PAPER AND BOARD PACKAGING

confederation of paper industries

Design for Recyclability Guidelines

Helping retailers and brands specify and design fibre-based packaging that can be reprocessed in standard paper mills in the UK

4th edition, February 2024

Contents

1 Overview

The CPI Design for Recyclability Guidelines are intended to provide broad direction and point the way towards resource efficient recycling of fibre-based packaging products. There is an enormous variety of products and packaging formats, and these guidelines demonstrate the opportunity offered by fibre-based products for packaging applications and their wider recyclability. The importance of this issue is also recognised by the Confederation of European Paper Industries (Cepi)[1] who has commenced work to provide a Europe-wide framework on recyclability.

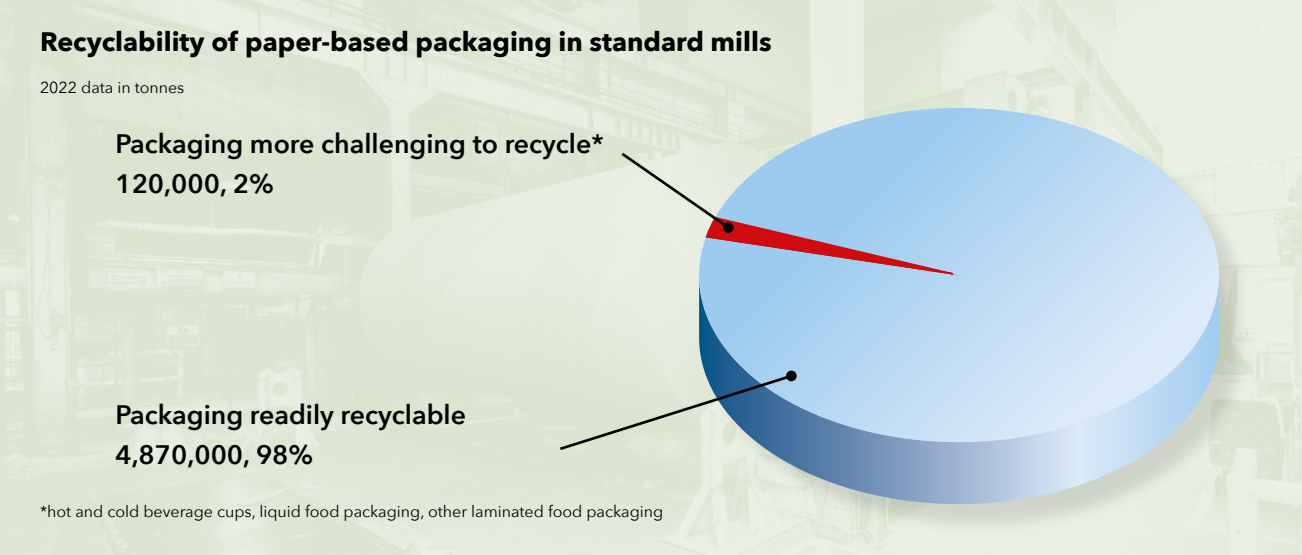
These CPI guidelines were originally developed in 2019 after broad consultation with the packaging supply chain. The current edition provides further clarity to retailers and specifiers on how new products can be designed that can be easily recycled, with the aim of inspiring the next generation of packaging products and assisting future technological development in packaging materials, whilst optimising recyclate entering the supply chain.

[1] www.cepi.org

2 Background

Paper is a **sustainable, renewable, and ecologically sound** choice, and nearly all fibre-based packaging products are recyclable. In practice, there are a small number of packaging products for which recyclability will be determined by their design, composition, and how they are collected and presented for reprocessing. However, the vast majority of fibre-based products are easily and widely recyclable.

Paper recycling in the UK is a success story, **with over 78%** of UK fibre-based packaging currently collected for recycling. **Paper for Recycling** (PfR) is collected primarily for use in manufacturing processes and is used as an alternative to virgin materials e.g., wood pulp. When presented it should therefore be of suitable quality and economically viable to use.



Packaging is vital in ensuring that goods arrive at the consumer in pristine condition. It often facilitates the extension of shelf life, as well as providing protection, and information, for the consumer. As society evolves, an increasing number of packaging applications are found for paper and board, some of which demand changes to its functionality. This is often achieved by combining the fibre as a substrate with another material to form a multi-material, multi-layer laminate, providing properties such as water resistance, or a gas barrier to extend product life.

The potential for a future increase in this type of packaging challenges pack designers to look for creative design alternatives which explore the potential for new materials and techniques. These new formats can provide challenges for recycling, and in some instances can increase the costs of reprocessing and of waste disposal. In rare cases, they may also cause damage to process machinery or be detrimental to the finished product or harm the environment.

For the purpose of this document, a standard paper mill refers to a paper mill for packaging that operates on a continuous flow basis and can handle a range of paper for recycling grades as its primary raw material. Material considered suitable for use in a **standard paper mill** should, as a minimum, comply with the EN 643 grade description for mixed paper grades 1.01.00, 1.02.00, 5.01.00 and 5.02.00. The result is very high-quality fibrous material suspended in water, ready for papermaking (i.e., recycled pulp).

For the avoidance of doubt, **these guidelines seek to address the design and construction of the next generation of fibre-based packaging**. As far as the consumer is concerned, nearly all fibre-based products should be considered recyclable, albeit in some circumstances they may need to be collected and treated separately from other fibre-based materials.

3 Purpose of the Guidelines

These guidelines are intended to provide design parameters, which, if generally adhered to, should deliver **high performing** and **recyclable** fibre-based packaging for the industry, and **improved environmental and social responsibility** in the supply chain. The overriding motivation is to optimise the quality and quantity of PfR, and through technological development and better design, improve the recyclability of the more challenging materials, and reduce waste in the supply chain.

It is anticipated that these guidelines will provide sufficient guidance for packaging designers and specifiers to make appropriate decisions about the recyclability of products, and drive developments in design and technology to improve the general recyclability of fibre-based packaging over the medium to long term.

