4evergreen
perfecting circularity together

DS Smith

Recyclability Evaluation Protocol

European Harmonised Laboratory Test Method (Oct 22)

Test Provider	DS Smith
Test Location	Fibre & Paper Development Laboratory, Kemsley Paper Mill, UK
Test Evaluator	DS Smith Lab Technician

Sample Information	
No. of Samples	1
Customer	XXXX
SO Number	XXXX
Sample Name	XXXX
Date Tested	XXXX
Test Value	

Recyclability Score

50 / 100

Suitable for Standard Mill recycling*

*should not be abundant in incoming fibre streams

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Why Is This Rating Important To Us?

DS Smith have developed our **Now and Next Sustainability Strategy** which sits at the heart of our business model and is core to **our Purpose of Redefining Packaging for a Changing World**.

Our **Key Sustainability Targets** are:

Closing the loop through better design

By 2023 we will manufacture 100% reusable or recyclable packaging. It is our aim that by 2030 all of our packaging will be recycled or reused.

Reducing waste and pollution

By 2025 we will take 1 billion pieces of problem plastics off supermarket shelves. By 2030 we aim to enable the circular economy by replacing problem plastics, reducing customer carbon and eliminating consumer packaging waste.

Protecting natural resources

By 2025 we will optimise fibre use for individual supply chains in 100% of our new packaging solutions. By 2030 we are aiming to optimise every fibre for every supply chain.

Driving carbon reduction

A science-based target for 2030, which will require 46% absolute reduction in CO2e emissions per tonne of production compared to 2019 and to reach Net Zero emissions by 2050.

Equipping people to lead the transition to a circular economy

By 2025 we will engage 100% of our people on the circular economy. By 2030 we will engage 5 million young people on the circular economy and circular lifestyles.

Recyclability Evaluation Protocol

Why Is This Rating Important To Us?

As sustainability is at the heart of what we do, we have partnered with 4evergreen along with 100+ other members.

See below **4evergreen's Executive Summary**:

4evergreen strives to increase the recycling rate of fibrebased packaging to 90% by 2030. In order to support this mission, 4evergreen issues factual guidelines and technical documents alongside efforts aimed at facilitating dialogue and consensus-building among more than 100 stakeholders belonging to the fibre-based packaging value chain. 4evergreen has already published a "Circularity by Design Guideline" and a "Guidance on the Improved Collection and Sorting for Fibre-based Packaging." These guides support the design of packaging destined to achieve the best possible 'circularity performance'. This document is an evaluation protocol that in its current version helps to assess the recyclability of individual packaging and/or materials in standard recycling mill (Part I). It is based on expert opinion and consensus-building, and utilises a vast amount of data from actual recycling tests. This data was reprocessed and calibrated to create the most up-to-date scoring for recyclability of fibre-based packaging.

Recyclability Evaluation Protocol
Standard Recycling Mill Definition

The **4EG Recyclability Evaluation Protocol** test method carried out on your product is a test method designed to understand how a product would behave in a Standard Recycling Mill.

The score given for your product is only an evaluation of how it would behave in a **Standard Recycling Mill**, and not that of a Flotation-Deinking Mill, or a Specialised Recycling Mill.

All of **DS Smith's** mills are classed as **Standard Recycling Mills**.

Below is a description from 4evergreen detailing what is classed as a Standard Recycling Mill.

MILL DESCRIPTION

Standard mills typically utilise paper for recycling belonging to the EN 643 grades 1-4. The standard fibre-based packaging recycling process includes the following steps:

(RE)PULPING

The purpose of repulping is to break down the paper into fibres and other paper components (fillers, inks, varnishes, coatings, etc.). In this step, the paper for recycling is mixed with warm water (35-50°C) of pH 6-8. Standard mills typically operate a low-consistency pulper (4-5% fibre concentration) in continuous mode. Batch pulping may also be used but is less common in the industry.
Average retention time in the pulper is 5-10 minutes.

