

# RecyClass

## Science behind Recyclability

Printing Inks

05 July 2023

Fabrizio Di Gregorio, Technical Director, Plastics Recyclers Europe

Jean-Emile Potaufeux, Technical Manager, Plastics Recyclers Europe

Annett Kaeding-Koppers, Circular Packaging & Sustainability Project Manager, AKK Innovation



# RecyClass

## RecyClass Test Campaigns

# RecyClass | Test campaigns: what, why & how?

## What are RecyClass test campaigns?

- Tests of one or more packaging features according to RecyClass Sorting and/or Recyclability Evaluation Protocols.

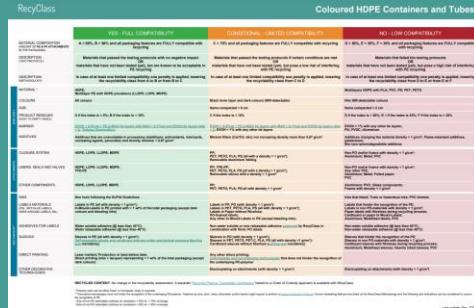
## Why does RecyClass perform test campaigns?

- Understand the effect of different features on plastic packaging recyclability by generating fact-based data.
- Use this knowledge to update the [Design for Recycling Guidelines](#).

## How does RecyClass do the test campaigns?

- Support from Members and non-members for sample provisions.
- Support from RecyClass Recognized Testing Facilities to carry out the tests.

# DESIGN FOR RECYCLING GUIDELINES



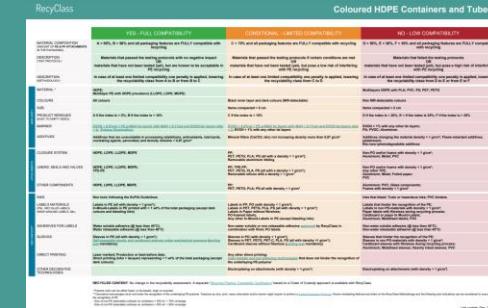
# MISSING FEATURE !

## TEST CAMPAIGN



- Samples from members & non-members
- Recognized Testing Facilities

# DESIGN FOR RECYCLING GUIDELINES



## FACT-BASED INFORMATION

# RecyClass | Test Campaigns: Process

RecyClass

## Coloured PE Flexible Films for Household and Commercial Packaging

| MATERIAL COMPOSITION (TOTAL AMOUNT OF PE & AMOUNT OF PP ATTACHMENTS IN THE PACKAGING)  |  |  |
|--|--|--|
| DESCRIPTION (TEST PROTOCOL)  |  |  |
| METHODOLOGY (MATERIAL, COLOURS, SIZE, PRODUCT RESIDUES (EASY TO EMPTY INDEX), BARRIER, ADDITIVES, CLOSURE SYSTEM, LINERS, SEALS AND VALVES, OTHER COMPONENTS, INKS, LABELS, ADHESIVES FOR LABELS, DIRECT PRINTING) |  |  |
| YES - FULL COMPATIBILITY   | CONDITIONAL - LIMITED COMPATIBILITY  | NO - LOW COMPATIBILITY   |
| A > 95%, B > 90% and all packaging features are FULLY compatible with recycling  | C > 70% and all packaging features are FULLY compatible with recycling   | D > 50%, E > 30%, F < 30% and all packaging features are FULLY compatible with recycling   |
| Materials that passed the testing protocols with no negative impact materials that have not been tested (yet), but are known to be acceptable in PE recycling  | Materials that passed the testing protocols if certain conditions are met OR materials that have not been tested (yet), but pose a low risk of interfering with PE recycling   | Materials that failed the testing protocols OR materials that have not been tested (yet), but pose a high risk of interfering with PE recycling  |
| In case of at least one limited compatibility one penalty is applied, lowering the recyclability class from A to B or from B to C  | In case of at least one limited compatibility one penalty is applied, lowering the recyclability class from C to D   | In case of at least one limited compatibility one penalty is applied, lowering the recyclability class from D to E or from E to F  |
| P, D, PE-LLD, PE-HD<br>Light colours, translucent colours<br>> 40 mm or 50 x 50 mm once compacted<br>A: the index is < 5%; B: if the index is < 10%  | P, D, PE-LLD, PE-HD<br>Multilayer PE/PP with PP < 5%<br>NIR-detectable dark colours (Sorting test)<br>< 40 mm or 20 x 20 mm<br>C: if the index is < 15%<br>< 5% EVOH (in polyolefinic combination film); metallized layers without coatings; <a href="#">PE-LLD PA 50% control with melting temperature &lt; 192 °C and incorporating &gt; 10% PE-g-MMA layers</a> | P, D, PE-LLD, PE-HD<br>Multilayer PE/PP with PP > 5%, Any other polymer (e.g. PET, PVC, etc.)<br>Non NIR-detectable dark colours<br>< 20 x 20 mm<br>D: if the index is < 20%; E: if the index is < 25%; F: if the index is > 25% |
| BARRIER  | Barrier in the polymer matrix; SiO <sub>2</sub> and AlO <sub>x</sub> without additional coatings   | > 5% EVOH (in polyolefinic combination film); metallized layers without coatings; <a href="#">PE-LLD PA 50% control with melting temperature &lt; 192 °C and incorporating &gt; 10% PE-g-MMA layers</a>                          |
| ADDITIVES  | Additives that do not increase the density higher than 0.97 g/cm <sup>3</sup>  | Bio-iso-biodegradable additives<br>Additives that do increase the density higher than 0.97 g/cm <sup>3</sup> (CaCO <sub>3</sub> , talc, glass fibers, etc.)  |
| CLOSURE SYSTEM   | P, D, PE-LLD, PE-HD  | Metal, aluminum, PVC, PET, PETG, PS, PLA, non PO or foams with density < 1 g/cm <sup>3</sup>   |
| LINERS, SEALS AND VALVES   | P, D, PE-LLD, PE-HD<br>PP, removable aluminum lidding  | Metal, aluminum, PVC, PET, PETG, PS, PLA, foiled paper, non PO or foams with density < 1 g/cm <sup>3</sup>   |
| OTHER COMPONENTS   | P, D, PE-LLD, PE-HD  | Metal, aluminum, PVC, PET, PETG, PS, PLA, paper, foams with density < 1 g/cm <sup>3</sup>  |
| INKS   | N: bleeding inks compliant with <a href="#">EuPIA Exclusion Policy</a>   | Inks that bleed; Inks non-compliant with EuPIA Exclusion Policy  |
| LABELS   | P: paper labels without fibers   | Metallized labels, any other; paper labels with fibers   |
| ADHESIVES FOR LABELS   | V: water soluble or water-releasable at less than 60°C   | Adhesives non-soluble in water or non-releasable in water at less than 60°C  |
| DIRECT PRINTING  | L: laser marked print; Printed production or expiry date; printing covering < 50%**  | Printing covering > 50% **   |
| RECYCLED CONTENT: No change in the recyclability assessment. A separate "Recycled Plastics Traceability Certification" based on a Chain of Custody approach is available with RecyClass                            |  |  |
| *Polymer resin can be either basic or bio-based, virgin or recycled.<br>**Temporary solution   |  |  |

1

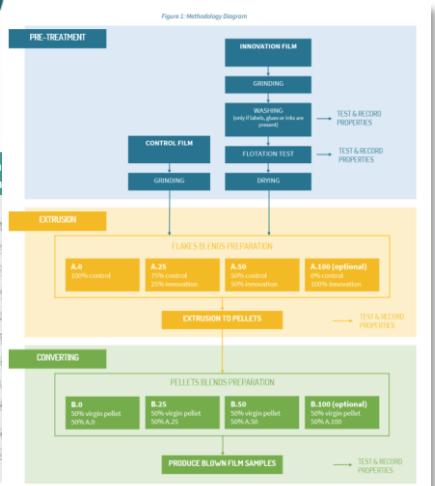
Ex: No information on **Printing Inks**



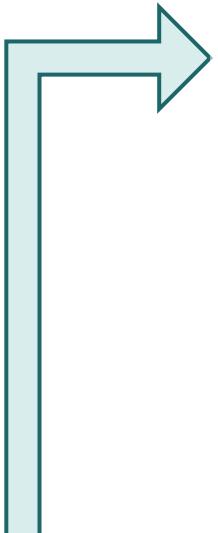
RecyClass TC defines the scope of the test campaign

