CIRCULARITY BY DESIGN GUIDELINE FOR FIBRE-BASED PACKAGING

4evergreen

Table of contents

Introduction

Consumers are increasingly aware of the environment and the importance of eco-design and recycling in both the goods they purchase and the way they are packaged. Brands and retailers are under pressure to respond to these market expectations. Fibre-based packaging is both a sustainable and 'circular' solution – closing the loop on resources to keep them in use or reuse longer – because it is renewable and has one of the highest recycling rates globally.

Packaging needs to fulfil various functions, such as protecting the contents, communicating information about the products, and facilitating their transportation. Using fibre-based packaging to achieve these different properties may require a combination of materials. The right combination of materials enables benefits such as longer shelf-life and more protection against external damage. Due to the wide variety of fibre-based packaging solutions, some adaptations in the recycling process may be needed to increase the rate of material recovery. Indeed, the amount and variety of fibre-based packaging on the market is continuously growing and becoming more complex. Innovative solutions are therefore needed to maintain and further increase the recycling rates across Europe.

This document, the Circularity by Design Guideline (Part A), has been produced by the 4evergreen alliance, involving packaging and sustainability experts of companies acting across the entire supply chain in the fibre-based industry. The primary purpose of this Guideline, the first of three parts (Part B on deinking mills and Part C on specialized mills will be released in 2022), is to explain how different components of fibrebased packaging impact the paper recycling process in standard recycling mills and whether they can be classified as "fully compatible with the standard recycling process", "conditional recyclable with the standard recycling process" or "not recyclable with the standard recycling process". Together, these design guidelines are based mainly on expert opinions. Reviews according to an updated test method are ongoing and an updated edition will be published.

Any fibre-based packaging that is not (fully) recyclable in standard recycling mills (i.e. Recyclability Evaluation Protocol under Part A) can potentially be recyclable in specialized recycling mills or deinking mills. Thus it does not mean that any negative assessment for compatibility with the standard recycling process suggests that the packaging is not recyclable. However, there are presently no design recommendations available for recycling fibre-based packaging in deinking mills (Part B) or specialised recycling mills (Part C). These are currently being developed within the 4evergreen alliance.

Scope of this document

This design guideline aims to present recommendations for the design of fibre-based packaging and addresses all actors along the entire value chain, from manufacturers to retailers, including packaging designers.

This document 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. Fibre-based packaging is non-explicitly divided into the following types[1]:

- paperboard (e.g. cereal boxes)
- corrugated board (e.g. shipping boxes)
- multi-layered board (e.g. folding boxes)
- packaging paper, special and functional paper (fibre-based flexible packaging e.g. shopping bags, food wraps, paper pouches)
- moulded pulp (e.g. egg-carton)

For the duration of the alliance, 4evergreen will continue the ongoing dialogue with members 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

Valuations 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 aim is to provide a comprehensive and fact-based guideline, for standard and specialised processes, hence the current recommendations will be verified with the new Cepi Harmonised European Laboratory Test Method, and the 4evergreen Recyclability Evaluation Protocol Part A/B/C once results have been evaluated and finalised within 4evergreen.

Applicability

This document is intended for the evaluation of compatibility with standard mill processes. The guideline is therefore applicable to fibre-based packaging that is likely to be recycled in standard recycling mills, provided that product-specific regulations of the packaging are observed. Recommendations on the suitability of special recycling processes and recycling including deinking will be implemented in further versions in 2022.

Innovations and future versions

This guideline is intended to support the use of fibre-based packaging and innovation as novel solutions to improve the environmental performance of packaging. The predominant focus of the guideline is to ensure that materials and packaging solutions currently on the market are suitable for recycling. Packaging using novel technologies requires testing to assess its compatibility with recycling processes. Future trends and innovations will be observed and evaluated by 4evergreen in the course of future versions.