These guidelines have been produced to help retailers and brands specify and design packaging that can be easily reprocessed at commercial scale in UK paper mills with current standard pulping technology[2], where the fibres are redispersed. The vast majority of PfR collected for recycling from households or "on the go" is reprocessed in this way, with only a very small proportion of material creating challenges for reprocessors. Packaging that is challenging to recycle should be separated for treatment at mills with specialist facilities.

Additionally, the guidelines can be a useful tool for retailers and brands to provide **a clear call to action to the consumer and help to reduce confusion**. Recent surveys indicate how complicated recycling can be to householders, and there is increasing public interest in the recyclability of packaging products. Although these guidelines may provide consumers with a better understanding of cellulose fibre-based packaging, they are primarily intended for use by brands and retailers to support design decisions. To provide an answer on the recyclability of cellulose fibre-based packaging products, the Paper Industry has developed **Papercycle**, which provides a definitive answer on recyclability.

These guidelines reflect the requirements of UK reprocessors and are compliant with the BS EN 643:2014[3]. Other markets offering export outlets for PfR may work to different standards in line with relevant national policies.

[2] Pulping is the means by which a solid paper and board sheet is reduced to individual fibres in suspension prior to being reformed into a new sheet, and is a prelude to the papermaking process.

[3] https://shop.bsigroup.com/ProductDetail/?pid=000000000030265770

4 Policy Landscape

In 2021 the UK Government launched three public consultations on proposed changes to the **Extended Producer Responsibility** system (EPR), the introduction of a **Deposit Return Scheme** (DRS), and **Simpler Recycling** (formerly known as Consistency of Recycling Collections) to be implemented under the Environment Act 2021. Collectively, these proposals will have a profound effect upon packaging, paper, and recycling industries, and will potentially impact all parts of the supply chain. However, there is still much work to be done for EPR and DRS to be fully developed and the recent Government response on Simpler Recycling[4] will impact on the quality of material collected. There are also questions on how all three reforms are going to work together and how the Government will support the Paper Industry to achieve an 89% recycling rate by 2030, whilst ensuring high quality recyclate.

As part of the EPR proposals, Government suggested that each packaging material needed its own assessment methodology to determine its recyclability. Producer fees would apply, correlated with the degree of their recyclability, and there were also proposals on a sliding scale of fees according to recyclability **(eco-modulation)**. The outcome of a recyclability assessment would enable a new mandatory binary labelling system for all consumer packaging to operate, aiming to provide a clear "yes" or "no" answer to whether a packaging item can be recycled.

However, for a labelling system to be implemented on a packaging item, there is a requirement first to determine its recyclability. Therefore, to support the forthcoming changes and determine recyclability in a definitive and credible way, there is a clear need for a comprehensive support mechanism.

Whilst in principle all fibre-based packaging is recyclable, innovations in material development can make some products more challenging to recycle. This means that **basic recyclability assessments based on visual, or a simple compositional, analysis are no longer sufficient to capture the complexities of the recycling process and accurately reflect the true recyclability of packaging**.

At the same time there is a great deal of work happening in Europe, with stakeholders working towards the goal of better defining recyclability and creating a framework of rules. CPI supports the move towards a pan-European methodology, so that all fibre-based packaging products are tested in the same way, whilst considering national differences (regulatory, collection and reprocessing methods) for the evaluation of the results. CPI wishes to see alignment between the UK and Europe on the evaluation criteria for recyclability for fibre-based products, whilst ensuring they are fit for purpose within the UK context. The laboratory testing methodologies are already aligned.

As the European Paper Industry intensifies its efforts towards a harmonised recyclability testing methodology and a protocol for evaluating recyclability, the UK Paper Industry will be following closely the work being undertaken under the 4evergreen alliance[5].

[4] https://www.gov.uk/government/consultations/consistency-in-household-and-business-recycling-in-england/outcome/government-response

[5] https://4evergreenforum.eu/

As a result of the upcoming legislative changes and innovation in material development, and in support of these guidelines, CPI has created a separate entity, **Papercycle**.

Papercycle's automated online tool was developed to provide a **robust, comprehensive system to assess the recyclability of fibre-based products and materials in a consistent and credible way** and it is the vehicle for delivering recyclability assessments for fibre-based packaging for certification purposes. To assist packaging design and development work, Papercycle also offers a product support service where companies, for a fee, can have novel packaging tested to determine how it is likely to perform in standard UK paper mills.

Papercycle may provide an instant diagnosis on recyclability following the online assessment, but for more complex products or materials, Papercycle can also conduct timely laboratory testing under the Harmonised European Laboratory Test Method[6] developed by Cepi.

For more information visit **papercycle.org.uk**.

Benefits of Papercycle

- Brings consistency and transparency
- Facilitates compliance with legislation
- Promotes credibility in paper recycling processes
- Builds trust across the value chain
- Helps you make more informed choices when developing new products
- Verifies recyclability claims for fibre-based products