2

| #   | Solvent | Isocyanate type | Polyol type | NCO/OH termination | NCO:OH ratio | Free-m |
|-----|---------|-----------------|-------------|--------------------|--------------|--------|
| 1   |         |                 |             |                    |              |        |
| 2   |         |                 |             |                    |              |        |
| 3   |         |                 |             |                    |              |        |
| 4   |         |                 |             |                    |              |        |
| 5   |         |                 |             |                    |              |        |
| 6   |         |                 |             |                    |              |        |
| 7   |         |                 |             |                    |              |        |
| 8   |         |                 |             |                    |              |        |
| 9   |         |                 |             |                    |              |        |
| 10  |         |                 |             |                    |              |        |
| 11  |         |                 |             |                    |              |        |
| 12  |         |                 |             |                    |              |        |
| 13  |         |                 |             |                    |              |        |
| 14  |         |                 |             |                    |              |        |
| 15  |         |                 |             |                    |              |        |
| 16  |         |                 |             |                    |              |        |
| 17  |         |                 |             |                    |              |        |
| 18  |         |                 |             |                    |              |        |
| 19  |         |                 |             |                    |              |        |
| 20  |         |                 |             |                    |              |        |
| 21  |         |                 |             |                    |              |        |
| 22  |         |                 |             |                    |              |        |
| 23  |         |                 |             |                    |              |        |
| 24  |         |                 |             |                    |              |        |
| 25  |         |                 |             |                    |              |        |
| 26  |         |                 |             |                    |              |        |
| 27  |         |                 |             |                    |              |        |
| 28  |         |                 |             |                    |              |        |
| 29  |         |                 |             |                    |              |        |
| 30  |         |                 |             |                    |              |        |
| 31  |         |                 |             |                    |              |        |
| 32  |         |                 |             |                    |              |        |
| 33  |         |                 |             |                    |              |        |
| 34  |         |                 |             |                    |              |        |
| 35  |         |                 |             |                    |              |        |
| 36  |         |                 |             |                    |              |        |
| 37  |         |                 |             |                    |              |        |
| 38  |         |                 |             |                    |              |        |
| 39  |         |                 |             |                    |              |        |
| 40  |         |                 |             |                    |              |        |
| 41  |         |                 |             |                    |              |        |
| 42  |         |                 |             |                    |              |        |
| 43  |         |                 |             |                    |              |        |
| 44  |         |                 |             |                    |              |        |
| 45  |         |                 |             |                    |              |        |
| 46  |         |                 |             |                    |              |        |
| 47  |         |                 |             |                    |              |        |
| 48  |         |                 |             |                    |              |        |
| 49  |         |                 |             |                    |              |        |
| 50  |         |                 |             |                    |              |        |
| 51  |         |                 |             |                    |              |        |
| 52  |         |                 |             |                    |              |        |
| 53  |         |                 |             |                    |              |        |
| 54  |         |                 |             |                    |              |        |
| 55  |         |                 |             |                    |              |        |
| 56  |         |                 |             |                    |              |        |
| 57  |         |                 |             |                    |              |        |
| 58  |         |                 |             |                    |              |        |
| 59  |         |                 |             |                    |              |        |
| 60  |         |                 |             |                    |              |        |
| 61  |         |                 |             |                    |              |        |
| 62  |         |                 |             |                    |              |        |
| 63  |         |                 |             |                    |              |        |
| 64  |         |                 |             |                    |              |        |
| 65  |         |                 |             |                    |              |        |
| 66  |         |                 |             |                    |              |        |
| 67  |         |                 |             |                    |              |        |
| 68  |         |                 |             |                    |              |        |
| 69  |         |                 |             |                    |              |        |
| 70  |         |                 |             |                    |              |        |
| 71  |         |                 |             |                    |              |        |
| 72  |         |                 |             |                    |              |        |
| 73  |         |                 |             |                    |              |        |
| 74  |         |                 |             |                    |              |        |
| 75  |         |                 |             |                    |              |        |
| 76  |         |                 |             |                    |              |        |
| 77  |         |                 |             |                    |              |        |
| 78  |         |                 |             |                    |              |        |
| 79  |         |                 |             |                    |              |        |
| 80  |         |                 |             |                    |              |        |
| 81  |         |                 |             |                    |              |        |
| 82  |         |                 |             |                    |              |        |
| 83  |         |                 |             |                    |              |        |
| 84  |         |                 |             |                    |              |        |
| 85  |         |                 |             |                    |              |        |
| 86  |         |                 |             |                    |              |        |
| 87  |         |                 |             |                    |              |        |
| 88  |         |                 |             |                    |              |        |
| 89  |         |                 |             |                    |              |        |
| 90  |         |                 |             |                    |              |        |
| 91  |         |                 |             |                    |              |        |
| 92  |         |                 |             |                    |              |        |
| 93  |         |                 |             |                    |              |        |
| 94  |         |                 |             |                    |              |        |
| 95  |         |                 |             |                    |              |        |
| 96  |         |                 |             |                    |              |        |
| 97  |         |                 |             |                    |              |        |
| 98  |         |                 |             |                    |              |        |
| 99  |         |                 |             |                    |              |        |
| 100 |         |                 |             |                    |              |        |



1



RecyClass

## Coloured PE Flexible Films for Household and Commercial Packaging

| YES - FULL COMPATIBILITY  | CONDITIONAL - LIMITED COMPATIBILITY  | NO - LOW COMPATIBILITY   |
|---|--|--|
| A > 95%, B > 90% and all packaging features are FULLY compatible with recycling   | C > 70% and all packaging features are FULLY compatible with recycling   | D > 50%, E > 30%, F < 30% and all packaging features are FULLY compatible with recycling   |
| Materials that passed the testing protocols with no negative impact materials that have not been tested (yet), but are known to be acceptable in PE recycling                           | Materials that passed the testing protocols if certain conditions are met OR materials that have not been tested (yet) but pose a low risk of interfering with PE recycling  | Materials that failed the testing protocols OR materials that have not been tested (yet) but pose a high risk of interfering with PE recycling   |
| In case of at least one limited compatibility one penalty is applied, lowering the recyclability class from A to B or from B to C   | In case of at least one limited compatibility one penalty is applied, lowering the recyclability class from C to D   | In case of at least one limited compatibility one penalty is applied, lowering the recyclability class from D to E or from E to F  |
| P, D, PE-LLD, PE-HD<br>Light colours, translucent colours<br>> 40 mm or 50 x 50 mm once compacted<br>A: the index is < 5%; B: if the index is < 10%                                     | P, D, PE-LLD, PE-HD<br>Multilayer PE/PP with PP < 5%<br>NIR-detectable dark colours (Sorting test)<br>< 40 mm or 20 x 20 mm<br>C: if the index is < 15%<br>< 5% EVOH (in polyolefinic combination film); metallized layers without coatings; <a href="#">PE-LLD PA 50% control with melting temperature &lt; 192 °C and incorporating &gt; 10% PE-g-MMA layers</a> | P, D, PE-LLD, PE-HD<br>Multilayer PE/PP with PP > 5%, Any other polymer (e.g. PET, PVC, etc.)<br>Non NIR-detectable dark colours<br>< 20 x 20 mm<br>D: if the index is < 20%; E: if the index is < 25%; F: if the index is > 25% |
| BARRIER   | Barrier in the polymer matrix; SiO <sub>2</sub> and AlO <sub>x</sub> without additional coatings   | > 5% EVOH (in polyolefinic combination film); metallized layers without coatings; <a href="#">PE-LLD PA 50% control with melting temperature &lt; 192 °C and incorporating &gt; 10% PE-g-MMA layers</a>                          |
| ADDITIVES   | Additives that do not increase the density higher than 0.97 g/cm <sup>3</sup>  | Bio-iso-biodegradable additives<br>Additives that do increase the density higher than 0.97 g/cm <sup>3</sup> (CaCO <sub>3</sub> , talc, glass fibers, etc.)  |
| CLOSURE SYSTEM  | P, D, PE-LLD, PE-HD  | Metal, aluminum, PVC, PET, PETG, PS, PLA, non PO or foams with density < 1 g/cm <sup>3</sup>   |
| LINERS, SEALS AND VALVES  | P, D, PE-LLD, PE-HD<br>PP, removable aluminum lidding  | Metal, aluminum, PVC, PET, PETG, PS, PLA, foiled paper, non PO or foams with density < 1 g/cm <sup>3</sup>   |
| OTHER COMPONENTS  | P, D, PE-LLD, PE-HD  | Metal, aluminum, PVC, PET, PETG, PS, PLA, paper, foams with density < 1 g/cm <sup>3</sup>  |
| INKS  | N: non-bleeding inks compliant with <a href="#">EuPIA Exclusion Policy</a>   | Inks that bleed; Inks non-compliant with EuPIA Exclusion Policy  |
| LABELS  | P: paper labels without fibers   | Metallized labels, any other; paper labels with fibers   |
| ADHESIVES FOR LABELS  | V: water soluble or water-releasable at less than 60°C   | Adhesives non-soluble in water or non-releasable in water at less than 60°C  |
| DIRECT PRINTING   | L: laser marked print; Printed production or expiry date; printing covering < 50%**  | Printing covering > 50% **   |
| RECYCLED CONTENT: No change in the recyclability assessment. A separate "Recycled Plastics Traceability Certification" based on a Chain of Custody approach is available with RecyClass |  |  |
| *Polymer resin can be either basic or bio-based, virgin or recycled.<br>**Temporary solution  |  |  |