[1] Please see the definitions for the product groups in the glossary p.32

List of abbreviations

ABS	Acrylonitrile Butadiene Styrene
AKD	Alkyl Ketene Dimer
Alu	Aluminium
ASA	Alkenyl Succinic Anhydride
BOPP	Biaxially Oriented Polypropylene
Cepi	Confederation of European Paper Industry
CMC	Carboxymethyl cellulose
COD	Chemical Oxygen Demand
DIN	German Institute for Standardisation (Deutches 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
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
PAAE	Polyamidoamine-epichlorohydrin
PAE	Polyamide-epichlorohydrin
PCC	Precipitated Calcium Carbonate
PET	Polyethylene Terephthalate
PE	Polyethylene
PFA	Perfluoroalkoxy Alkanes
PLA	Polylactic Acid
PfR	Paper for Recycling
PP	Polypropylene
PPWD	Packaging and Packaging Waste Directive
PS	Polystyrene
PVA	Polyvinyl Acetate
PVC	Polyvinyl Chloride
PVDC	Polyvinylidene chloride
PVOH	Polyvinvyl alcohol
RFID	Radio-frequency identification
S / A	Styrene acrylic
S / B	Styrene butadiene
SB	Solvent-Based
SBB	Solid Bleached Board
SiOx	Silicon Oxide
UV	Ultra Violet
WB	Water-Based

1. REGULATORY BACKGROUND

The packaging industry is working to improve recycling processes and enhance sustainable/ecological 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, which was published in July 2018, is a major driver of progress in environmental standards and actions. Among other things, the package led to modifications of several regulations concerning packaging, including 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 table below provides an overview of the European regulations concerning packaging and packaging waste.

Regulation	Abbreviations	Enforcement Date	Implementation in National Law	Content
Packaging and Packaging Waste Directive 94/62 (PPWD)	**94/62/EC**	1994	July 1996	> Recycling targets for packaging materials > Encourage producers to use recycled content for packaging > Essential requirements for packaging composition
Amendment to PPWD (2018)	**2018/852/EC**	July 2018	July 2020	> Revision of all recycling targets: Paper - 75% by 2025 - 85% by 2030 > New calculation method for recycling rates
Waste Framework Directive 2008/98 (WFD)	**2008/98/EC**	December 2008	December 2010	> Definition of waste terms (recycling, waste, reuse) > Waste hierarchy > Promotes separate collection and high-quality recycling
Amendment to WFD	**2018/851/EC**	July 2018	July 2020	> Recycling target for municipal waste

Table 1. European packaging and waste regulations

Food contact materials

4evergreen aims to increase the recycling of on-the-go and household packaging by ensuring separate collection streams are available for all fibre-based packaging types. Food packaging represents a large part of this sector. Besides the directives concerning recycling and circular design, food packaging needs to fulfil safety requirements – parts of the packaging can be in direct contact with food. The two most important regulations concerning packaging material in direct contact with food are the Regulation (EC) No. 1935/2004 and Regulation (EC) No. 2023/2006. They establish the framework for producing food packaging materials and defining the materials allowed on the European market.

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

2. 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 paper-making (re)cycle, the fibres gradually deteriorate until they may be rejected during preparatory pulp-cleaning process. According to Kreplin, Schabel and Putz (December 2019), 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.

2.1 Recycling processes in paper mills

When reprocessing fibre-based packaging, the process needs to be carefully set up and calibrated to handle the different components 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. "Standard recycling mills" can handle small amounts of non-fibre material, whereas "specialised recycling mills" can handle larger amounts of non-fibre materials and fibre-based materials that need dedicated conditions during pulping and cleaning (Cepi 2019). Some fibre-based packaging can also be recycled in deinking mills. The suitability of specific recycling processes can be evaluated using the 4evergreen Recyclability Evaluation Protocol listed in Table 2 and corresponding assessment schemes.

Part	Scope	Release (*expected)
Part A	Standard recycling mill	Q1. 2022
Part B	Deinking mill	2022*
Part C	Specialised recycling mill	2022*

Table 2. 4evergreen Recyclability Evaluation Protocol

2.2 Standard recycling mills

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

(Re)pulping
The purpose of pulping is to disintegrate the paper and separate fibres from other components. In this step, the paper for recycling is blended with water, the temperature is typically around 40°C and the acid-alkaline value is about pH7. These mills typically have a low-consistency pulper (5% fibre concentration). The aim of this first step is to disintegrate and separate fibres from other materials.

Deflakers
Deflakers are used to separate the fibre bundles and break down any pieces of paper that are not defibred properly after pulping.

Coarse and fine screening
Screening is the process of removing impurities from the pulp, to separate the fibres from potential contaminants. This can be divided into coarse and fine screening. Coarse screening can already be implemented after the pulping step itself as the fibre suspension flows through screening holes and large non-fibre particles are retained. The objective of the fine screening is to remove smaller-sized particles.