COARSE AND FINE SCREENING

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

CLEANING

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

PAPERMAKING

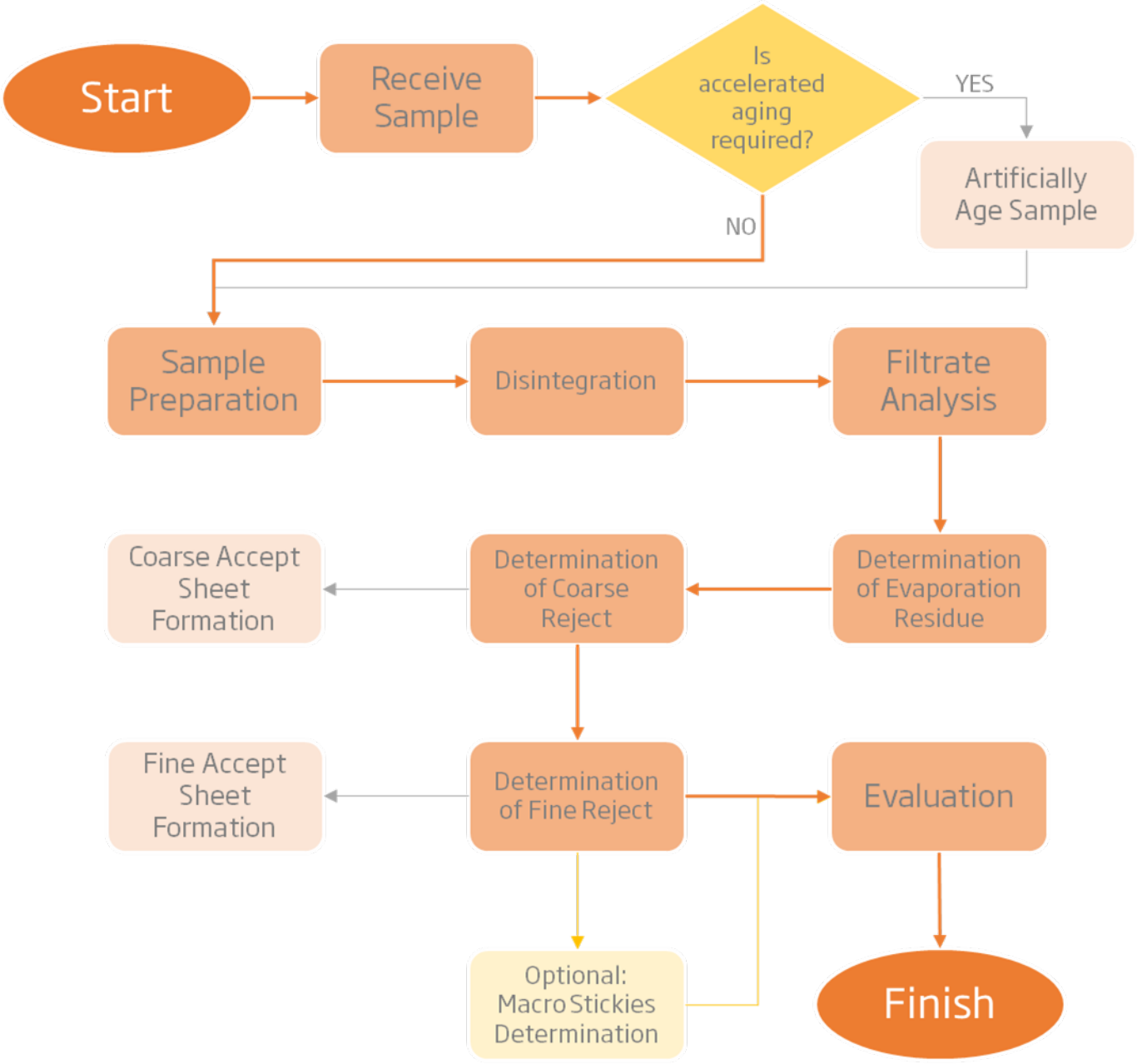
After the screening and cleaning steps, the recovered pulp is mixed with additives to form a papermaking furnish which is fed into a paper machine to produce recycled paper.

NOTE: The above equipment types were included in the lab-scale recyclability test scenario based on their prevalence in European standard mills, according to expert knowledge and data from CEPI – other processes/equipment types, such as de-flaking, are known to be used in specific mills or regions.

Text on this page was taken from: FIBRE-BASED PACKAGING RECYCLABILITY EVALUATION PROTOCOL BETA RELEASE DECEMBER 2022

Recyclability Evaluation Protocol

Methodology Flow Diagram



Please refer to the full 4EG Recyclability Evaluation Methodology for more details on how this testing was carried out.

Please note: While macro stickies determination is optional, we do offer an alternative test to the one in the 4EG Methodology which utilises our '3D Stick' testing equipment.

Recyclability Evaluation Protocol

Additional Testing

Group R&D

In addition to the 4evergreen/CEPI harmonised test methodology, the Fibre & Paper Development Laboratory also carries out a repulpability test.

If the accepted material from the Recyclability Evaluation Protocol is deemed to be of 'good' visual quality, further testing *may* be carried out at the tester's discretion to determine the overall quality of the fibrous materials.

Possible further tests:

- Fibre dispersion analysis
- Ash testing
- Fibre Image Analysis
- Quality Control Strength Testing

These tests help to build up the picture that tells us the overall quality of the material. By studying these fibres, their properties, and how they behave, we can determine how useful they are for recycled paper manufacturing. By doing so, we are edging closer to making the most of every fibre and ensuring circularity, which sits at the heart of DS Smith's Now and Next Sustainability Strategy.

Recyclability Evaluation Protocol

Results

Sample Preparation

Sample Description

The sample consisted of a fibre based pouch with assumed metallic coating on the inside, and printing on the outside. Traces of coffee granules noticed.

Preparation Method

Preparation of the sample was carried out as shown in the Recyclability Methodology under '**Complex sample preparation'**.

The sample was split into relevant components, and the **dry content** of each was determined.

53.75g *(50g oven-dry equivalent)* of material was cut into 3x3cm pieces, ready for disintegration.

The average **dry content** of the product was calculated from the individual components.

Calculated average dry content: **93.26%**

Further comments regarding Sample Preparation

No further comments.

Recyclability Evaluation Protocol

Results

Disintegration & Filtrate Analysis and Evaporation Residue

Disintegration

Tap water (at 40˚C and pH 7) was added to the prepared sample to achieve a stock consistency of 2.5%.