[6] https://www.cepi.org/wp-content/uploads/2021/02/REC-21-002.pdf

5 Contamination in Paper for Recycling

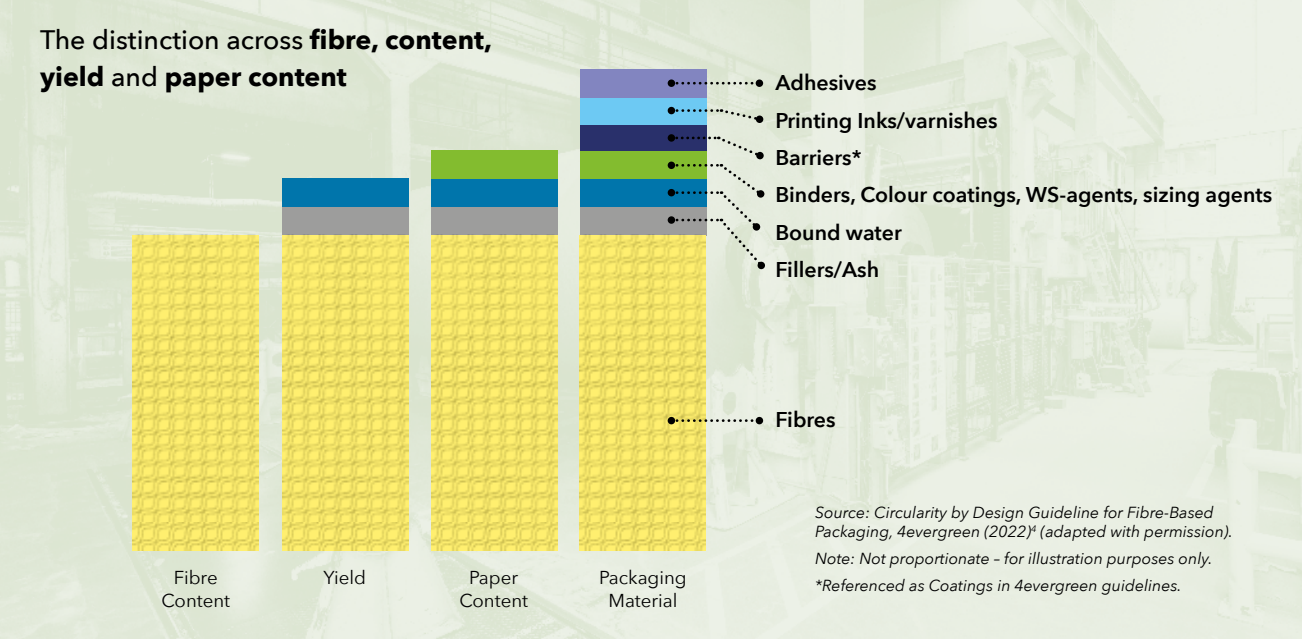
5.1 Contamination due to Product Design

Paper components

A typical fibre-based packaging product may contain papermaking fibres and other ingredients such as **filling material, starch, coating colourants, binding material, and additives** (wet-strength agents, sizing agents, bound water). These are standard components of paper, and they can normally be dealt with by standard paper mills. As a general rule, cellulose fibre-based packaging products with high fibre content result in higher quality of recyclate.

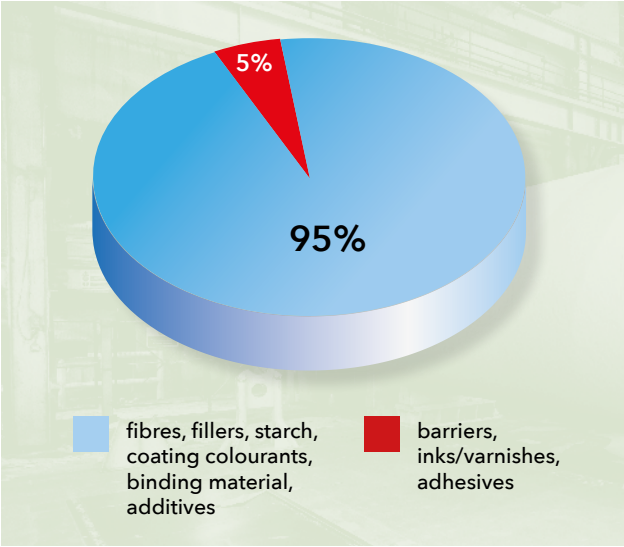
Non-paper components

Components such as **barriers, inks, varnishes, and adhesives,** as detailed in the upcoming sections, can have a detrimental impact on recycling, particularly where they make up a high volume of the paper pack[7]. These ingredients can affect the quality of paper, lead to inferior runnability of the machinery, and depending on their amount, composition and interaction with other components, can lead to undesired consequences, even for simple types of packaging.



Target design guideline

The UK Paper Industry encourages packaging designers and specifiers to limit non-paper components in new products to **5% of the pack weight**. This 5% serves as a design recommendation, meant to be taken into account alongside other guidance in this document. It is an ambitious goal that will become more attainable as technology in fibre-based packaging advances. However, it is not a strict rule for determining recyclability; the assessment of packaging products must be done on a case-by-case basis.



We acknowledge the challenges faced by designers in meeting the 5% guideline and are dedicated to collaborating with them towards achieving this target. CPI is actively engaged with the supply chain to aid in developing fibre-based products that are easily recyclable. This commitment is evident not only through the publication of these guidelines, but also in the development of Papercycle, which facilitates recyclability assessments of products that are either finished or under development.

Driving innovation

The purpose of the above design guideline is to drive advancements in design and technology and enhance the overall recyclability of fibre-based packaging during the product design stage. However, it cannot be applied to assess the recyclability of a product or material once it has been developed. Depending on their amount, composition and interaction with other components, non-paper components can have a variable impact on recyclability and the quality of recyclate.

Assessing recyclability

The recycling process of fibre-based items is complex, and all these ingredients impact on the quality of the recycled material. A compositional assessment of a packaging item is not a determinant for its recyclability, and although this document offers guidance on packaging design, the recyclability of a product can only be determined once it has undergone a comprehensive assessment. To better understand our approach towards the recyclability of fibre-based products, you should refer to our **Position Paper**.

TO VIEW THE POSITION PAPER SCAN THE QR CODE:

5.2 Contamination due to Collection Methods

Recycling collection methods, particularly commingled recycling, can introduce contaminants and undesired materials into the recycling stream. In the UK, the majority of local authority paper and card recycling collections are commingled, producing "dry mixed recyclables". This results in substantial amounts of contaminants and undesired materials (such as general plastics, plastic bottles, cans, and glass) being present in certain PfR grades.

The recent Government announcement of its intention to introduce exemptions allowing for commingled collections further exacerbates this concern. It is expected to negatively impact the quality of recyclate and increase the amount of undesired materials in the paper recycling stream.

In light of these challenges, **there is a need to place even greater emphasis on the quality of upstream materials**. Excessive contaminants can overwhelm paper mill cleaning processes and compromise machinery efficiency, even causing damage. For this reason, these guidelines aim to encourage the minimisation of the inclusion of non-paper components in the recycling stream through design considerations to enhance the quality of recyclate.

5.3 Contamination due to Harmful Substances

Packaging intended to be in direct contact with potentially harmful contaminants such as **medical waste, animal products** or **toxins** can contaminate PfR and should be considered unrecyclable.