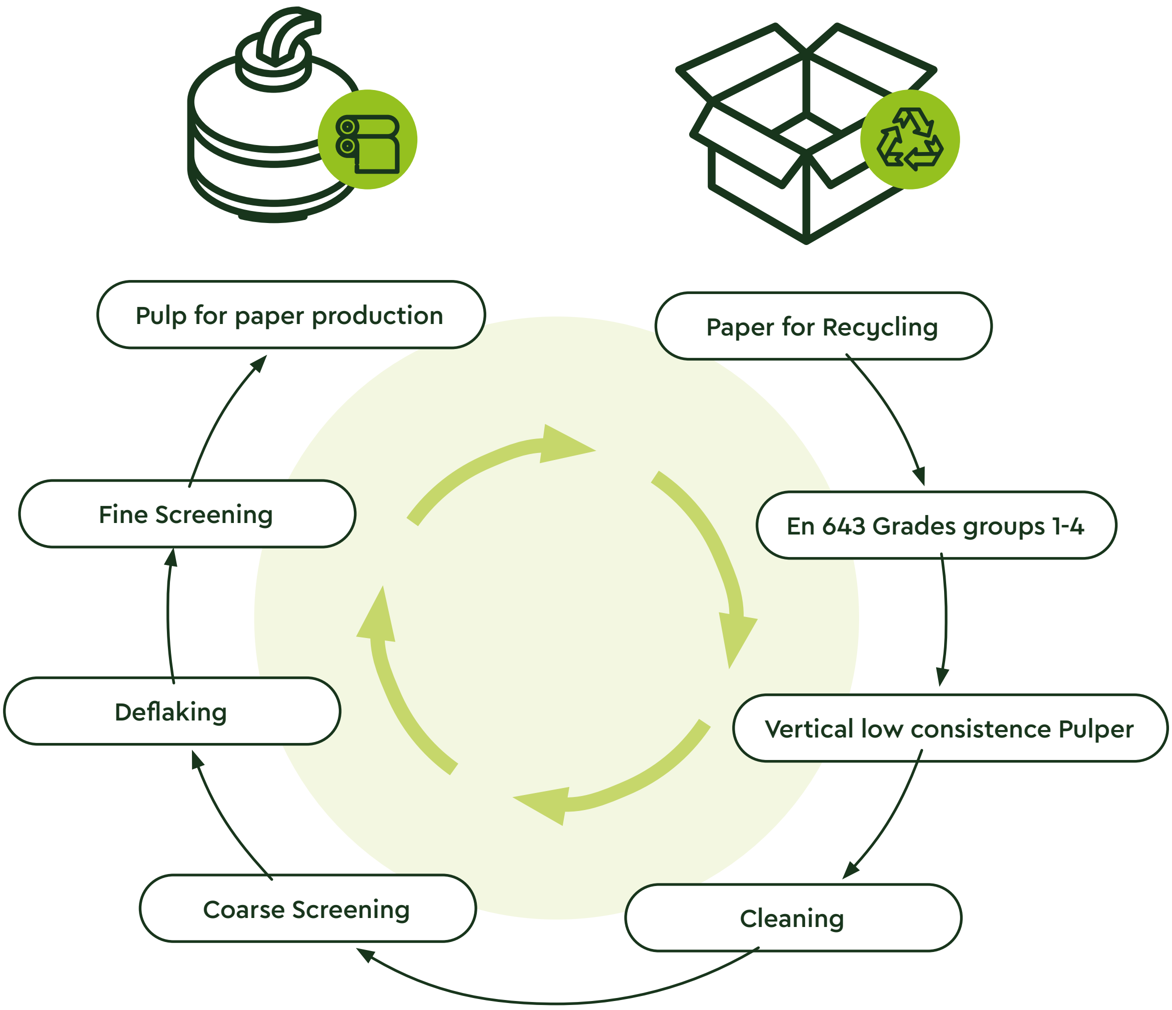

Figure 1. Recycling in standard paper mills

3. 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 and viable substitute for so-called "virgin material" (i.e. "secondary materials" that meet the quality and safety standards to replace "primary materials"). 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 recommendations included later in this document refer to the recyclability of fibre-based packaging by classifying the components according to their compatibility with the **standard recycling process**. Table 3 shows the definition by which the components are classified.