This was disintegrated for 10 minutes (30,000 revolutions).

The sample managed to repulp however large pieces of undispersed metallic film were present in the pulp.

The fibre components appeared to break down, with few fibre bundles noticed.

The disintegrator was initially rather violent when attempting to repulp the material, but eventually ran smoothly.

Filtrate Analysis and Evaporation Residue

Filtrate Analysis was carried out as per the 4EG Recyclability Methodology.

There was a yellow/brown tint and medium opacity to the filtrate pictured left. Excess coffee granules could be affecting this.

This analysis was carried out twice for the filtrate and once for tap water.

The Evaporation Residue was calculated as follows:

Evaporation Residue g/g	0.00107
Evaporation Residue of the sample mg/g	26.55
Evaporation Residue of the product %	**2.66%**

Recyclability Evaluation Protocol

Results

Coarse Screening

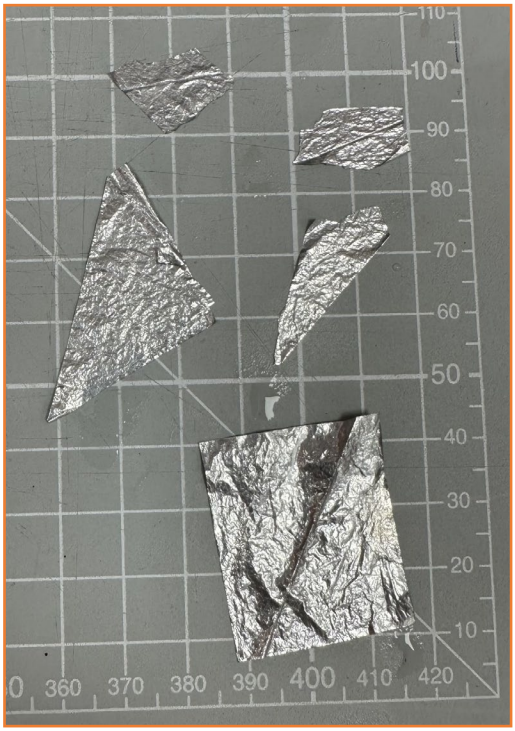
The Sommerville fractionator was fitted with the 5mm perforated plate.

The entire repulped sample was added, and processed for 5 minutes, with all of the accept material collected.

The rejects collected on the plate (pictured left) were transferred to a foil dish and dried.

Below: Close-up image of reject components.

Coarse reject incl. dry removed components	**10.40%**
Description of Coarse Screening reject	General impression
Are there fiber specks in the reject?	**No**
If yes, how much?	
in which type / size?	
Are non-paper product components in the reject?	**yes**
If yes, how much?	many
in which type / size?	big particle
How is the integration grade of the particles?	partially disintegrated
Out of which material consists the non-paper component?	Metallic film

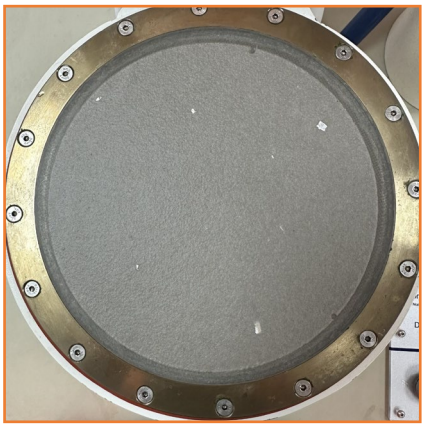


Recyclability Evaluation Protocol

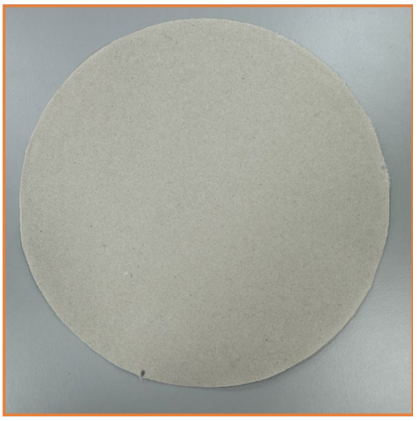
Results

Coarse Accept Visual Impurities Evaluation

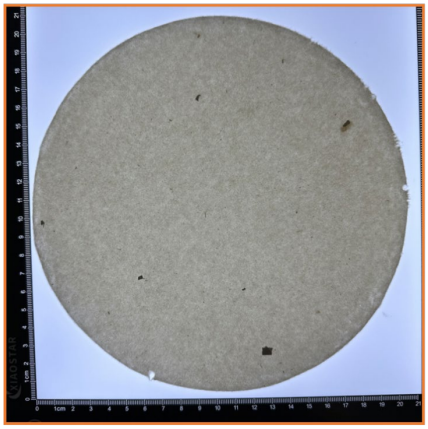
Two lab sheets were made with the coarse accepts material collected from the coarse screening, and the evaluation is determined from the decision tree shown on Page 22.