UK REACH regulations apply to the majority of chemical substances that are manufactured in or imported into Great Britain[8]. REACH restrictions limit, ban, or set conditions on, the manufacture, placing on the market, or use of a substance or group of substances.

If a packaging product is intended to contain harmful or hazardous contents, it may contaminate recycled paper. Examples include medicines, industrial chemicals, and other items prohibited in BS EN643:2014 Paper and board – European list of standard grades of paper and board for recycling.

5.4 Food Contamination

Food Contamination is prohibited in Paper for Recycling in BS EN 643:2014.

Paper and board — Guidance on the application of Term 2.2 Prohibited materials of BS EN 643:2014 addresses the presence of food contamination and has been developed to assist the users of BS EN 643:2014 to better understand the term **prohibited materials** and which materials may be limited accepted in paper and board for recycling.

Paper containing stains or even traces of food which are unavoidable in collection of post-consumer material and do not fully soak the paper, is acceptable for recycling. Surface staining, for example stains due to grease and spots of the toppings in delivery boxes for pizza and sandwich packs, and traces such as breadcrumbs in bags, sugar, salt, flour or food in emptied boxes or bags can be tolerated.

Food waste sitting in the pack (free moving food), food attached to the surface (3D residue), and traces and stains that fully soak the paper, are regarded as unacceptable.

Any packaging, such as oven ready food trays, that is likely to contain food attached to the surface cannot be recycled in standard paper mills.

Remains of liquids and solids can also be found in some special grades of BS EN 643:2014 – in used liquid packaging board, used paper cups and on other used tableware.

Careful consideration should be given to the proposed application of fibre-based packaging to prevent inadvertent contamination by food substances. There should be clear information on the packaging that any food residue should be removed prior to recycling, and removable layers would help reduce the potential for contamination. However, to ensure the consumer enacts, there should also be a strong call to action and clear information on the packaging on how this should be done effectively.

Food packaging products such as pizza boxes and sandwich packs can be recyclable. The Paper Industry has developed the following guidelines to assist designers and specifiers of food packaging products to develop recyclable solutions:

- Avoid the use of:
  - composite, laminated or coated paperboard.
  - strongly attached windows consider the use easily detachable, thin, lightweight solutions.
- Consider the use of a detachable liner or a separate covering (which should be disposed of separately).
- Packs should be clearly marked to encourage removal of liners and food waste before recycling.
- The overall % target weight for contaminants should be in line with the guidance provided in this document.

[7] Lamination is not exclusively mentioned above on the basis that it is not classified as a component, but it is the process that combines a sheet of a non-cellulose fibre-based material (such as a plastic or foil film) with a sheet of paper or board, usually with some form of adhesive or binder to adhere the two materials together. More information on laminates can be found in section 6 of the Guidelines.

[8] www.hse.gov.uk/reach

6 Design recommendations

6.1 Plastic Content

The Paper Industry would prefer not to receive any plastic in the fibre stream since it reduces efficiency in reprocessing, increases energy consumption, and negatively impacts the economics of paper recycling. Plastic is a contaminant and will be rejected from the process. Currently, standard paper machine reprocessing technology is designed to cope with a maximum of 1.5% non-paper components (such as plastic and metals) in the material delivered to the machinery. This implies an average across all material delivered to the mill, but in practice is assessed by sampling individual loads upon delivery at the mill.

Plastic content attached to any fibre-based packaging product should be minimised.

The Paper Industry would prefer that, where possible, laminated paper material should be collected separately and sold as a distinct and separate grade to mills with the specialist facility to reprocess it effectively. However, it understands that currently, in most cases, this is not practicable.

It would also help if designers could ensure the consumer can remove laminate faces, e.g., using a tear-off tab, and dispose of them into the appropriate waste stream. They should, in any event, minimise the adhesion between the laminate face and fibreboard, so that material passing into the reprocessing system is easily separated and comes away in one piece without fragmenting, either by the consumer or by the water-based separation process.

Two-sided laminates such as beverage cartons, and hard to recycle laminates with water resistant properties, such as drinks cups, should be marked appropriately, collected separately, and reprocessed at facilities capable of accepting them.

Most paper mills would prefer not to receive plastic laminated board.

A tear-off facility should be provided for plastic facings, which should come out in one piece and display clear instructions for consumers to remove them.

Two-sided laminates, such as beverage cartons and drinks cups, should be collected and reprocessed separately.

If collected and presented appropriately, almost all fibre-based products can be recycled. The amount of composite, non-fibrous material the industry can absorb is dependent on how and where it is presented.

- Laminated coffee cups, cold cups, beverage cartons, and oven ready meal trays can be reprocessed if collected and presented in baled form to mills that can handle them.
- Similar material, when presented to standard mills in high concentrations, is likely to be removed as contamination in the papermaking process and will pass into the waste stream for energy from waste or landfill.

In practice, the majority of composite and laminated paper is likely to be collected and presented for recycling as **"mixed papers"**. This is traditionally the lowest grade of PfR, and is used by packaging mills as a significant proportion of feedstock.

Exports of this grade to China have been banned since 2017, other Asian countries have introduced far stricter requirements for imports of PfR, and exports are becoming more strictly controlled. This trend is due to the fact that the 'mixed papers' grade is known to contain high levels of contaminants and non-target material. Therefore, every effort must be made to ensure that material going into this grade is easily recyclable by design. Multi-material laminates should be re-pulpable, releasing fibre easily and without adverse impacts on papermaking or the environment.

The industry standard for paper grades for recycling is **BS EN 643:2014**, which describes the levels of non-target material allowable in recognised grades of PfR. BS EN 643:2014 provides overarching guidance on recognised grades of PfR, but cannot be used to judge the recyclability of packaging on a case for case basis.

It is a particular wish that plastic that has potential to cause environmental harm or damage to recovery systems is designed out. For instance, polymers with low shear strength that break down in the pulper into micro-plastics should be avoided, because micro-plastics may pass through mill wastewater cleaning systems and be discharged into water courses or pass into and contaminate the finished product.

Papermakers would prefer all plastics be minimised.