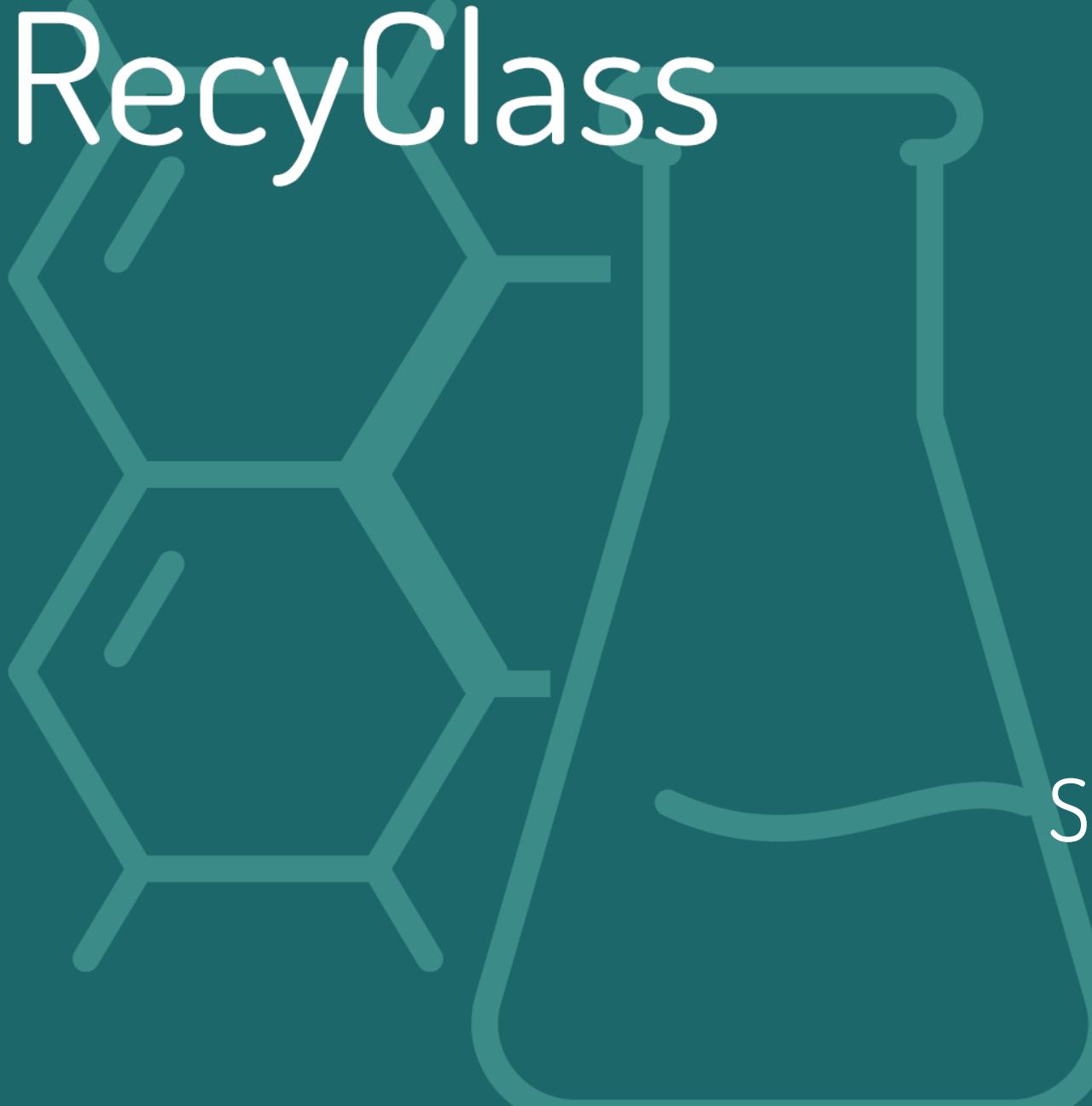
3

Laboratory results reviewed within RecyClass TC

4

DfR Guidelines updated with findings of the test campaign

# RecyClass



## Printing Inks in Flexible Packaging

-

### State-of-the-art Printing Inks

# RecyClass | WHAT ARE PRINTING INKS?

RecyClass endorsed the **definition of EuPIA<sup>1</sup>** on inks:

- a. Mixtures of colourants with other substances which are applied on materials to form a graphic or decorative design together with or without.
- b. Other coloured or uncoloured overprint varnishes/ coatings or primers which are normally applied in combination with a) in order to enable the printed design to achieve specific functions such as ink adhesion, rub resistance, gloss, slip/friction, durability etc.

Table 2: Overview of Printing Processes used for Flexible Plastic Packaging

|                  | PRINTING PROCESS   | INK DEPOSIT THICKNESS |
|------------------|--------------------|-----------------------|
| ANALOG PRINTING  | Silk screen        | 5 – 280 µm            |
|                  | Offset             | 0,5 – 2 µm            |
|                  | Flexography        | 1 – 8 µm              |
|                  | Gravure            | 1 – 20 µm             |
| DIGITAL PRINTING | Inkjet             | 1 – 3 µm              |
|                  | Electrophotography | ± 10 µm               |

"Printing inks" does not include **coatings** which are applied with the **prime objective of enabling the material or article to achieve a technical function** such as heat sealing, barrier, corrosion resistance etc., as opposed to a graphic effect, even though they may be coloured.

<sup>1</sup> EuPIA definition of inks and other associated definitions can be found in the EuPIA glossary.

# RecyClass | WHAT ARE PRINTING INKS?

For flexible applications, majority is currently solvent based.

Usually, inks are composed of 4 different components:

- **Solvent** (organic solvents like alcohol, esters, or water with alcohols)
- **Polymeric binder** (NC, PVB, PU, PVC, acrylates, ...)
- **Pigments** (Azo, Naphtol AS, Chinacridon, Phtalocyanin, TiO<sub>2</sub>, SiO<sub>2</sub>...)
- **Some additives** (Wax, slip additives, plasticizers, ...)

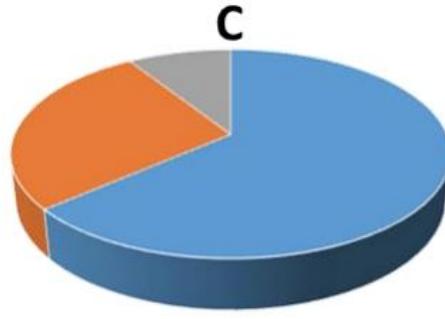
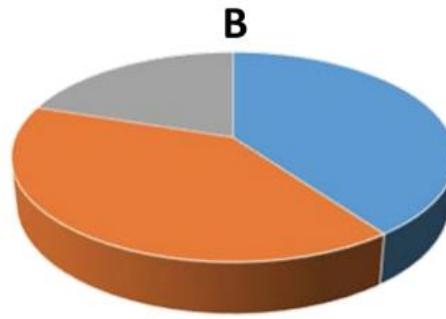
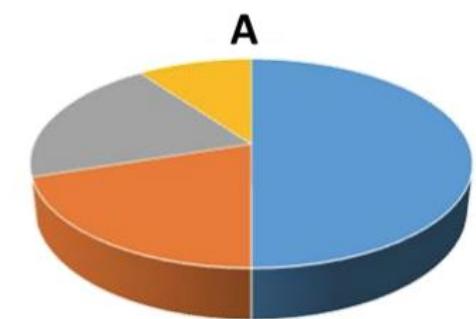
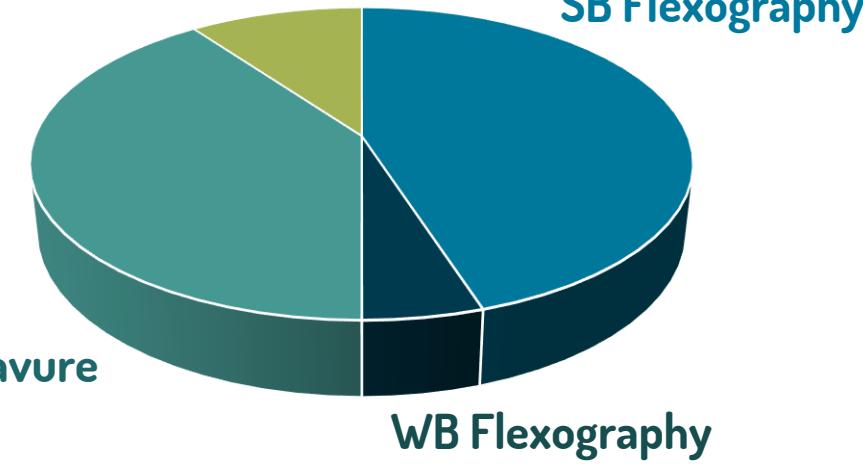