Wet Formation Sheet



Dry Sheet



Sheet with Back Light

Visual Assessment of the Coarse Accept	Sheet 1 Assessment	Sheet 1 Rating	Sheet 2 Assessment	Sheet 2 Rating
Absent				
Wax Stains				
Metallised Particles	Some	Level 3	Some	Level 3
Translucent Particles				
Colour Shading	Light grey	Level 1	Light grey	Level 1
Ink and Varnish Particles	Few Small	Level 1	Few Small	Level 1
Pigment Coating Particles				
Others	Many Small	Level 3	Many Small	Level 3
Evaluation	Level 3		Level 3	
Overall Evaluation	**Level 3**			

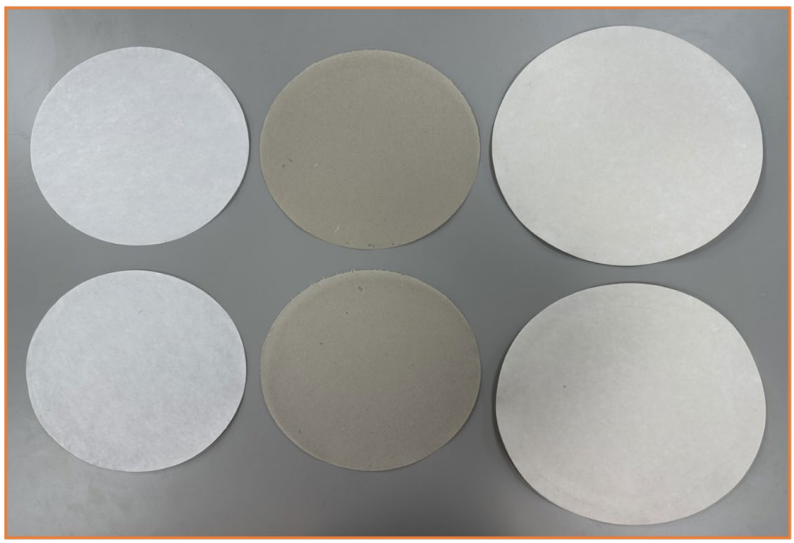
Recyclability Evaluation Protocol

Results

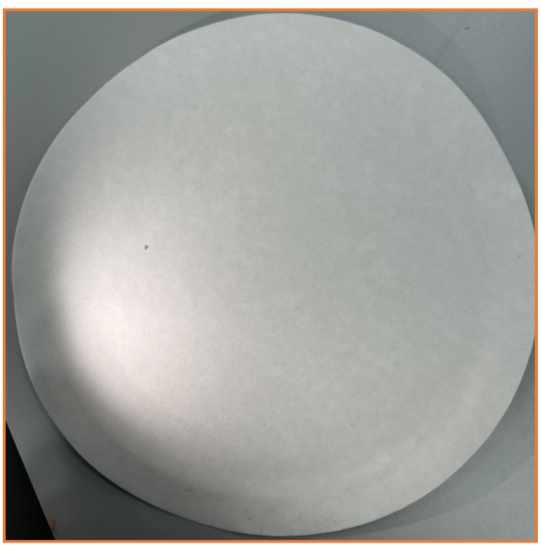
Coarse Accept Sheet Adhesion Evaluation

Two lab sheets were made with the coarse accepts material collected from the coarse screening, and each was assessed for sheet adhesion. More information on this evaluation can be found on page 23.

Sheet Adhesion Evaluation of Coarse Accepts	Sheet 1 Assessment	Sheet 2 Assessment
Adhesive Test	Absent	Absent
Damages/breakages		
Fibres on support/cover		
Fragments of paper on support/cover		One present
Summary	Absent	Absent
Evaluation	Level 1	Level 1
Overall Evaluation	**Level 1**	