NOTE: The definition of recyclability using different recycling processes (standard mill, deinking/flotation mill or specialised mill) is an ongoing discussion. **4evergreen's current testing and assessment is expected to provide some much-needed clarity.**

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

Table 3. Compatibility with standard recycling process

3.1 Pre-requisite for fibre-based packaging

3.1.1 Pre-requisite for fibre-based packaging

Paper consists mainly of natural fibres (min. 50% w/w, both of primary and secondary fibre source) and can possibly contain other ingredients such as filling material, starch, coating colourants and binding material, as well as additives typically used in the paper industry, such as wet-strength agents, sizing agents and bound 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 quality of recycled paper.

Fibre-based packaging material essentially means papermaking fibres, fillers, coatings, pigments, binders and other wet components, but also starch and a range of "dry strength" agents as well as functional and process chemicals used in "wet-end" paper machining, including printing inks, overprint varnish, adhesives (e.g. binding paper and plastic film), polymeric barrier layers, and other accompanying elements (e.g. tape, label).

The paper content calculation effectively grades the packaging material's fibre content and is derived from the Paper weight/Fibre-based packaging material weight*100%. **A minimum of 50% paper content** is needed to be considered or classified as "fibre-based packaging".

In this guideline, the paper content of the packaging should therefore **be at least 50%.**

3.1.2 Components to avoid in fibre-based packaging

The presence of certain elements may lead to undesired consequences even for simple packaging.
In general, all sources of toxic (including toxic to reproduction), mutagenic, cancerogenic, endocrine disrupting chemicals must be avoided in any package or packaging component.

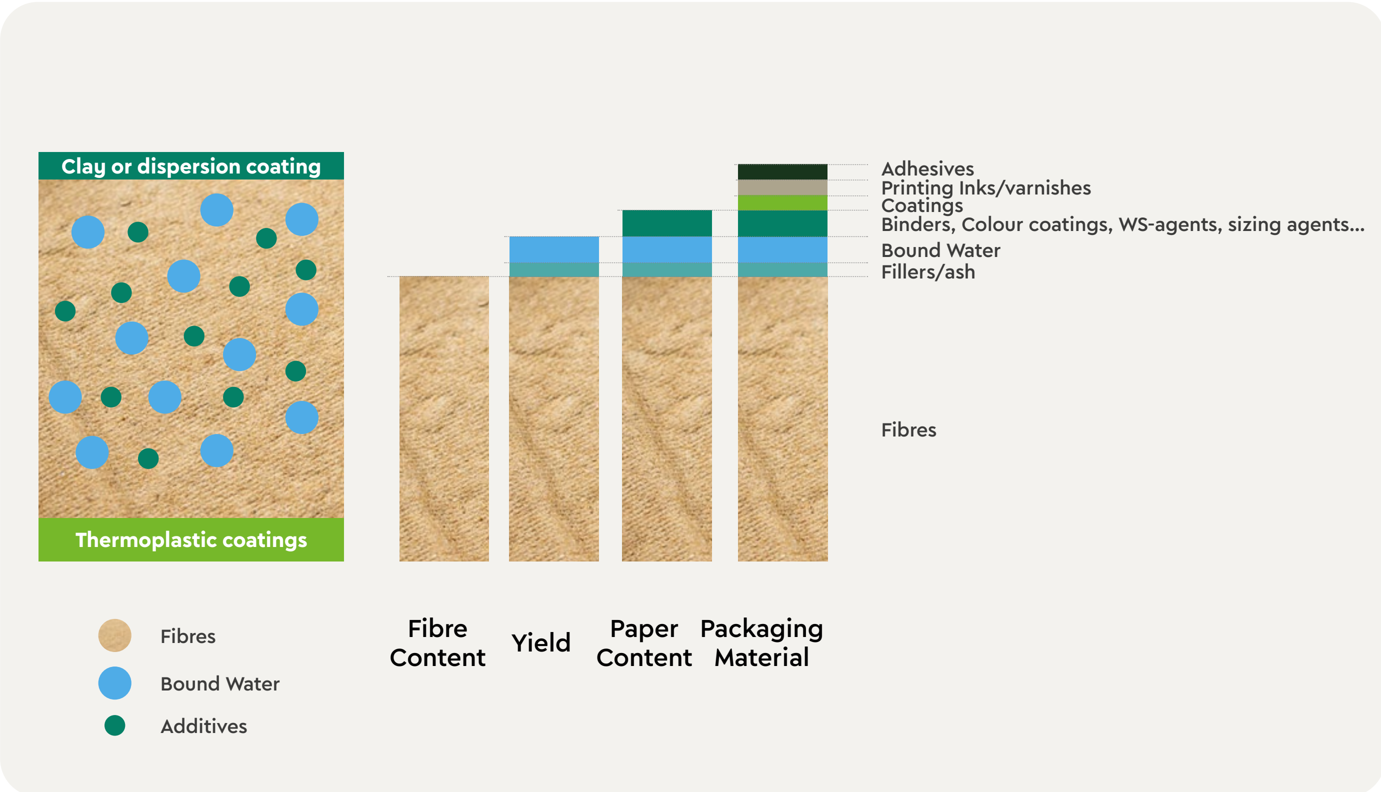

Figure 2. Distinction of fibre-content, yield and paper-content[2]