Figure 1: Composition of A) wet flexography / gravure inks, B) dried solvent or water-based inks, and C) UV- or EB-cured flexography inks

Others (Offset, UV, digital, ...)

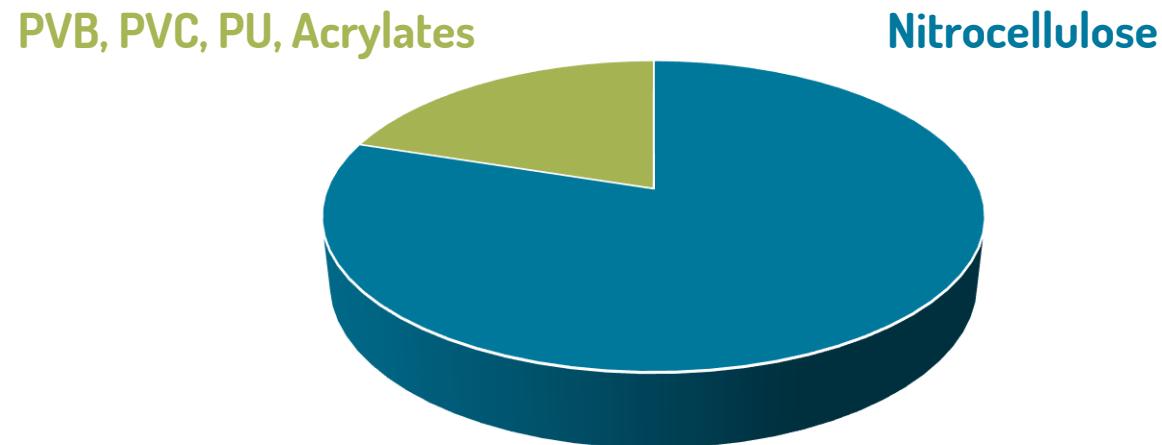


Other printing inks exist:

- Metallic inks
- Pearlescent inks
- Inks with chrome or mirror effect
- Conductive inks

# RecyClass | FOCUS ON BINDERS

Distribution of binders

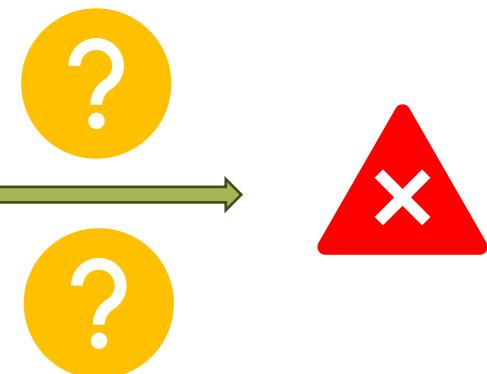


## Main binders:

- **Nitrocellulose**
- **PVB**
- **PU**
- **PVC**
- **Acrylates**

(PE, OPP films, surface or reverse printing)  
(PE, OPP, PET, mainly reverse printing)  
(PE, OPP, reverse printing)  
(PET, PA, reverse printing)  
(PE, OPP, water and solvent based)

