[8] unknown	Comment
Extrusion barrier coating	Thermoplastic (one side coated, inside the pack only)				⊗	Not relevant in UBC recycling. Packaging with coating only on the inside of the packaging would potentially not be recognised as UBC target material in sorting plants. Please refer to chapter 7.3 Design guidance (Part III - FBCP mills).
	Thermoplastics (two sides coated)	⊗[9]				Specialised recycling mills for UBC recycling 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 ACE Design for Recyclability Guidelines.
Adhesive barrier film	Adhesive lamination with water-soluble adhesives (some grades of PVOH, starch, etc.)	⊗				Adhesive lamination with water-soluble adhesives is fully compatible with UBC recycling.
	Adhesive lamination (inside of pack) of PET, mPET, PET/PE etc.		⊗	⊗[9]		PET content with <5% share of weight relative to polymer structure is non-desirable but manageable. PET content with 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 UBC recycling. For PET/Alu/PE barriers, please refer to guidance on adhesive lamination containing PET above.

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

Specialised recycling (PART III)

Parameter	Sub-parameter	Fully compatible with UBC recycling process[8]	Conditionally compatible with UBC recycling process[8]	Not compatible with UBC recycling process[8]	Compatibility with UBC recycling process[8] unknown	Comment
Wet-barrier coatings	Aqueous polymer dispersions (among others some grades of acrylics, EEA, SB, ABS, PVDC, etc.)				⊗	Application of materials in LPB products and performance in UBC recycling is unknown.
	Solvent-based coatings				⊗	Application of materials in LPB products and performance in UBC recycling 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 grades of PVOH, EVOH EVA Biobased, etc.)				⊗	Application of materials in LPB products and performance in UBC recycling is unknown.
Wax coatings	Dipping of paper in molten wax (two-sided)				⊗	Not relevant in UBC recycling. Please refer to chapter 7.3 Design guidance (PART III –FBCP mills).
Barrier metallization	Direct metallisation on paper (primer, Alu nanoscale, protective coating) – inside	⊗ [9]				Vapour deposition of thin-layer metallisation can be applied. Thresholds and material compatibility as defined in ACE DfR Guidelines apply.
	Direct metallisation on polymer (Primer, Alu/AlOx/SiOx nanoscale, protective coating) – inside	⊗ [9]				Vapour deposition of thin layer metallisation can be applied. Thresholds and material compatibility as defined in ACE DfR Guidelines apply.
	Transfer metallisation (adhesive + transfer metallisation) – inside				⊗	Not relevant in UBC recycling. Packaging with coating only on the inside of the packaging would potentially not be recognised as UBC target material in sorting plants. Please refer to chapter 7.3 Design guidance (PART III –FBCP mills).

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 specialised recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

[8] Including PolyAl recycling.
[9] Detailed information on material compatibilities and thresholds as defined in the ACE 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 (PART III)

Parameter	Sub-parameter	Fully compatible with UBC recycling process[10]	Conditionally compatible with UBC recycling process[10]	Not compatible with UBC recycling process[10]	Compatibility with UBC recycling process[10] 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 1.6mm in diameter (see EPRC scorecard for the removability of adhesives).
	Polyurethane Hotmelt	⊗ #				
Cap/straw attachment for beverage cartons	Hotmelt[11]	⊗				
Multipack attachment	Hotmelt	⊗ #			⊗	
	Pressure sensitive hotmelt				⊗	* 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. NOTE: 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
	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 specialised recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

[10] Including PolyAl recycling.
[11] 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 specialised recycling mills, two different cases in applying them on liquid packaging board have to be considered:

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

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 standard recycling mills applies.

Specialised recycling (PART III)

Parameter	Sub-parameter	Fully compatible with UBC recycling process[12]	Conditionally compatible with UBC recycling process[12]	Not compatible with UBC recycling process[12]	Compatibility with UBC recycling process[12] unknown	Comment
Offset	Oil-based (mineral)		⊗			Nor relevant for UBC-recycling process. 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.

[12] Including PolyAl recycling.

Specialised recycling (PART III)

Parameter	Sub-parameter	Fully compatible with UBC recycling process[12]	Conditionally compatible with UBC recycling process[12]	Not compatible with UBC recycling process[12]	Compatibility with UBC recycling process[12] unknown	Comment
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	⊗				
Digital[13]	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.