[2] Ash =residues from inorganic elements like chemicals fillers and coatings , Yield= combination of fibres and ash

4. DESIGN RECOMMENDATIONS

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 components affect the recycling process. Following a "design for recycling" approach helps packaging designers learn which components might have a negative impact on the recycling process, already in the design phase of packaging.

This chapter provides specific design recommendations for single product groups, to help designers refine their designs. This guideline provides recommendations, presented in a compact design table, for the following materials and components, and their compatibility in the standard recycling process:

- Fillers, additives, and agents
- Barrier coatings and treatments
- Adhesives
- Inks and Varnishes
- Metallic components
- Additional components

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

The design tables found elsewhere in this document refer to single components categorised as:

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

Please see Table 3 (p.12) for the detailed description of each category.

NOTE: The given design recommendations are - based on expert opinion and valid for recycling in standard recycling mills. Actual testing prevails the given recommendations in the guideline, the guideline will be updated in future version with test results by the Cepi Harmonised European Laboratory Test Method.

4.1 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.
Please be aware that the recommendations in the design tables only refer to the recyclability of the components. Further environmental impacts and safety aspects must be considered when creating efficient and sustainable packaging.

Component	Sub-category	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with 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. Threshold needed.
	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 a number of 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				⊗	Recyclability depends on a number of factors such as relative wet strength level, amount of WS agent etc. Recyclability can be improved by e.g. 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/Melamine				⊗	Unclear whether these WS agents are still used in paper and board manufacturing. Testing needed to evaluate recyclability and set thresholds.
	Glyoxylated polyacrylamide (GPAM)	⊗				
Sizing, surface	Starch	⊗				

Component	Sub-category	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with recycling process unknown	Comment
Other	Colorants/ dye for shading	⊗				
	Colorants/ pigments	⊗				Physically recyclable but certain dyes are not approved for food packaging applications and such dyes should be avoided.
	Polyvinyl alcohol	⊗				
	PAC	⊗				
	Retention polymers	⊗				
	Siliconising agents		⊗			Used, for example, in release papers for labels. The compatibility for recycling depends on the chemistry of siliconizing treatments. Most siliconised papers can be recycled in specialised mills, but are not compatible with the standard recycling process. Water-based siliconizing agents are an expectation as they are recyclable in standard recycling mills. Testing is needed to evaluate the recyclability.

Table 4. Compact design table for different materials and components

4.2 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 fit 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).

4.2.1 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 don't contain substances considered by the EU's REACH regulation to be of "very high concern"[3], for example rendering them unsuitable for food contact, and/or accumulating over several cycles.
Use only the required quantity of wet-strength agents to fulfill 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. That way, it keeps their presence in Paper for Recycling at a manageable level – as in standard recycling processes – so no specialised process is required for recycling.
For fibre-based packaging grades that have no (or low) compatibility with standard processes there are potentially EN 643 grades defined (grades 5.XX) which enable recycling in specialised mills with dedicated processing setups.

4.3 Barrier Coatings and Polymer Content

Fibre-based packaging including paper and paperboard do not have intrinsic barrier properties. Barriers are required to provide adequate protection to food and non-food goods from external factors, such as moisture caused by high relative humidity, oxidation, contamination introduced through mineral oils, and other hazardous substances. 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.

[3] REACH candidate list of substances of high concern; plus candidate list of substances of very high concern for authorisation, ECHA (europa.eu)

Component	Sub-category	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with 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 Harmonised European Laboratory Test Method is available.
	Thermoplastics (two sides coated)			⊗		This is considered to have limited recyclability or conditionally compatible with standard recycling until further information from Cepi Harmonised European Laboratory Test Method is available. It can only be recycled in enhanced recycling mills with a dedicated pulper.
Adhesive barrier film	**Adhesive lamination with water-soluble adhesives (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 laminationfoil are difficult to ascertain; adhesives tend to increase the potential of stickies. The initial consensus is that this product has limited recyclability, but further test results are needed (courtesy of the Cepi recyclability laboratory test method). Aluminum film has influence on flowmeters based on inductivity.
	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 side extrusion coating.