## Impact on recyclability



# RecyClass



## Printing Inks in Flexible PP Packaging

-  
PrintCYC project

# Recycling compatible inks

Together for circular economy

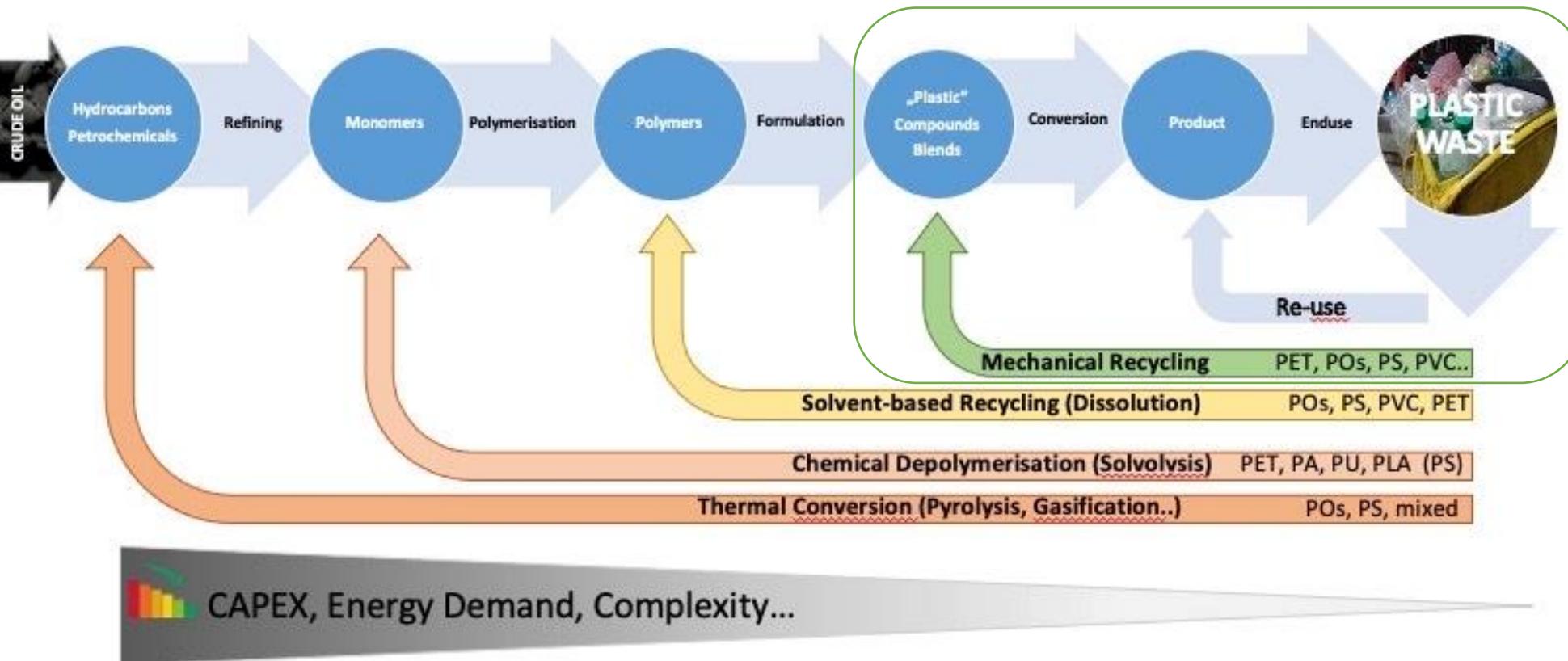
Together for sustainability

Dr. Annett Kaeding-Koppers, AKK Innovation



# Design for mechanical recycling

## Printed packaging films for premium recyclates



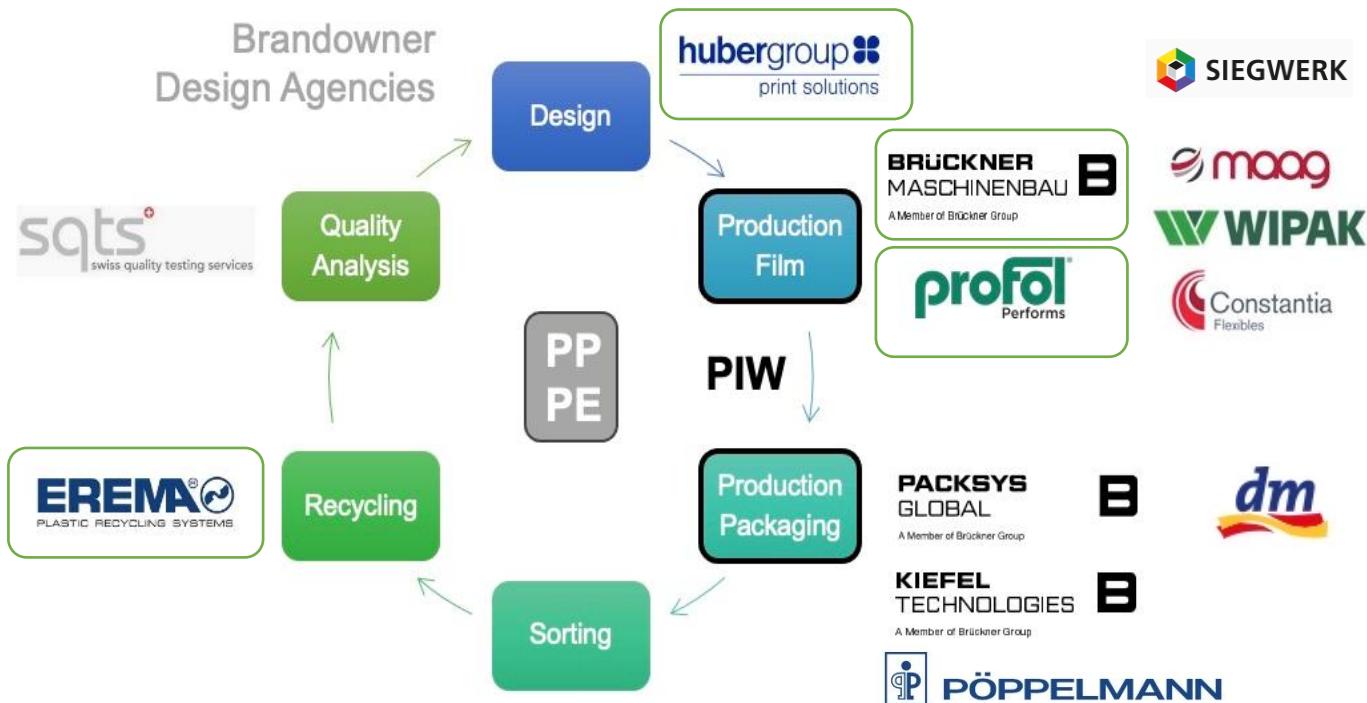
### Mechanical recycling

- Without De-Inking
- With De-Inking

The only short-term option

# Together for circular economy

Partnership and value chain collaboration  
(2019 – 2022)



Result presentation & discussions with:  
Recycla – ForumRezyklat – CosPaTox – Ceflex  
Polycycle – Plastcycle

INNOFORM



Initiator, coordinator & sustainability strategy

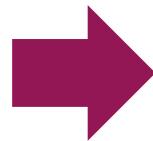
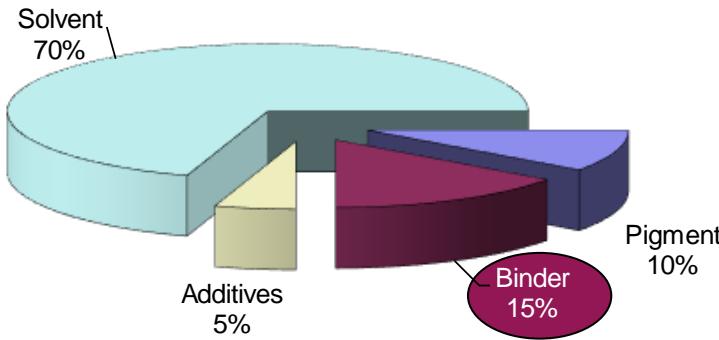
Dr. Annett Kaeding-Koppers



Excellent  
collaboration!  
Thank you!

## Printing inks and mechanical recycling without de-inking

### Ink composition



| Binder                             | NC<br>NC/PU | PVB       | PVC       | PU            |
|------------------------------------|-------------|-----------|-----------|---------------|
| Gravure printability               | 😊           | 😊         | 😊         | 😊             |
| Flexo printability                 | 😊           | 😐         | 🙁         | 😊             |
| Pasteurisation                     | 😐           | 😊         | 😊         | 😊             |
| Sterilisation                      | 🙁           | 😊         | 😊         | 😊             |
| Range of substrates                | universal   | universal | universal | veryuniversal |
| Printing speed                     | very high   | high      | very high | very high     |
| Surface printing                   | 😊           | 🙁         | 🙁         | 🙁             |
| Lamination<br>High Performance     | 🙁           | 😊         | 😊         | 😊             |
| Lamination<br>Medium Performance   | 😊           | 😊         | 😊         | 😊             |
| Lamination<br>Standard Performance | 😊           | 😊         | 😊         | 😊             |

Phase 1

Phase 3

n.r.

Phase 2

# Impact of binder

## From printed BOPP films to coloured recyclates

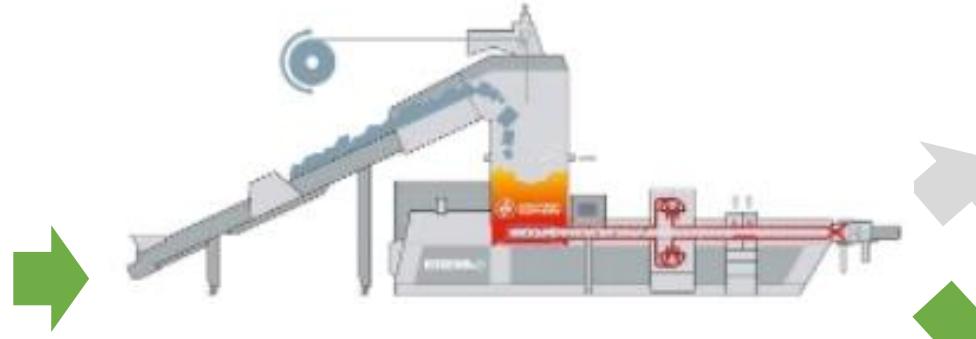
### Printed films BOPP

Full surface printed:  
1,2 – 1,6 g/m<sup>2</sup>  
6 – 9 W% of ink  
94 – 91 W% of PP  
Pigment white: TiO<sub>2</sub>



Binders:  
Nitrocellulose (NC)  
Polyurethane (PU)  
Polyvinylbutyral (PVB)