Left to right: Cover sheet, handsheet, cover board

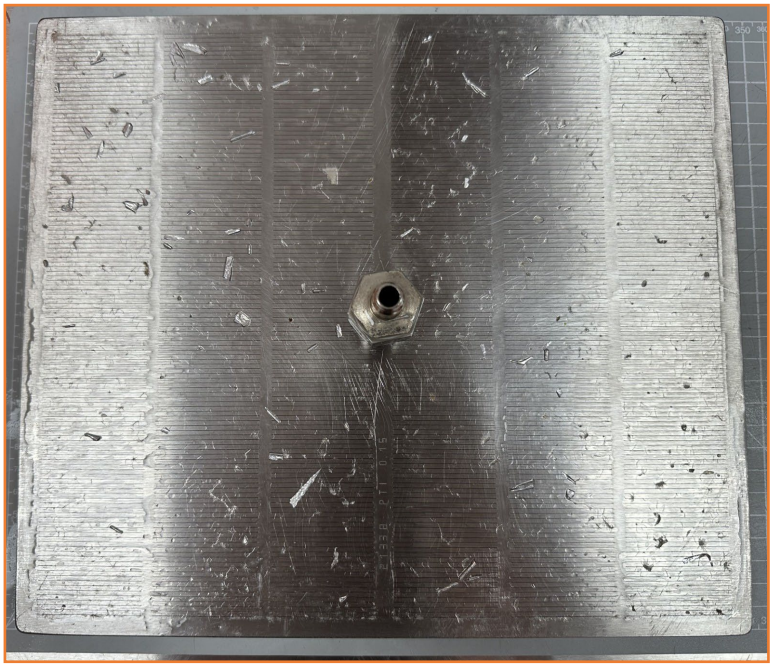


Cover board under oblique light

Recyclability Evaluation Protocol

Results

Fine Screening



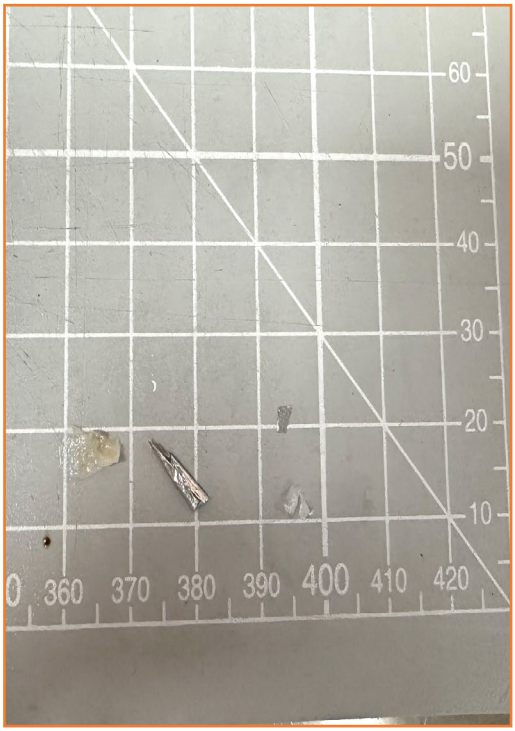
The Sommerville fractionator was fitted with the 0.15mm slotted screen.

The equivalent of 20g OD sample was added and processed for 20 minutes, with the first 50L of accept material collected.

The rejects collected on the plate (pictured left) were transferred to a foil dish and dried.

Below: Close-up detail of fine reject components.

Fine reject related to total product	**0.15%**
Description of Fine Screening reject	General impression
Are there fiber specks in the reject?	Yes
If yes, how much?	some
in which type / size?	flecks
Are non-paper product components in the reject?	yes
If yes, how much?	some
in which type / size?	big particle
How is the integration grade of the particles?	disintegrated
Out of which material consists the non-paper component?	Metallic film

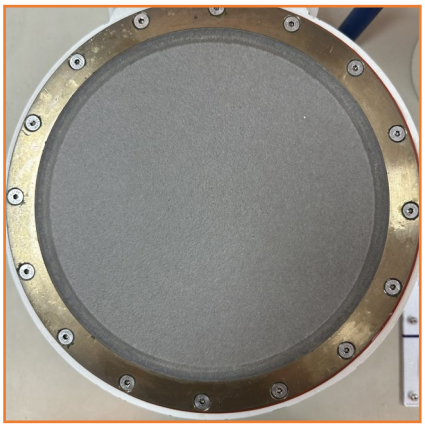


Recyclability Evaluation Protocol

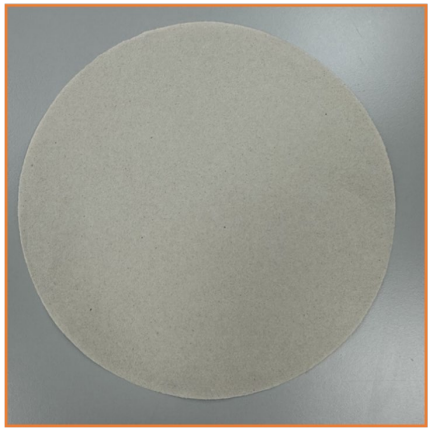
Results

Fine Accept Visual Impurities Evaluation

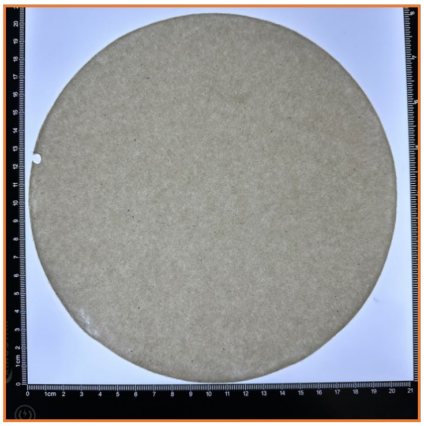
Two lab sheets were made with the fine accepts material collected from the fine screening, and the evaluation is determined from the decision tree shown on Page 22.



Wet Formation Sheet



Dry Sheet



Sheet with Back Light

Visual Assessment of the Fine Accept	Sheet 1 Assessment	Sheet 1 Rating	Sheet 2 Assessment	Sheet 2 Rating
Absent				
Wax Stains				
Metallised Particles	Few	Level 3	Few	Level 3
Translucent Particles				
Colour Shading	Light Grey	Level 1	Light Grey	Level 1
Ink and Varnish Particles	Few Small	Level 1	Few Small	Level 1
Pigment Coating Particles				
Others	Many Small	Level 3	Many Small	Level 3
Evaluation	Level 3		Level 3	
Overall Evaluation	**Level 3**			