Component	Sub-category	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with recycling process unknown	Comment
Wet-barrier coatings	**Aqueous polymer dispersions (acrylics, EEA, SB, ABS, PVDC, etc.)**	⊗	⊗			Testing required, as properties of polymer dispersion coatings depend on the amount and strength of the adhesives and the presence of fillers.
	Solvent-based coatings	⊗	⊗			Testing required.
	Wax dispersion (incl. microcrystalline waxes)		⊗			This is expected to have a potential impact on stickiness.
	Water soluble coatings (PVOH, EVA Biobased, etc.)	⊗	⊗			Needs thorough cleaning in milling to prevent issues like foam forming. The COD load will be higher for soluble polymers.
Wax coatings	**Dipping of paper in molten wax (two sided)**			⊗		May impact on stickiness and cause screen clogging.
Barrier metalliza-tion	**Direct metallization (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 5. Overview of typical barrier coatings/treatments 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.

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

4.3.1 Barrier coatings used in fibre-based packaging

There is no widely adopted or standardised classification of polymeric treatments, coatings, and laminations, which are 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 online during 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-side thermoplastic film extrusion coating of paper and board
- Two-side thermoplastic film extrusion coating of paper and board
- Water-soluble extruded coatings (e.g. polyvinyl alcohol, ethylene vinyl alcohol)

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, 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

4.3.2 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. Water-based coatings include polymers like polyvinylidene chloride (PVDC), acrylics, styrene butadiene copolymers, vinyls, etc. The total coating amount can vary between 5 and 20 g/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 (acrylics, EEA, SB, ABS, PVDC, PVOH etc.)
- Solvent-based coatings
- Wax dispersion coating (incl. microcrystalline waxes)
- Water-soluble coatings (PVOH, EVA Biobased, etc.)

Wax coating (dipping paper in a molten wax bath)
Waxing paper is a traditional process where paper is given waterproofing properties ("hydrophobized") 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 50 nm-thick (ca. 0.14 g/m2) aluminium layer that is applied in a vacuum deposition process. The metallisation is transferred on paper using adhesive (acrylic, polyurethane, EVA, etc.) courtesy of release-coated PET film. The overall polymer thickness and protective layers, along with metallisation, is usually not more than 5 μm.

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)
Fluoroalkyls 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.

4.3.3 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[4], 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 eventually 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 mill with special equipment to mitigate the effects of barriers being present.

4.4 Inks and varnishes

Printing inks are used to colour the substrate surface to produce an image, text or design. They are composed of colorants, binders, additives and diluents (i.e. substances used for dilution). Colorants are responsible for the colour impression and consist mostly of organic or inorganic pigments. Binders contain polymers, which wrap and stabilise the pigment particles in the ink mixture, and fix the pigment on the substrate. They determine the ink properties depending on packaging application, printing technology and ink chemistry. Additives are used to fine-tune the ink properties towards the desired application. The diluent dissolves the binder and determines the flow properties of the ink in order to ensure a good transfer to the substrate. Typical diluents are water, oil and organic solvents.
Varnishes are unpigmented systems and contain binders, additives and solvents. They have a variety of functions. As a medium, varnishes are added to the ink during printing to adjust the pigment concentration. Applied as a primer, varnishes help to improve the printout behaviour of inks. The most common application of varnishes is their use as overprint varnishes (OPVs). OPVs have a huge variety of functions, including protection against mechanical and environmental factors and decorative finishes to printed surfaces (gloss, matt, haptic, etc.). If varnishes have a barrier function they are treated as barriers, as described in chapter Barrier coatings and polymer content.

The following design table aims to give a compact overview of typically used inks and varnishes in the industry and their compatibility for the 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.

[4] COD= chemical oxygen demand ; BOD= biochemical oxygen demand

Component	Sub-category	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with recycling process unknown	Comment
Offset	Oil-based (mineral)	⊗				
	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 6. Compact design table of recommendations for inks and varnishes

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.

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

4.4.1 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.