### Mechanical Recycling without De-Inking Intarema TVE plus

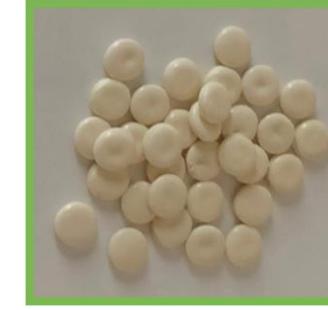


**Recycling criteria:**  
**Temperature resistance**

**240-250°C / 2min**

**Produced amount:**  
**150 – 300 kg  
of recyclates**

### Regranulates rPP



### Results

#### NC based binder

- Colour change
- Odour
- Volatiles

#### PVB based binder

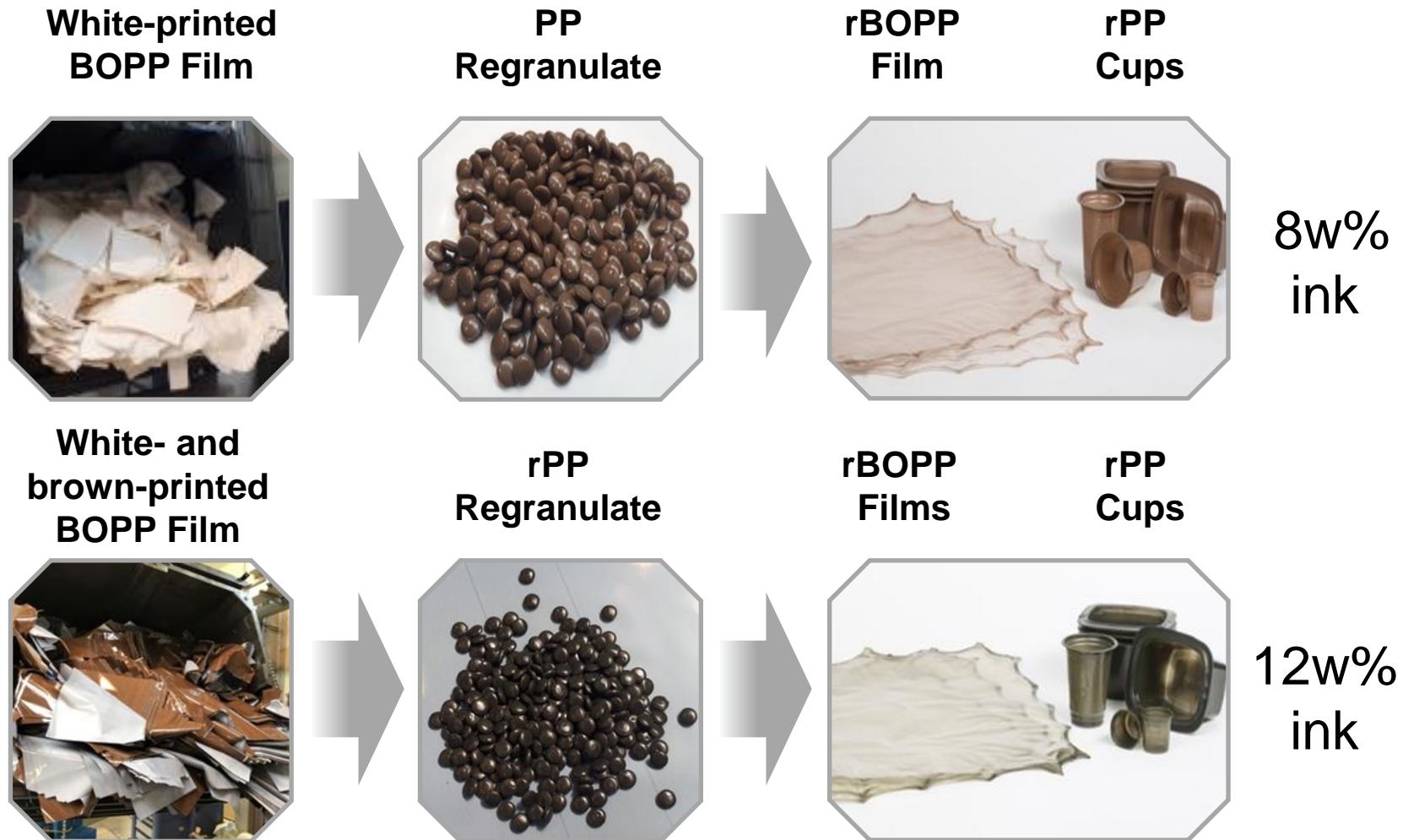
- Nearly stable
- Light odour
- No volatiles

#### PU based binder

- Colour stable
- Odour free
- No volatiles

# Recycling results – Binder (NC)

## Closing the loop

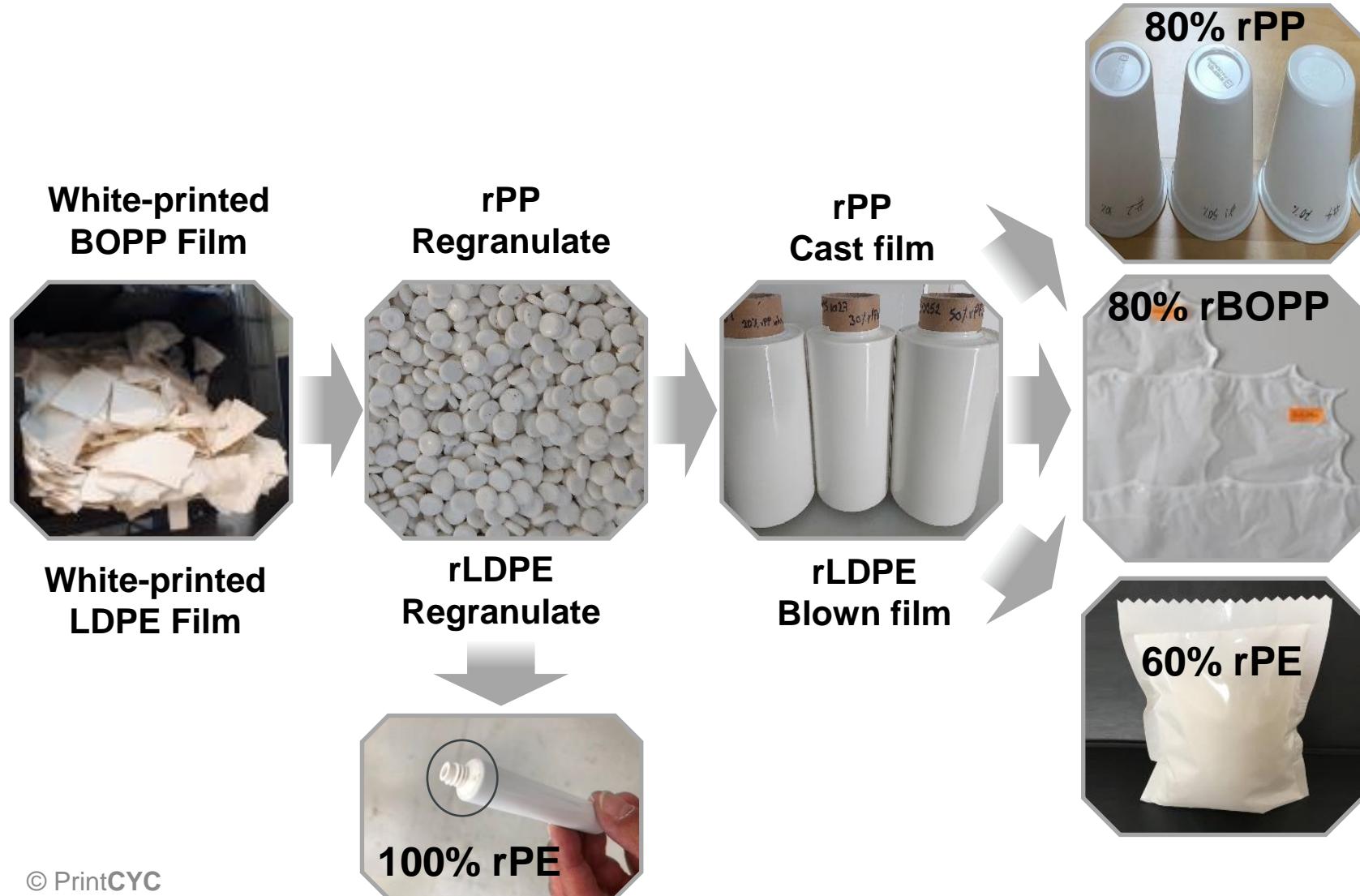


## Results

- Decomposition of Nitrocellulose:
  - Volatiles
  - Odour
  - Colour change
  - Impact on film properties by recyclate reuse
- Recycling possible with limitations

# Recycling results – Binder (PU)

## Closing the loop



### Results

- Excellent colour stability („white stays white“)
- Excellent recycling (no gassing, no odour)
- Excellent processability (comparable to virgin material)
- Valid for PE and PP

## Interlayer full-surface printing

### Composition „Barrier bag for recycling“

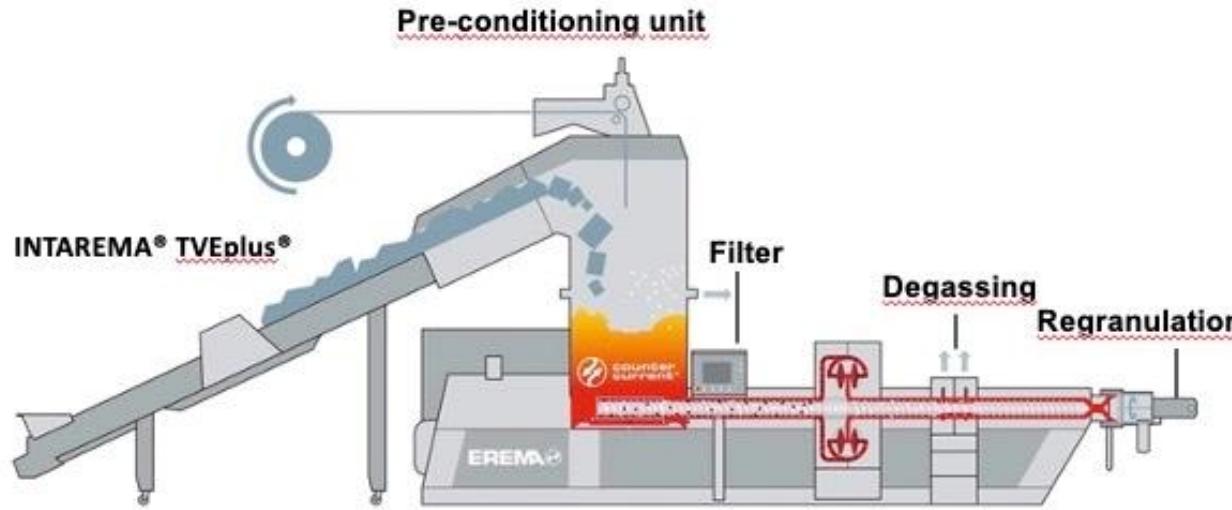
| Packaging     | Weight<br>g/m <sup>2</sup> | W%    |                |                 |
|---------------|----------------------------|-------|----------------|-----------------|
| BOPP, 20µm    | 18,4                       | 44,93 |                |                 |
| Ink coloured  | 0,55                       | 1,34  |                |                 |
| Ink white     | 2                          | 4,88  | <b>6,22 %</b>  | <b>Ink</b>      |
| Adhesive      | 1,5                        | 3,66  | <b>3,66 %</b>  | <b>Adhesive</b> |
| Metallization | 0,1                        | 0,24  | <b>0,24 %</b>  | <b>Metal</b>    |
| BOPP, 20 µm   | 18,4                       | 44,93 | <b>89,86 %</b> | <b>PP</b>       |
| <b>40,95</b>  |                            |       |                |                 |