Table 20. PART III – Design recommendations inks and varnishes

NOTE: The given design recommendations are based on expert opinion and valid for recycling in specialised recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

13 Digital printing technologies emerging; continuous surveillance required.

7.2.5 Decorative metallic elements

Metallic elements with a thickness lower 1 micron are not causing any issue during the UBC 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 UBC 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 (PART III)

Parameter	Sub-parameter	Fully compatible with UBC recycling process[14]	Conditionally compatible with UBC recycling process[14]	Not compatible with UBC recycling process[14]	Compatibility with UBC recycling process[14] unknown	Comment
Decorative metallic 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 elements

NOTE: The given design recommendations are based on expert opinion and valid for recycling in specialised recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

[14] Including PolyAl recycling.

7.2.6 Additional components

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

Specialised recycling (PART III)

Parameter	Sub-parameter	Fully compatible with UBC recycling process[15]	Conditionally compatible with UBC recycling process[15]	Not compatible with UBC recycling process[15]	Compatibility with UBC recycling process[15] unknown	Comment
Caps and closures	PE	⊗ [16]				Thresholds and material compatibility apply, as defined in ACE DfR Guidelines.
	PP	⊗ [16]				
	PET			⊗ [16]		
	Biodegradable polymers			⊗		
Spouts	PE	⊗ [16]				
	PP		⊗ [16]			
	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 additional components

NOTE: The given design recommendations are based on expert opinion and valid for recycling in specialised recycling mills. 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 grades of the materials, 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 recyclability of the parameters. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

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

7.3 Design guidance (Part III – FBCP mills)

The recycling of fibre-based packaging would require a specialised fibre recycling process when the functionality and/or complexity of the packaging is increased by additional elements or additives, or indeed higher pulp quality is required for the end product. Certain fibre-based packaging would require a specialised recycling process when added functionality is required, such as hygiene requirements and food safety measures that they are not suitable for processing in standard mills.

Specialised mills can process EN 643 grade 5 papers, and some from grades 1-4.

These fractions include packaging which, due to its composition, is more suitable for re-processing in specialised paper mills, e.g. Kraft paper sacks with a plastic layer and polymer liner.

These mills are designed to handle materials that need longer pulping times and gentle slushing to avoid cutting off the reject. These facilities employ advanced technology and equipment to process materials that standard recycling mills cannot handle. This allows them to recycle packaging which includes additional elements 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 elements, and their recyclability depends on the presence/ use of enhanced equipment. The input requirements for specialised mills focus on the quality and type of fibre and the quantity of non-paper parameters 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 (Design for Circularity Guideline and Recyclability Evaluation Protocol), members from the entire value chain discovered that there is no uniform standard for specialised FBCP mills. The processes in these mills highly depend on the incoming raw material and the targeted output quality after the recycling process.
Given this complexity and variety, this chapter offers general design guidance for fibre-based composite packaging, whereas detailed design recommendation tables are provided in Chapter 7.2. Design Recommendation Tables (Part III – UBC).

To ensure that fibre-based composite packaging, which cannot be handled using standard processes or in specialised mills for UBC, can be recycled effectively in other specialised mills certain general rules apply:

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

8. DESIGN FOR RECYCLING (D4R) CHECKLIST

The primary aim of D4R 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 proposed checklist seeks to minimise the need for extensive testing especially products that only include materials from the green column, thus streamlining the process and maximising efficiency.

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

To further improve collection and sorting, the D4R checklist will be updated according to new findings as part of the 4evergreen recyclability evaluation protocol and any subsequent revisions of this guidance document.

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

Prerequisite for using the D4R checklist: To estimate the design for recycling compatibility of packaging, indicate if the design involves a separation of parameters. And if so, consider each separate parameter as a separate item for the D4R check. This means each distinct component from the main body which is typically discarded prior to or separated from the packaging unit (Article 3(43)). It also means each integrated component (Article 3 (42)) which does not need to be separated from the main packaging unit to ensure it functions as intended and is typically discarded at the same time as the packaging unit, although not necessarily in the same disposal route/pathway.

Figure 8. Design for recycling checklist

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

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

1|

Determining if a fibre-based packaging can be considered designed for recycling, the behaviour of the packaging in the recycling facilities as well as consideration of the sorting behaviour of the packaging must be considered. Hence, the D4R checklist aims to indicate if the packaging contains any constituents that could pose issues with regards to state-of-the-art sorting techniques (e.g. eddy-current or NIR). See 5.2.5 Decorative metallic effects.
4evergreen is currently investigating the impact of various non-paper parameters on the sorting process. As a 4evergreen-specific sorting protocol for fibre-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 mill type, a minimum paper content must be guaranteed to ensure sufficient target material for recycling mills. According to 4evergreen's Fibre-based Packaging Recyclability Evaluation Protocol for standard mills, a minimum of 80% paper content must be ensured; lower than this would theoretically fail standard mill requirements. This question will be updated as soon as the testing methods and corresponding evaluation protocols of 4evergreen are available.