In addition, Polyvinyl Chloride (PVC) has potential to release toxins into the air during energy recovery.

In simple terms, paper mills would encourage a hierarchical approach to plastic laminates so that they are:

1. designed out altogether or reduced to a necessary minimum;
2. designed to peel off in one piece by the consumer with a clear call to action;
3. designed to be easily separated by the process, so it can be rejected in the system at the beginning of the papermaking process; and
4. designed to deliver minimal impact, both to the environment and to existing recovery systems.

Where plastics are necessary, it would be better for them to be of a type that does not readily degenerate or break into micro-plastics for several reasons:

- During repulping, plastics can disintegrate into sizes that will pass through screening elements in stock preparation. They may also be too "flexible" and thin – "two dimensional" (foil particles), and so pass through even low slot width screens.
- Plastic with the same density as fibre can create problems. For example, material with a density in a range of 0.95 to 1.15 g/cm³, e.g., the same density as fibres and similar to water, are impossible to separate with the hydrocyclonic cleaners that are used in paper mills.

The Paper Industry welcomes innovative approaches to fibre-based packaging, and such products have increased in the last few years. However, innovations which either include fine non-fibrous material (<0.15mm in any one dimension) or which use non-fibrous materials which are likely to disintegrate/shatter into very fine particles may result in products that are more challenging to recycle.

6.2 Coatings and Barriers

Barrier coatings is a term used to describe a variety of materials applied to a sheet of paper to impart specific properties. These can be either inorganic inclusions, printed, or varnished, and can be applied at different stages in the paper and box making process. There is a great variety of methods which are used to create barrier properties and therefore they can create different challenges in the recycling process.

Lamination is a process/technique of barrier application and occurs when a sheet of a non-cellulose fibre-based material (such as a plastic or foil film) is combined with a sheet of paper or board, usually with some form of adhesive or binder to adhere the two materials together. Lamination is a technique, and not a paper component *per se*. **Two-sided lamination** occurs if a barrier has been applied on both sides of a sheet of paper or board.

In printing, **lacquering, coating** or **varnishing** refers to the application of a liquid or paste, unpigmented ink-like product, which, after drying, is mostly transparent. Thereby, certain surface properties are obtained, for example protection against mechanical damage, gloss or matt surface effects, and/or specific slip or adhesion properties.

6.2.1 Laminates

Depending on the amount and type of the adhesive, as well as the strength of the adhesion between the film and paper, fibre may or may not be released during the recycling process. For preference, the industry would wish that laminates be lightly bonded with a water-soluble adhesive agent, so that the plastic layer separates easily in the paper pulping process.

Providing the film does not interfere with the separation of the fibre (such as occurs with two-sided laminates, stacked paper cups etc), some fibre should be recovered. This will be determined by the degree of adhesion between film and fibre.

If the plastic film can be separated as relatively large particles, it can be removed using conventional mill technology. However, the removal and disposal add cost, and can overload the ability of the system to handle the quantities involved.

The Paper Industry prefers that for plastic facing, for example of food trays, a tear-off facility is provided with a clear call to action for it to be removed.

Two-sided laminated products, such as beverage cartons, are more challenging to recycle in standard paper mills; they should be collected and reprocessed separately for recycling in specialist facilities.

Peelable laminates are preferred, as they provide an opportunity for the consumer to remove the laminate before recycling, and they imply a loose bond between laminated face and base substrate. However, unless there is a strong call to action on the packaging itself for the consumer to act on, peelable laminates, if not removed, will negatively impact the quality of recycled material.

The public should be provided with clear and consistent instructions to separate contaminated plastic liners for disposal and to recycle the fibre layer. Care over the wording needs to be taken to encourage consumers to peel off or remove laminated coatings, windows or linings.

The Paper Industry supports peelable barriers, in particular when a functional barrier is required and laminates cannot be replaced by alternative material. However, the Paper Industry also acknowledges that more research into technical solutions is required as well as more evidence on their effectiveness.

6.2.2 Wet barrier coatings

Wet barrier coatings can be either water-based or solvent-based. Water-based coatings include polymers such as Polyvinylidene Chloride (PVDC), acrylics, styrene butadiene copolymers and vinyls. 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 such as curtain coating, printing, or spraying the coating onto the surface. Although they may be recycled in standard paper mills, their behaviour depends on the amount and strength of adhesives and the presence of fillers and a laboratory test may be required to determine their recyclability.

6.2.3 Barrier metallisation

Recently, **direct** (primer, Alu nanoscale, protective coating) and **adhesive** and transfer metallisation processes have been explored as a method of inducing effects or properties on paper, such as light barriers, water vapour barriers, and oxygen barriers. Depending on the overall amount, barrier metallisation may result in a 'stardust' effect in the visual appearance of the paper produced from the recycled fibres, as well as creating potential stickiness issues and reduce the yield impact of the recycled paper produced.

This method has been traditionally used for decorative effects on paper. Metallised films/ aluminium films are usually less tightly bonded to the paper substrate (in some cases a plastic film may be applied over the surface for durability), and fibre can be recovered from them.

In sufficient quantities, the small 'metallic' particles produced can interfere with equipment used to measure flows in paper mills. There is increasing concern about thin foils passing through the recycling process and onto the finished product.

The Paper Industry would favour peelable liners and windows, as long as there are clear instructions and a strong call to action on the packaging on how consumers can remove and dispose of the peelable components.

This has two consequences; it can provide an effect on the paper similar to glitter, causing imperfections; secondly, it activates the metal detectors used by box converters to guard against metallic items passing into the food chain from their boxes. The alarm stops the machines, causing downtime, and creating waste.

Hot and Cold foil transfer can be dealt with by paper mills. However, if the surface area is fully covered with metallisation, this could cause issues regarding the detection of fibre. Therefore, it is very likely that metallised fibre-based products may have to be tested under laboratory conditions to determine their recyclability. Furthermore, the impact of the metallic ions that will arise in the mill wastewater also needs to be assessed.

Metallised polymer coatings with the transfer of a very thin layer of metallic foil onto board tend to break down into very small particles, like glitter, and then by-pass the screen and get into the paper production.