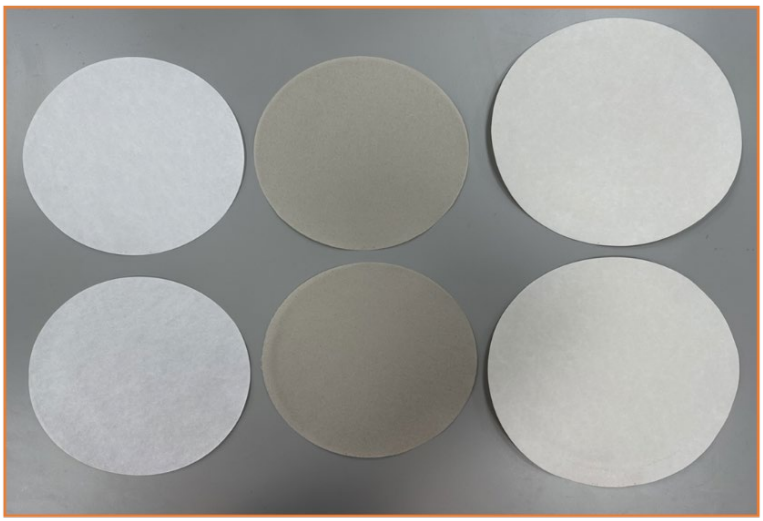
Recyclability Evaluation Protocol

Results

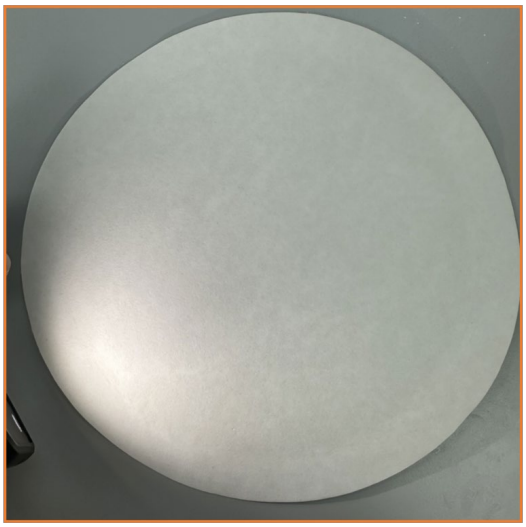
Fine Accept Sheet Adhesion Evaluation

Two lab sheets were made with the fine accepts material collected from the fine screening, and each was assessed for sheet adhesion. More information on this evaluation can be found on page 23.

Sheet Adhesion Evaluation of Fine Accepts	Sheet 1 Assessment	Sheet 2 Assessment
Adhesive Test	Absent	Absent
Damages/breakages		
Fibres on support/cover		
Fragments of paper on support/cover		
Summary	Absent	Absent
Evaluation	Level 1	Level 1
Overall Evaluation	**Level 1**	



Left to right: Cover sheet, handsheet, cover board



Cover board under oblique light

Recyclability Evaluation Protocol

Results

Scorecard

Recyclability Results	INPUT	Unit	Recyclability Score Standard Mill	Score Range	Comment
Coarse Reject	**10.40**	0 - 100 [%]			*Cepi method lab result for Coarse Reject*
Fine Reject	**0.15**	0 - 100 [%]			*Cepi method lab result for Fine Reject*
Yield	*89.5*	0 - 100 [%]	**65**	*min -100, max 100*	*Yield percentage, after applying a correction factor of 0.9 to the Fine Reject. (100%-CR-0.9* FR)*
Visual Impurities	**3**	1 - 4 [Level]	**-15**	*min -30, max 0*	*See VI decision tree for the appropriate level assignement.*
Sheet Adhesion	**1**	1 - 3 [Level]	**0**	*min KO, max 0*	*KO (Knock Out) is applied by limiting the final score to negative values.*
			50	**/100**	**Total Score.** *For interpretation, see description table below.*

This scorecard was generated as part of the 4EG Recyclability Evaluation. The overall score is rated from between **-100 to +100**.

Any score that is <0 is not suitable for Standard Mill recycling, but could potentially be recyclable in other mill types.

The score is determined by three main properties: Yield, Visual Impurities, and Sheet Adhesion.

Yield is calculated from both the Coarse Reject % and Fine Reject %.

Continue on to next page for the score component breakdown.

Recyclability Evaluation Protocol

Results

Scorecard: Yield

Yield	
Score	**Description**
90-100	The method indicates that the packaging is expected not to pose any repulpability issues in the standard mill and is therefore considered **Best in Class.**
70-89	The method indicates that the packaging has **minor repulpability issues** that could have limited impact on the recyclability in the standard mill.
50-69	The method indicates that the packaging has **some repulpability issues** that affect the process in the standard mill and should therefore not be abundant.
0-49	The method indicates that the packaging has some **significant repulpability issues** that have a significant impact on the process in the standard mill and should therefore be avoided when possible.
<0	The method indicates that the packaging has **major repulpability issues** which could stop the process at a standard mill and therefore are not suitable for this mill. It is recommended to evaluate this product with either part II or III.

This packaging product had a **Coarse Reject percentage of 10.40%,** a **Fine Reject percentage of 0.15%** and has an overall yield of **89.5%**, corresponding to a score of **+50**.

This Recyclability Score indicates that the packaging has **some repulpability issues** that affect the process in the standard mill and should therefore not be abundant.