#### Composition:



# Mechanical recycling of printed films (PU inks)

## Recyclability results



### Recyclability:

- + No volatiles
- + No odour
- + No colour change
- + Processability
- + Safety

#### Input

Defined samples



0w%

#### Recycling criteria:

Temperature resistance  
of 240-250°C / 2min

#### Output

PP recyclate,  
coloured



3,5w%



4,1%w%



(met. 0.5w%)



6,2w% Ink content

# Regranulates

## Safety assessment



- **Comparison of input/output material**  
→ Screening test (film/recyclate)
- **Analysis of binder degradation**  
→ degradation products
- **Analysis of pigment degradation**  
→ primary aromatic amines
- **Analysis of PP degradation**  
→ low molecular weight components

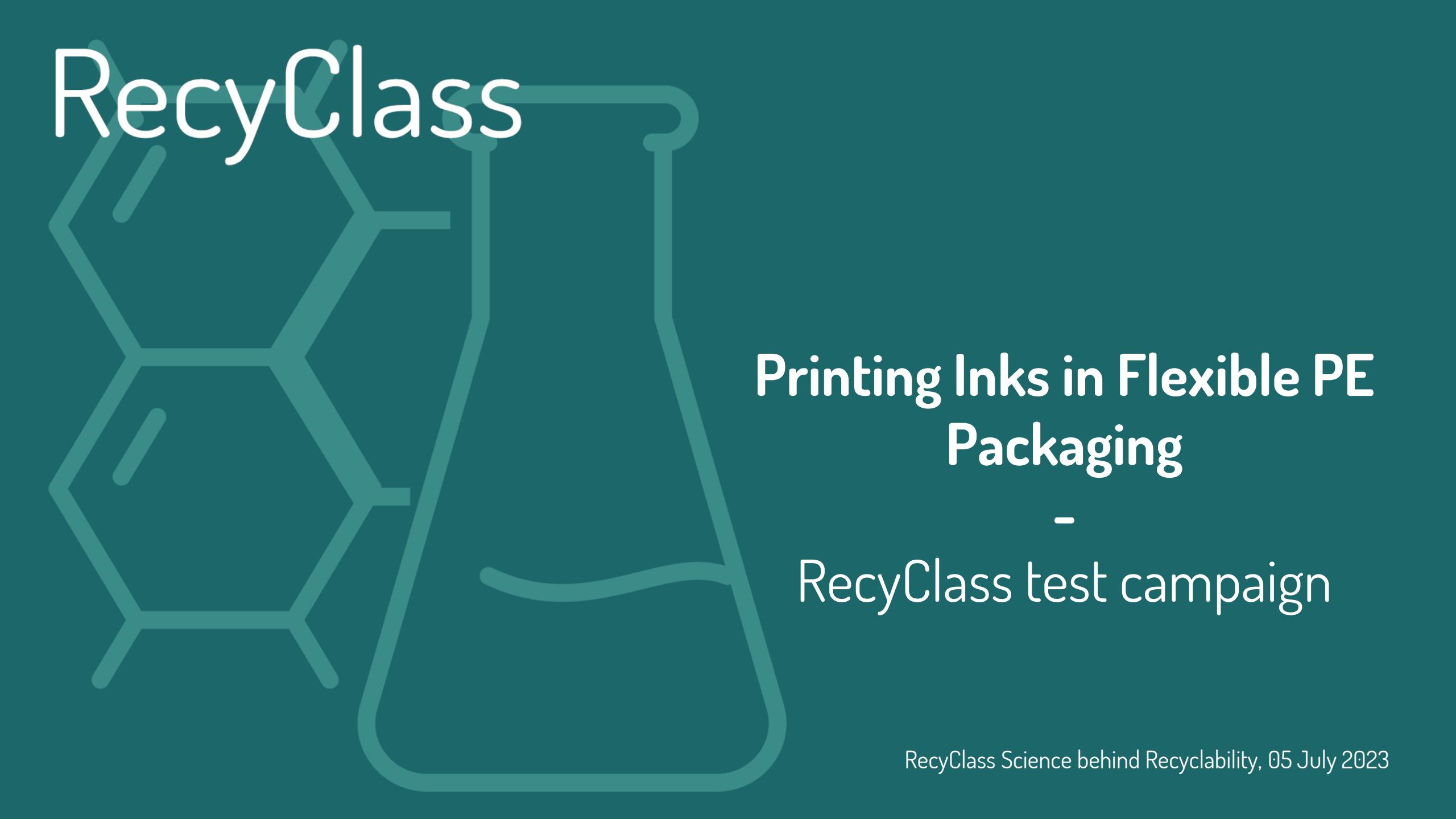
### Methodology:

1. **GC-MS headspace** - volatiles  
1h at 100°C
2. **Worst Case Extraction**  
Cryomill preparation  
2 days at 60°C in 95% EtOH + 2h USB  
**Extract:** 5g/50ml  
GC-QTOF-MS/FID-Screening

### Testing according to :

- ✓ **Plastics Regulation EU10/2011**
- ✓ **Swiss Ordinance SR 817.023.21**

# RecyClass



## Printing Inks in Flexible PE Packaging

–  
RecyClass test campaign

# RecyClass | RECYCLASS LA WG

## STRUCTURE OF THE PRINTING INKS WORKING GROUP:

- Working Group launched in 2021 with 2 inks suppliers and EuPIA
- Now composed of 3 inks suppliers, 1 Constantia Flexibles, and EuPIA
- Objectives:**
  - Assessed the impact of different ink binders (NC, PU) on flexible PE packaging
  - Discriminate the impact of inks on recyclability based on their chemistries and wt%
  - Develop a quick test method to evaluate inks impact on recyclability
  - Discriminate impact of binders, pigments & other inks components

# RecyClass PRINTING INKS CAMPAIGN

Evaluating impact of **typical ink systems** used for flexible packaging on recyclability

Focus on **Nitrocellulose and Polyurethane** binders

Work with **non-company specific** systems to allow general conclusion

Test of binders systems **alone and also as full formulation** with pigments

**Ink coverage** based on CEFLEX D4ACE

**Characterisation** of pellets and blow films

Addition of a **deinked sample** to evaluate achievable quality improvement of recyclates

## OBJECTIVE

Given the multitude of ink formulations and raw materials used result will represent an insight but can be used as a guideline for the development of a quick test protocol of ink systems to increase knowledge and as guideline for future ink developments