6.2.4 Wax coating

Waxed or waxed coated papers should be minimised. Wax cannot be removed by mill cleaning systems, and can pass onto the finished product. Wax coatings may impact on stickiness, and cause screen clogging. Other moisture resistant papers can be dealt with by mill systems, but are not preferred feedstock and may not be fully recycled, unless separately collected and presented.

6.2.5 Alternative barriers and coatings

A range of solutions have been developed that offer barrier properties whilst reducing or even eliminating the use of conventional plastics. **Alternative barrier products** include custom polymer product, water-soluble, and dispersion coatings, which are methods of creating coatings

using mostly biodegradable ingredients. These products can affect the chemical balance found at the wet end of the paper machine and/or cause chemicals to pass through the paper mill system and be potentially discharged with effluent waters. They may be more challenging to recycle and more testing is needed to determine their impact on recyclability.

The Paper Industry welcomes and supports research to develop alternative barrier technologies. However, the implications of barrier coating materials need deeper examination, with regards to their impact, both within the finished paper and in the wastewater. The extent of this impact is currently unknown, necessitating additional research to better understand the challenges.

In general terms, recyclability in any alternative barrier system is more likely to be achieved where:

- the fibreboard or paper within the packaging, when exposed to water, is capable of breaking down into single fibres in suspension;
- polymers and other sealing agents can be removed from the fibre during the papermaking process;
- polymers and sealing agents can be dealt with efficiently by paper mill effluent systems and do not compromise the finished product, the production process or the environment whilst being recycled.

6.3 Inks and Varnishes

Inks are layers of coloured dispersions that are applied onto paper and board packaging by a printing and/or coating process to provide information and/or decoration. They may be manufactured from combinations of colourants, binders, plasticisers, solvents, driers, and other additives.

Varnishes are generally a thicker layer of resinous mixture printed onto paper and they are typically used to protect the ink film, provide a degree of robustness to the print, and for aesthetic effect. They are non-fibrous sealants coated onto the surface of paper that has often been printed with water-based inks. The 'active component' (typically a resin) is thinly spread onto the surface of the paper, and a carrier medium evaporates or is absorbed into the sheet leaving a film of the active component. In some cases, where a more robust surface is required, the resin may then be cured by the application of heat and/or ultraviolet radiation.

Depending on the recycling route a product takes it can be subject to a different recycling process. In standard paper mills the ink particles remain in the pulp, whereas in mills with de-inking facilities ink particles can be separated from the fibres. The ease of de-inking substrates may be affected by various printing parameters, in particular the thickness of any varnish layer.

In the UK, due to the predominance of commingled collections, fibre-based packaging products are mainly collected as mixed papers and they are not separated on the basis of the presence of inks and varnishes.

In most cases the majority of the printed materials are removed in standard paper mills after pulping and screening, but in some cases discrete particles of ink or varnish may be produced. Particles of inks and resins that are broken up during pulping can travel through the process.

There are also concerns that these very small particles can travel through the mill water system and be discharged into watercourses.

The concentration of products containing inks and varnishes during the recycling process also plays a role, and higher quantities will result in bigger challenges.

Due to the huge variety of products and their complex composition, some inks and varnishes can behave differently when used together and create certain challenges. This doesn't mean they cannot be recycled, but they will have to be examined on a case-by-case basis, and it is likely they will need to be tested under laboratory conditions to determine their recyclability.

The Paper Industry recommends that cured varnished material in packaging products is kept to a necessary minimum.

Based on the current volumes of fibre that UK paper mills receive, the UK Paper Industry has listed basic inks and varnishes in order of preference:

1	**Water-based** inks and varnishes (excluding plasticised inks) use water as a solvent, and are applied in gravure, flexographic, and digital printing. Water-based systems dry physically by the solvent evaporating. Inks and varnishes that are soluble in water can generally be treated in paper mill effluent treatment processes. While they offer advantages for recycling, it's important to note that ink formulations may vary, and may still contain additives or components that could pose challenges during the recycling process.
2	**Liquid and dry toners** are used in electrophotographic digital printing and are composed of pigments, resins, and various additives[9]. Although they are often compatible with the recycling process, the extent of their impact may vary and may require additional steps for them to be removed.
3	**Solvent-based** inks and varnishes use organic solvents (alcohols, esters, etc), and are used in gravure and flexographic printing[10]. They can have a notable impact on recyclability due to volatile organic compounds and other chemicals and can affect the strength, brightness and overall appearance of the recycled fibres, limiting their applications.
4	**Ultraviolet (UV)** and **Electron beam (EB)** curing inks and varnishes are solvent-free systems[11]. In standard mills UV and EB inks and varnishes can cause flecking on the new paper sheet. They can be particularly challenging for paper mills manufacturing graphical papers, and where they cannot be easily removed by the de-inking process, they pass into the new sheet, causing flecking and pin holes.
5	**Plasticised** inks are one of the more challenging ink products due to the way the ink is deposited on the surface of the sheet of paper and then fuses to the surface. The ink is released from the printed paper surface but the resultant ink film flake gets dispersed around the recycling process, passing through all washing, screening, cleaning and de-inking stages travelling with the fibre stream and causing high dirt/speck count in the final pulp. Plasticised inks can be problematic and even small amounts can make a whole load of paper unusable for recycling. They can only be suitable for the production of board products.

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

Due to health concerns associated with the effects of human exposure to mineral oil traces, and as a precautionary measure, the European Paper and Board Industry made a commitment to phase out the use of printing inks based on mineral oils for printing paper and board packaging and refrain from mineral oil-based process chemicals for food contact materials. The Paper Industry recommends that designers and specifiers use oil-free materials to protect against the potential migration of mineral oils to food.

[9] 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.

[10] Solvent-based systems dry physically by the solvent evaporating.

[11] UV inks and varnishes use monomers (acrylates) as a diluent, which polymerise with the aid of photo initiators and under irradiation (UV-light). EB systems do not contain any photo initiators and the polymerisation is initiated using a high-energy electron beam.