4.4.2 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 this version of the guideline, only the compatibility of inks and varnishes for the standard recycling process is considered. Recommendations including the compatibility for recycling in deinking mills will be implemented in further versions.
Based on industry feedback, inks and varnishes as classified in Table 6 typically do not cause problems in standard recycling processes. This is confirmed by a study conducted by FFI/PTS, Recyclability of Folding Cartons and Material Combinations (October 2020).

4.5 Adhesives

In today's packaging industry, a wide range of adhesives is 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 tables aims to give a compact overview of typically used adhesives in the industry and their compatibility with standard recycling process.

Component	Sub-category	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with recycling process unknown	Comment
Adhesives	Corrugated board making	Starch-based, PVA				
	Window patching	Hotmelt#				
	Box making	Hotmelt#			Protein glues	
	Side seaming	Starch-based				
	Box closing/ End-of-line	Hotmelt#				

Component	Sub-category	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with recycling process unknown	Comment
Adhesives	**Palletising**	Pressure sensitive hotmelt*	Pressure sensitive hotmelt			* only valid for materials with a positive rating according to Cepi Harmonised European Laboratory Test Method. Existing positive results according to the legacy methods PTS-RH:021/97 and Aticelca MC501:2017 should also be accepted. #) 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)
	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	
	Litho-lamination	PVA				
	Cold seal	Natural rubber latex*				
	Heat seal	PVA*, Acrylic*			Hotmelt	
	Water-based labelling				Protein glues, Acrylic	
	Pressure sensitive applications (self-adhesive labels, tapes)	Pressure sensitive hotmelt*	Pressure sensitive			
	Pressure sensitive closures		Pressure sensitive hotmelt			
	Bonding of supplements	Hotmelt#, Polyurethane hotmelt#				
	Multipack attachment	Hotmelt#, Pressure sensitive hotmelt*			Pressure sensitive hotmelt	

Table 7. Compact design table of recommendations for adhesives

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.

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

4.5.1. 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[5] 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.

[5] The term "cold applied" is used here rather than "cold set". At times, the term "cold set" is used; it is however more easily misunderstood. For example, hotmelt adhesives also "set" when they become "cold". Furthermore, it is sometimes alleged that "cold set" adhesives do not melt or soften at elevated temperature. While this is true for some cold applied adhesives, it is not true for all.

These adhesives set[6] 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
- Acrylic

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

They contain reactive groups that engage in chemical reactions within the adhesive itself .

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

4.5.2. 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.

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

[6] The process of "hardening" of non-reactive adhesives is called "setting". For reactive adhesives, the term "curing" is used to describe the reaction that leads to the hardening of the adhesive.

4.6 Decorative metallic components

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

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

Component	Sub-category	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with recycling process unknown	Comment
Metallic components	**decoration**	hot and cold transfer		PP/PET metallised laminates, PET-metallised film		Designers should not cover the surface of fibre-based products fully with metallization, as this could cause issues regarding the detection as fibre product. The available test results are only applicable for certain types of packaging. For exact thresholds, testing is required!

Table 8. Design table of recommendations for typical decorative metallic elements

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.

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

4.6.1 Decorative metallic components used in fibre-based packaging

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

- Direct metallisation
- Hot stamping
- Cold transfer

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

Metallic components can cause different issues during the paper recycling process, as well as during sorting. If the papers´ surface is not fully covered with metallic decoration, it will not cause major issues regarding the detection as fibre product and end up in the right recycling stream. If the surface is covered with a very high share of metallization, it may cause detection issues, as the metallic effect reflects the NIR light, and the fibre product may end up in the wrong recycling stream

To mitigate this issue, it is recommended to:

- not fully cover the fibre-based packaging with metallization and
- minimise the percentage of plastic used, it is recommended to use hot stamping or cold transfer instead of lamination.

4.6.3 Additional Components

Designer should not fully cover the fibre-based packaging with metallization to avoid problems during the sorting process

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

Component	Sub-category	Fully compatible with standard recycling process	Conditionally compatible with standard recycling process	Not compatible with standard recycling process	Compatibility with recycling process unknown	Comment
Additional components	**Materials**		PE-LD, PP. PET, PVC, DI-acetate film			
	Packaging aids		Security label, RFID tag, pull strip, plastic and metal spout, carrying handle			
	Outer wrap		OPP			
	Colour for caps and closure	Clean, natural and pale colours; NIR-sortable	Dark colours	NIR, absorbing masterbatch		

Table 9. Design recommendations for additional components

NOTE: The given design recommendations are based on expert opinion and valid for recycling in standard recycling mills. Ongoing testing (i.e. Cepi Harmonised European Laboratory Test Method) is likely to supersede the present recommendations and inform a future update of the guideline.