Recyclability Evaluation Protocol

Results

Scorecard: Visual Impurities

Visual Impurities		
Level	**Score**	**Description**
Level 1	0	Poses **no visual quality issues**.
Level 2	-5	Poses **minor visual quality issues** that can be acceptable in the mix.
Level 3	-15	Poses **some visual quality issues** that can be acceptable in the mix for certain types of production.
Level 4	-30	Poses **significant visual quality issues** that can be problematic in the mix. Sample is at risk of receiving a KO in future revisions of the Evaluation Protocol.

This packaging product has been given a **Visual Impurities** rating of **Level 3,** correlating to a score of **-15.** This was determined from the fine accepts lab sheets.

This means the packaging poses **some visual quality issues** that can be acceptable in the mix for certain types of production.

Please refer to Page 20 which shows how a Visual Impurities Level is decided upon.

Recyclability Evaluation Protocol

Results

Scorecard: Sheet Adhesion

Sheet Adhesion		
Level	**Score**	**Description**
Level 1	0	Poses **no adhesion issues**.
Level 2	0	Poses **minor adhesion issues** that can be acceptable in the mix.
Level 3	KO	Poses **significant adhesion issues** that can have a significant impact on the process in the standard mill.

This packaging product has been given a **Sheet Adhesion** rating of **Level 1,** correlating to a score of **0**.

Sheet adhesion was not noticed in either coarse accepts or fine accepts handsheets.

Recyclability Evaluation Protocol

Results

Conclusion

This sample was determined as **Suitable for Standard Mill recycling.**

The score indicates the packaging has **some repulpability issues** that affect the process in the standard mill and should therefore not be abundant.

Some **visual impurities** were observed which could be of concern to certain types of production. No **sheet adhesion** noticed.

The Recyclability Score was calculated to be **+50/100**.

Recyclability Results	**INPUT**	**Unit**	Recyclability Score Standard Mill	**Score Range**	**Comment**
Coarse Reject	**10.40**	0 - 100 [%]			*Cepi method lab result for Coarse Reject*
Fine Reject	**0.15**	0 - 100 [%]			*Cepi method lab result for Fine Reject*
Yield	*89.5*	0 - 100 [%]	**65**	*min -100, max 100*	*Yield percentage, after applying a correction factor of 0.9 to the Fine Reject. (100%-CR-0.9* FR)*
Visual Impurities	**3**	1 - 4 [Level]	**-15**	*min -30, max 0*	*See VI decision tree for the appropriate level assignement.*
Sheet Adhesion	**1**	1 - 3 [Level]	**0**	*min KO, max 0*	*KO (Knock Out) is applied by limiting the final score to negative values.*
			50	**/100**	**Total Score.** *For interpretation, see description table below.*

Recyclability Evaluation Protocol

Appendix

Results Determination: Yield

SCORE CALCULATION

In order to translate the output values into one final score, the sum of three components is considered: yield, visual impurities and sheet adhesion. The yield score assesses the amount of fibrous material that can be retrieved from the fibre-based packaging. The visual impurities score assesses the optical quality of the pulp obtained. The sheet adhesion score assesses the potential to form tacky impurities that are detrimental to the paper production process. For the sheet adhesion parameter a 'knockout' is issued, this means that one result can indicate the packaging product is not recyclable in a standard mill irrespective of the other output scores. Minor adhesion issues (level 2 in CEPI test method) do not have impact on the overall score.

Yield score

The total reject (TR) is calculated according to the method in Equation 1. The total reject measures how much material is screened and approximates the total mass of the packaging product as a percentage that will not be recycled. All terms used in Equation 1 can be found in Table 1 except for α which is a correction factor used to mitigate the impact of errors commonly observed when assessing fine rejects at the lab scale. The value of α is set to 0.9 based on expert consensus. The constant value of α might be changed into a variable taking the fine reject composition into account in future versions.

EQUATION 1

$$TR = CR + FR * \alpha$$

where

- TR is the Total Reject (%);
- CR is the Coarse Reject rate (%);
- FR is the Fine Reject rate (%);
- α is the correction factor.

Complementary to the total reject (TR) is the yield, which defines the percentage of material mass that can be reused in a new fibre product. The calculation is shown in Equation 2.

EQUATION 2

$$Y = 100\% - TR$$

where

- Y is the Yield as mass percentage of material that can be reused (%);
- TR is the Total Reject (%).

For a standard recycling mill striving for high yield, total reject amounts need to be kept to a minimum. This has clear financial, technical and ecological benefits as well and is reflected in the number of points allocated. The calculation for the yield score is shown in Table 3 and is divided into four intervals or ranges. Each indicates an increasing loss of points as the yield is lower and less material can be recovered. A value of 0 is reached at 80% yield or 20% total reject. A visual representation of the yield score intervals as a function of yield is shown in Figure 1. As fewer points are lost when reject amounts are lower, a greater error % on the results in lower ranges ensures the scoring is still reliable.