6.4 Adhesives

Adhesives are integral to the manufacture of packaging, and standard paper mill technology is designed to separate and remove these during the papermaking process. However, some adhesives found on some tape, labels, and in the binding of packaging have the potential to soften or plasticise in the heat of the process to form "stickies" that can end up on the finished paper, spoiling the performance and appearance of the paper.

Most hot melt and pressure sensitive adhesives are insoluble in water, and dispersal during the pulping process can therefore be problematic. The adhesive can soften in the pulper to form small jelly like globules that, if not removed, can travel through mill filter systems and stick to the finished paper product. Some packaging grade hot melt adhesives, however, have previously demonstrated dispersal as larger particles during processing, which are easier to remove during screening.

The limited use of water-soluble adhesives is preferred on the assumption that the chemicals formed when the glue dissolves are not detrimental to the mill water or wastewater systems. Some products such as Polyvinyl Acetate (PVA) re-disperse and can create sticky deposits.

Overall, adhesives can lead to multiple challenges in the paper recycling process; they can contaminate the paper pulp, reduce the quality of the finished paper, damage the recycling equipment and cause downtime, and lead to a reduction in the quality of recycled paper.

Therefore, the Paper Industry would encourage designers to:

- minimise the adhesive use where possible;
- use adhesives which create larger particles that can be effectively removed by mill screening systems;
- consider using water-soluble adhesives with no deposit risk, provided they are compatible with the recycling process; and
- avoid adhesives that have a tendency to soften or plasticise during recycling.

Some manufacturers are actively working on developing fibre-based products with adhesives that are specifically designed to be more easily removed during the recycling process. This may involve adhesives with improved formulations that break down more effectively, or the use of removable labels.

Addressing adhesive-related challenges is essential to improve the efficiency and quality of paper recycling. Collaboration between the Paper Industry, designers, and adhesive manufacturers can lead to more sustainable and recyclable paper products.

6.5 Fillers and Binders

The use of fillers and binders in paper and board production is a common practice. **Fillers** comprise inorganic materials, which are added to paper and board to provide enhanced surface qualities. In order to achieve proper adhesion to the surface of the paper, they are often combined with binders.

The filler content is often comprised of Calcium Carbonate (CaCO3) and is typically used to improve printability in graphics papers. A percentage will be removed in the papermaking process, producing a sludge that may be landfilled or sent to Energy from Waste (EfW). It is important to note that CaCO3 coatings do not contribute to the strength of recycled fibres, and it is advisable to keep filler content to a minimum to avoid overloading the recycling process with non-fibrous materials.

Binders are often used in paper coatings to enhance the adhesion of fillers and pigments to the paper's surface. However, some binders can create issues, such as stickies, which can result in "black spots" on the paper and negatively impact the runnability of both production and converting machines.

Fillers and binders are normal constituents of the papermaking process and can usually be dealt with by paper mills. High filler content in the input fibre can lead to high levels of coarse rejects. Coarse rejects are materials that cannot be effectively recycled and must be separated and disposed of, adding complexity and costs to the recycling operation.

Fillers and binders are important components of fibre-based products, with fillers enhancing surface properties and binders helping adhere them. The Paper Industry wishes to manage these elements effectively to maintain paper quality and ensure a smooth recycling process, while also minimising environmental impact.

7 Speciality Products

Gift wrap: The Paper Industry encourages the use of paper gift wrap, and offers the following guidelines to specifiers. In principle:

- Paper-based wrapping paper may be easily recyclable.
- Wrapping paper that is heavily laminated and/or contains non-paper additives such as metallised gold and silver coloured shapes is not likely to be recycled.
- Glitter should not be used as it passes into the finished product, causing imperfections in the finished product and causing paper to be unprintable. Glitter can also melt within the process acting like glue, ripping the paper, and building up within the process. Glitter should be avoided and glittered paper is considered unrecyclable.
- Metallised films, foil-decorated wrapping paper and plastic-based wrapping are not likely to be recycled with paper.

Lightweight papers with low lamination levels can be challenging to design while ensuring their recyclability; quite often, lightweight papers contain components that may hinder recyclability, such as dispersion coatings and double lamination. Paper bags and other types of paper used for packaging purposes may have 'wet strength' properties and not pulp down in pulp systems or plastic windows, which can prove problematic to standard paper mills. They may require specialist mills that have a slower pulping process.

In general, translucent papers for use in food-related applications are likely to have wet strength or water resistance and are more challenging to recycle. They can be recycled, subject to testing, but generally need to be collected and treated separately in specialist facilities. Specifically:

Tracing paper: It has no water resistance and is fully pulpable.

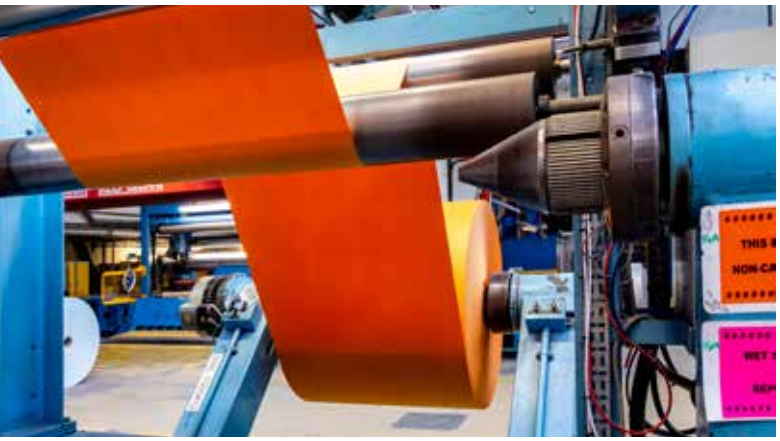
Hard-sized products: They are papers and boards treated with starch to make them moisture resistant. A typical example is the surfaces of some frozen food packaging. These products are slow to pulp, but can be recycled in most standard paper mills.

Glassine paper: If it is pure paper and not siliconised, it can be reprocessed, but if it is treated in any form, (baking paper is usually also siliconised), it is not likely to be recycled in a standard paper mill.