3|

If packaging features any parameter in the red category it is not considered "designed for recycling". Therefore, the D4R checklist recommends redesigning the packaging features or (sub)parameters focusing on the green column or carefully considered parameters from the orange column.

4|

The given design recommendations in the guideline are widely based on expert opinions covering the entire value chain represented in 4evergreen, but only represent a picture of the status quo at the time of publication. Anything that might be classified as "unknown" may in due course be superseded based on new findings and/or relevant testing.

5|

It is important to acknowledge that this guideline may not encompass all conceivable material or component types or scenarios, including those in development.
If positive recyclability evaluation test results for these types of materials combinations of components already exist, it is appropriate to proceed to the next step.
If there is no recyclability information available about the behaviour of such a material or components in combination, recyclability testing with the current available test methods and evaluation protocols for the dedicated mill type 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.

9. 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
The gathering of discarded fibre-based packaging and/or other recyclables from various sources (i.e. household, commercial, industrial) which are ultimately (directly or indirectly) destined for recycling at a dedicated plant.

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.

Directive on Waste (2008/98/EC)
Also known as the "Waste Framework Directive", it defines key elements such as waste, the waste hierarchy and recovery. The Directive sets the legal framework for waste management in all Member States of the European Union.

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).

EU Circular Economy Package
The Circular Economy Package, which entered into force July 2018, sets new targets towards a circular use of raw materials and on increasing the recycling rates for all packaging materials.

EU Packaging and Packaging Waste Directive (PPWD)
The Directive (94/62/EC) defines recycling targets for the main packaging materials and serves as guidance to improve the sustainable performance of packaging in the European Union.

EN 643 – European List of Standard Grades of Paper and Board for Recycling
The European List of Standard Grades of Paper and Board for Recycling gives a general description of the standard grades by defining what they are allowed and not allowed to contain.

Fibre-based composite packaging
Packaging composed of paper and a considerable share of non-paper elements that by design are not separated after use.

Fibre-based packaging
A product, based on paper and/or cardboard, suitable to pack filling goods. Design and properties of the fibre-based packaging typically are specific for the respective filling goods.

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 2,500nm. NIR is used in the sorting process to separate packaging from each other based on reflected surface material.

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 papermaking 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 for Recycling (PfR)

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

Recycling

The mechanical reprocessing of paper for recycling in a paper and board mill as part of a production process into new products, materials, or substances.

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).

Standard recycling mill

Standard mills typically produce high-quality end-products based on EN 643 groups 1-4. In large 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 (i.e. recycled pulp).

Specialised recycling mill

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

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

ANNEX

4evergreen has shared previous versions of this guideline with a select group of industry stakeholders and associations to gather their inputs and feedback. 4evergreen is committed to fostering a fruitful dialogue with partners across the fibre-based packaging industry and other sectors, and their contributions to 4evergreen's work are highly valued.

Feedback received on previous iterations of this publication has been incorporated into the current document. It concerns:

- Completely revised decision tree, to guide users of the guideline precisely to the most relevant design recommendation tables. Including a disclaimer that is only an illustrative example which cannot encompass all packaging available on the market.
- Additional D4R checklist to support designer in estimating if a packaging is designed to be recyclable
- Consistent use of terminology
- The revision of EN 643 was considered very useful and necessary in WS-2. As soon as this has been completed, the changes will be integrated into the Circularity by Design Guideline.

Stakeholders from across all industries and sectors involved with fibre-based packaging are invited to share this document in their own networks and 4evegreen would be pleased to receive any further feedback or comments on its implementation.

Please contact the 4evergreen Secretariat (4evergreen@cepi.org) to receive further information about how to get involved in the consultation process.

NOTES

NOTES

ABOUT 4EVERGREEN

4evergreen is a cross-industry alliance perfecting the circularity of fibre-based packaging to contribute to a climate-neutral and sustainable society. Our goal is to raise the overall recycling rate of fibre-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 fibre-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.

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For general enquiries please contact 4evergreen@cepi.org