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

4.7 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.

4.7.1 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.

4.8 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 plan 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.

4.8.1 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)

5. RECYCLING IN SPECIAL RECYCLING AND DEINKING MILLS REQUIRED

5.1 Recycling in specialised mills

The recycling of paper and board can become more challenging when the functionality and/or complexity of the product is increased by additional elements and additives, or when higher pulp quality is required for the end product.
For instance, if wet-strength agents or functional barriers are added, standard mill technologies might be incapable of recovering the multitude of fibres and materials combined in one package. To recover a viable amount of fibre during milling, specialised processes and enhanced equipment is required.
Fibre-based materials that are currently compatible with standard recycling, and even those that are not or only conditionally compatible, can potentially be fully or conditionally compatible with more enhanced recycling processes too (i.e. deinking or special recycling mills).
The suitability for enhanced recycling processes can be evaluated using the Cepi Harmonised European Laboratory Test Method listed in table 3 and corresponding assessment schemes.

5.2 Recycling in deinking mills

Deinking mills have been designed for pulping, cleaning and deinking graphic paper grades, typically newspapers and magazines corresponding to grade 1.11. and other grades defined in EN 643 as intended for deinking.

The deinking process is also capable of processing white/bleached fibre-based packaging paper types if they fulfil the brightness and general quality requirements. In a shrinking graphic paper market suitable white fibre-based packaging materials could be a potential future fibre source for high-value recycling of bleached fibres. Already today, grades intended for deinking contain a certain amount of packaging paper recycled in the graphic paper loop. One reason is that, during sorting, pigment-coated papers show very similar NIR fingerprints compared to coated magazine paper.

For assessing the suitability, an adapted test method for fibre-based packaging, based on the INGEDE Method 11, has been developed and which informs the 4evergreen Recyclability Evaluation Protocol Part B (see also Recycling processes in paper mills). The process is ongoing, as too the development of a corresponding assessment scheme.

NOTE: Recommendations for fibre-based packaging that require reprocessing in specialised recycling mills or deinking mills are currently under development in 4evergreen, thus not included in the design recommendations tables of this guideline.
The implementation of recommendations for special recycling mills and deinking mills will follow in updated versions of this guideline.

6. GLOSSARY

The glossary is based on the official document, Pulp and Paper Industry Definitions and Concepts, produced by Cepi, 2021.

Cartonboard
May be single or multiple, coated or uncoated. It is made from virgin and/or recovered fibres, and has good folding properties, stiffness and scoring ability. It is mainly used in cartons for consumer products such as frozen food, cosmetics and for liquid containers. Includes solid board, solid bleached board, solid unbleached board, folding box board, white lined chipboard, boxboard or carrier board.

Chemical pulp
Wood pulp obtained by subjecting pulpwood, wood chips or residues to a series of chemical treatments. It includes sulphate (kraft) wood pulp; soda wood pulp and sulphite wood pulp. It may be bleached, semi-bleached or unbleached. It excludes dissolving grades of wood pulp.

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

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

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

Directive on Waste (2008/98/EC)
Also known as the "Waste 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 EN 643 List gives a general description of the standard paper and board grades by defining what they do and do not contain.

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

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

Mill
The building or buildings and area where the pulp and papermaking operations are carried out. Sometimes called a plant when referring to one area of the whole operation. It can also refer to rotating steel rolls used in mixing materials.

Moulded pulp
Thermoformed fibres pressed into shape.

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

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

Packaging paper(s)
Paper or paperboard mainly used for wrapping and packaging purposes. Products in this category are generally manufactured in strips or rolls of a width exceeding 36 cm or in rectangular sheets with one side exceeding 36 cm and the other exceeding 15 cm in the unfolded state. It excludes unbleached kraft paper and paperboard that is not "sack kraft paper" or "kraftliner" weighing more than 150 g/m², but less than 225 g/m². It also excludes felt paper and paperboard, tracing paper(s), and uncoated paper that is not further process and weighs 225 g/m² or more. It is reported in metric tonnes.

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

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

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

Recycling
The mechanical reprocessing of used paper in a production process into new paper and board. See also the Waste Directive 2008/98/EC.

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

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

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

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

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.

For general enquiries please contact 4evergreen@cepi.org

4ever
green