Silicone and Greaseproof papers: Whilst not damaging to the process, they cannot readily be pulped by high volume standard paper machines, and therefore often pass into the mill waste stream.

The acceptability of a product for recycling also depends on the way it is collected and presented. Currently, sorting facilities can only handle mixed papers, and there is no infrastructure for separate collections of lightweight papers from domestic waste streams. Examples of innovation exist and have increased in the last few years and the Paper Industry welcomes and supports research in this area. All fibre-based packaging products are reprocessed the same way by standard paper mills, regardless of the basis weight of the underlying fibre substrate.

In graphic mills dyed papers are considered a contaminant and there are strict limits in place regarding the quantity of dyed fibre. If the quantity of dyed material is exceeded, the quality of the pulp can be significantly impacted and it may need to be rejected and reprocessed. Dyes with strong chemical bonds may be more difficult to remove, and dyes that have good solubility may have less impact.



Promotional magazines and papers may be recycled either in packaging or graphic paper mills. Some inks and varnishes can be particularly challenging for paper mills manufacturing graphical papers, such as newsprint and magazine papers; they are not easily removed by the de-inking process and pass into the new sheet, causing flecking and pin holes. Parameters and criteria under the inks and varnishes section apply.

Dyed papers: Fibres can be dyed during the manufacturing process to add colour to the paper produced for decorative or functional purposes. The extent of the impact of papers made from dyed fibres on recyclability is influenced by several factors such as the nature of the dye used, the quantity of dyed material and the recycling process. Dyed papers can have a significant impact on the optical properties of the final pulp and in particular the brightness of the product.

Dyed fibres that are not printed may not require ink removal, although the dye may impact upon the use of other chemicals within the pulp or paper production process. However, it is very common that dyed fibres are also printed, and therefore ink will still need to be removed.

Achieving high-quality pulp from dyed materials can be challenging and the Paper Industry recommends that dyed papers, particularly those aiming to enhance the aesthetic appeal of the paper, are minimised.

8 Other Types of Fibre

8.1 Moulded Fibres

Moulded fibre and pulp products continue to gain popularity. They are manufactured through a series of processes, including pulp preparation, forming, pressing and drying to create various types of three-dimensional fibre products. These products have found applications in a wide range of items, ranging from food-related products like egg boxes to industrial packaging and clinical health care products.

Traditionally, papermaking fibres have been sourced from wood, but potential sources can be non-wood fibres, such as grass and palm. Provided that the fibres have been prepared for use in papermaking and presented in a form suitable to be utilised in the papermaking process, these fibres may be recycled.

Different fibre sources can impact on recyclability. For example, egg boxes, which are a common type of moulded product, can be easily recycled when they are made from recovered paper and wood fibres. However, for novel moulded products that utilise non-wood fibres, the inclusion of additional materials to enhance their performance or properties may make them more challenging to recycle. Due to their different chemical composition or physical properties they may require testing to determine their recyclability.

All design parameters that affect recyclability are still applicable.

Packaging products made from **glass fibres** (fibres that are made from extremely fine fibres of glass), or **carbon fibres** (fibres made from organic polymers and consisting of long strings of molecules held together by carbon atoms) are associated with numerous technical challenges and cannot be reprocessed by paper mills.

8.2 Non-wood Fibres

Most UK paper mills are set up to reprocess cellulose fibre derived from trees. The Paper Industry acknowledges that **alternative fibrous** materials are frequently used in papermaking, particularly those derived from agricultural residues. Examples of plant fibres include bagasse, palm, fibre, rice straw, wheat straw, barley straw, oat straw, grass straw, flax, hemp, and bamboo.

Non-wood fibres are subject to ongoing investigation, and stronger evidence is needed on their recyclability. The varying properties of alternative fibres could mean they will be separated out in the process at the mill and may be discarded in the waste stream. Therefore, there can be no guarantee the fibres will not be rejected in the recycling process.

The UK Paper Industry supports the use of fibre derived from trees, which most mills are set up to reprocess, and they have come from certified sources and/or from mills with recognised environmental management systems. Alternatives to wood-based fibres may be recycled, subject to having been prepared for use in papermaking and presented in a form suitable for use, and they are subject to ongoing investigation.

9 Biodegradable Paper Packaging

All cellulose fibre is potentially biodegradable in the right conditions, so whether fibre-based packaging is marked biodegradable is irrelevant for the purpose of papermaking. It makes little difference in the recycling process whether plastic is conventional, biodegradable, or oxo-degradable, as biological processes will not have sufficient time to cause any significant degradation of the material before it passes through the papermaking process. These types of plastic behave like all other plastic contaminants, and have the same consequences for the end product from the paper machine. For products that cannot be recycled, it is preferable if they are compostable, as they decompose into natural elements and break down much faster.

The process of remanufacturing paper through a standard mill takes a matter of minutes, so degradation of the fibre or liner is unlikely to occur in this time. If a package is marketed as biodegradable, but is likely to pass into the paper recycling stream and through a paper mill it should, nonetheless, meet these guidelines.

Whether packaging is marked biodegradable or not is largely irrelevant to the paper recycling process. Other factors such as the type of fibre and liners used are much more important.

For example, products containing bio-glitter behave in the exact same way as glitter, and have the same consequences for the end product from the paper machine, so it should be avoided.

Where Polylactic Acid (PLA) liners are used, PLA is unlikely to degrade in standard processes, and will behave like all other plastic contaminants.

The Paper Industry has no preference for biodegradable or conventional plastics since all plastic waste from the paper machine will be treated in the same way and sent to EfW facilities or landfill, unless separately collected and processed by specialist operators.

Acknowledgements

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List of Abbreviations

CaCO3	Calcium Carbonate
Cepi	Confederation of European Paper Industries
CPI	Confederation of Paper industries
EB	Electro Beam
EfW	Energy from Waste
PfR	Paper for Recycling
PLA	Polylactic Acid
PRAM	Papercycle Recyclability Assessment Method
PVA	Polyvinyl Acetate
PVC	Polyvinyl-chloride
PVDC	Polyvinylidene chloride
UV	Ultra Violet
WRAP	Waste and Resources Action Programme

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