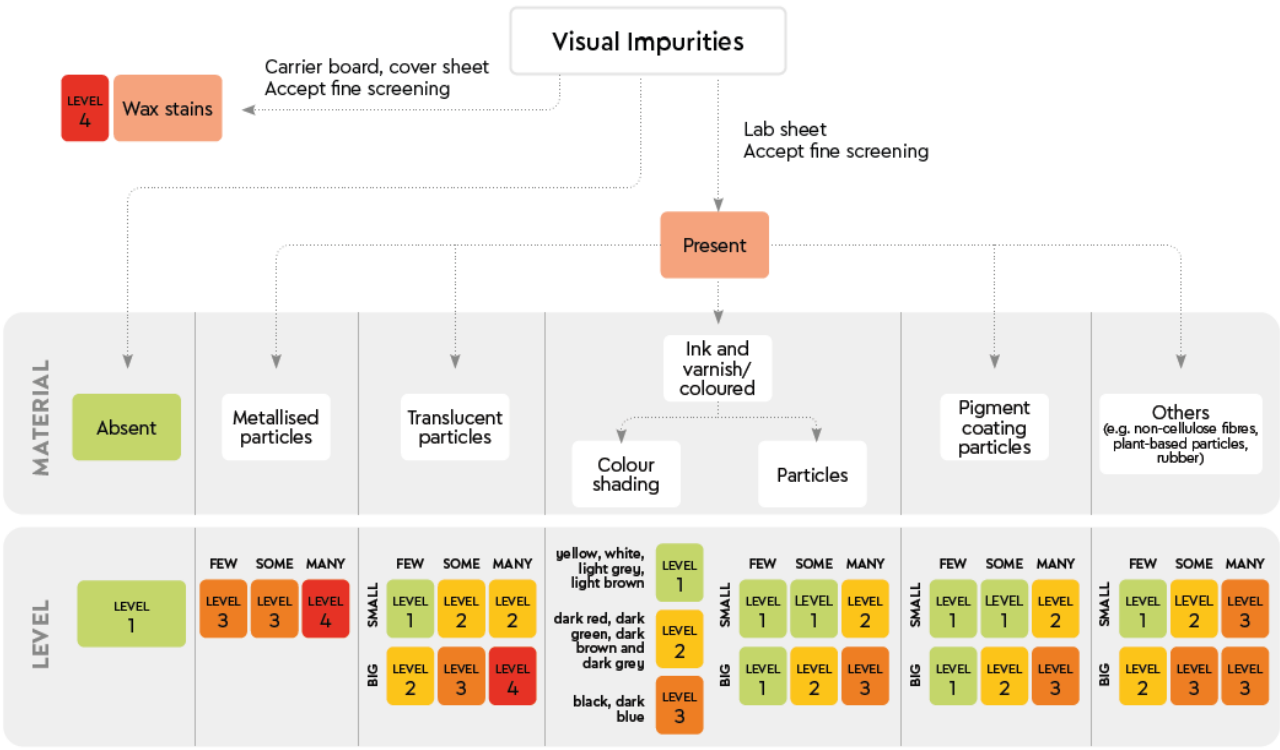
Recyclability Evaluation Protocol

Appendix

Results Determination: Visual Impurities

Visual impurity score

For the visual impurities, a qualitative and quantitative evaluation is described in the CEPI Recyclability Laboratory Test Method. The method uses a decision tree (Figure 2) to convert this assessment into a level from 1 to 4. Each level defines a range of visual impurities observed in the pulp, where level 1 is considered to have no visual quality issues and level 4 shows significant issues impacting the optical quality of the pulp.



NOTE: All applicable columns should be evaluated. Worst case level allocation applies.

LEVEL 1 No visual quality issues
LEVEL 2 Minor visual quality issues
LEVEL 3 Some visual quality issues
LEVEL 4 Significant visual quality issues

Visual impurities per hand sheet

Amount	Few	Some	Many
	<10	10 - 100	>100
Size	Small	Big	Combination
	<1 mm	>=1 mm	Consider the worst case level

Figure 2. Decision tree to evaluate the level of the visual impurities.

Recyclability Evaluation Protocol

Appendix

Results Determination: Sheet Adhesion

Sheet adhesion score

Similarly to visual impurities, sheet adhesion is a qualitative evaluation that is assigned to three possible levels. Level 1 indicates no adhesion issues are observed when using the recovered material. Level 2 is assigned to material that shows some indication of sheet adhesion but likely has a limited impact on the production process. Lastly, Level 3 is assigned when sheet adhesion is clearly observed and the recovered material would likely lead to production problems. Given the severity of level 3, it is considered a 'knockout' factor and the total score is immediately set to a negative value, making the tested product unsuitable for recycling in a standard mill. The CEPI recyclability laboratory test method provides details and examples for the level assignment.2

In Table 5, sheet adhesion levels are given a final score. As can be seen no points are lost or gained when level 1 and 2 are observed. Given the difficulties of differentiating between level 1 and 2 using the lab-test method, both are set to a score of 0. However, level 2 does alert the packaging designer that there is some granularity in the final product.

Sheet adhesion level	Sheet adhesion score
1	0
2	0
3	Knockout

Table 5. Conversion table for sheet adhesion level to sheet adhesion score

Total score

The final total score is the sum of all the individual scores discussed in this section – calculated based on yield and visual impurities scores and the sheet adhesion evaluation. It can be in the range from +100 to -100 and has been fully implemented into the Scorecard Excel tool provided.

It should be noted that the yield score is the only parameter that has a positive contribution to the total score (above the threshold limit, see Figure 1). The visual impurity score is either 0 or negative and the sheet adhesion is a knockout criteria. In practice, if a threshold is exceeded or a knockout criterion is triggered, the total score will be negative, resulting in a failed assessment of the fibre-based package.