# RecyClass | PRINTING INKS TEST CAMPAIGN

## General workplan:

- ✓ Evaluate impact of inks and their components on **flexible packaging recyclability**
- ✓ Focus on **NC and PU-based binders**
- ✓ Tests on films **only coated with the binders**
- ✓ Tests on films printed with **4 ink formulations** corresponding to **standard and heat-stable CMYK-pigments**
- ✓ Full characterisation of **extruded material and produced blow film**
- ✓ Include a **deinked sample**

| ID | Description                 | Coating weight (Target)           | Comments  |
|----|-----------------------------|-----------------------------------|---|
| 1  | <b>Unprinted PE</b>         | n.a.                              | 50-60µm LDPE (control film)   |
| 2  | <b>NC/standard pigments</b> | <b>5% = 2.8g/m<sup>2</sup></b>    | max amount according CEFLEX D4ACE, worst case as colored ink  |
| 3  | <b>NC/HPP</b>               | <b>5% = 2.8g/m<sup>2</sup></b>    | max amount according CEFLEX D4ACE, worst case as colored ink  |
| 4  | <b>PU/standard pigments</b> | <b>5% = 2.8g/m<sup>2</sup></b>    | max amount according CEFLEX D4ACE, worst case as colored ink  |
| 5  | <b>PU/HPP</b>               | <b>5% = 2.8g/m<sup>2</sup></b>    | max amount according CEFLEX D4ACE, worst case as colored ink  |
| 6  | <b>NC/standard pigments</b> | <b>3% = 1.7g/m<sup>2</sup></b>    | 60% max amount according CEFLEX D4ACE (more critical in terms of recyclability as NC-system)                    |
| 7  | <b>PU/HPP</b>               | <b>7% = 3.8g/m<sup>3</sup></b>    | 140% max amount according CEFLEX D4ACE (less critical in terms of recyclability as PU-system)                   |
| 8  | <b>NC-binder</b>            | <b>1.25% = 0,7g/m<sup>2</sup></b> | coating weight corresponding to average percentage NC and PU in ID2 - 5 (=25%)                                  |
| 9  | <b>PU-binder</b>            | <b>1.25% = 0,7g/m<sup>2</sup></b> | coating weight corresponding to average percentage NC and PU in ID2 - 5 (=25%). Optionally anti-blocking agent. |
| 10 | <b>Deinked sample 6</b>     | n.a.                              |   |

# RecyClass PRINTING INKS CAMPAIGN

**Test formulations aligned by Flint, SUN and SW represent typical ink systems used in the industry with main binder NC and PU\***

Test formulations binders and inks

| binder system   | standard pigments (SP)*  | heat-stable pigments (HPP)* |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
|---|--|-----------------------------|--------|-----------------------|-------|------------------|-------|------------------|-------|----------------|-------|------------------|-------|-------------------|--------|---------|--------|--|--------------|---------|------------------|--|-----------------------|-------|-----------------------|-------|------------------|-------|------------------|-------|-----------------|-------|----------------|--------|-------------------|--------|-----|-------|-------------------|-------|---------|--------|
| <b>nitrocellulose (NC)</b><br>alcohol soluble A-grade | <table><tbody><tr><td>polymeric plasticizer</td><td>5,4 %</td></tr><tr><td>monomeric plasticizer</td><td>2,0 %</td></tr><tr><td>Pigment P.B.15:4</td><td>1,1 %</td></tr><tr><td>Pigment P.R.57:1</td><td>2,1 %</td></tr><tr><td>Pigment P.Y.13</td><td>2,2 %</td></tr><tr><td>Pigment P.Bk.7</td><td>1,0 %</td></tr><tr><td>NC (phlegmatized)</td><td>21,0 %</td></tr><tr><td>Wax</td><td>0,4 %</td></tr><tr><td>adhesion promoter</td><td>1,5 %</td></tr><tr><td>Solvent</td><td>63,3 %</td></tr></tbody></table> | polymeric plasticizer       | 5,4 %  | monomeric plasticizer | 2,0 % | Pigment P.B.15:4 | 1,1 % | Pigment P.R.57:1 | 2,1 % | Pigment P.Y.13 | 2,2 % | Pigment P.Bk.7   | 1,0 % | NC (phlegmatized) | 21,0 % | Wax     | 0,4 %  | adhesion promoter  | 1,5 %        | Solvent | 63,3 %           | <table><tbody><tr><td>polymeric plasticizer</td><td>5,4 %</td></tr><tr><td>monomeric plasticizer</td><td>2,0 %</td></tr><tr><td>Pigment P.B.15:4</td><td>1,1 %</td></tr><tr><td>Pigment P.R.122</td><td>2,1 %</td></tr><tr><td>Pigment P.Y.185</td><td>2,0 %</td></tr><tr><td>Pigment P.Bk.7</td><td>1,0 %</td></tr><tr><td>NC (phlegmatized)</td><td>21,1 %</td></tr><tr><td>Wax</td><td>0,4 %</td></tr><tr><td>Adhesion promoter</td><td>1,5 %</td></tr><tr><td>Solvent</td><td>63,4 %</td></tr></tbody></table> | polymeric plasticizer | 5,4 % | monomeric plasticizer | 2,0 % | Pigment P.B.15:4 | 1,1 % | Pigment P.R.122  | 2,1 % | Pigment P.Y.185 | 2,0 % | Pigment P.Bk.7 | 1,0 %  | NC (phlegmatized) | 21,1 % | Wax | 0,4 % | Adhesion promoter | 1,5 % | Solvent | 63,4 % |
| polymeric plasticizer                                 | 5,4 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| monomeric plasticizer                                 | 2,0 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.B.15:4                                      | 1,1 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.R.57:1                                      | 2,1 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.Y.13  | 2,2 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.Bk.7  | 1,0 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| NC (phlegmatized)                                     | 21,0 %   |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Wax   | 0,4 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| adhesion promoter                                     | 1,5 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Solvent   | 63,3 %   |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| polymeric plasticizer                                 | 5,4 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| monomeric plasticizer                                 | 2,0 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.B.15:4                                      | 1,1 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.R.122                                       | 2,1 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.Y.185                                       | 2,0 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.Bk.7  | 1,0 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| NC (phlegmatized)                                     | 21,1 %   |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Wax   | 0,4 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Adhesion promoter                                     | 1,5 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Solvent   | 63,4 %   |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| <b>polyurethane (PU)</b><br>Neorez U-475              | <table><tbody><tr><td>aliphatic PU</td><td>29,5 %</td></tr><tr><td>Pigment P.B.15:4</td><td>1,0 %</td></tr><tr><td>Pigment P.R.57:1</td><td>1,9 %</td></tr><tr><td>Pigment P.Y.13</td><td>1,9 %</td></tr><tr><td>Pigment P.Bk.7</td><td>1,0 %</td></tr><tr><td>Inorganic filler</td><td>2,7 %</td></tr><tr><td>Wax</td><td>0,2 %</td></tr><tr><td>Solvent</td><td>61,9 %</td></tr></tbody></table>   | aliphatic PU                | 29,5 % | Pigment P.B.15:4      | 1,0 % | Pigment P.R.57:1 | 1,9 % | Pigment P.Y.13   | 1,9 % | Pigment P.Bk.7 | 1,0 % | Inorganic filler | 2,7 % | Wax               | 0,2 %  | Solvent | 61,9 % | <table><tbody><tr><td>aliphatic PU</td><td>28,9 %</td></tr><tr><td>Pigment P.B.15:4</td><td>1,0 %</td></tr><tr><td>Pigment P.R.122</td><td>1,9 %</td></tr><tr><td>Pigment P.Y.185</td><td>1,9 %</td></tr><tr><td>Pigment P.Bk.7</td><td>1,0 %</td></tr><tr><td>Inorganic filler</td><td>2,7 %</td></tr><tr><td>Wax</td><td>0,2 %</td></tr><tr><td>Solvent</td><td>62,4 %</td></tr></tbody></table> | aliphatic PU | 28,9 %  | Pigment P.B.15:4 | 1,0 %  | Pigment P.R.122       | 1,9 % | Pigment P.Y.185       | 1,9 % | Pigment P.Bk.7   | 1,0 % | Inorganic filler | 2,7 % | Wax             | 0,2 % | Solvent        | 62,4 % |                   |        |     |       |                   |       |         |        |
| aliphatic PU  | 29,5 %   |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.B.15:4                                      | 1,0 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.R.57:1                                      | 1,9 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.Y.13  | 1,9 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.Bk.7  | 1,0 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Inorganic filler                                      | 2,7 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Wax   | 0,2 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Solvent   | 61,9 %   |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| aliphatic PU  | 28,9 %   |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.B.15:4                                      | 1,0 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.R.122                                       | 1,9 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.Y.185                                       | 1,9 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Pigment P.Bk.7  | 1,0 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Inorganic filler                                      | 2,7 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Wax   | 0,2 %  |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |
| Solvent   | 62,4 %   |                             |        |                       |       |                  |       |                  |       |                |       |                  |       |                   |        |         |        |  |              |         |                  |  |                       |       |                       |       |                  |       |                  |       |                 |       |                |        |                   |        |     |       |                   |       |         |        |

\* PW6 not included as considered as thermally stable, in so far „worst case“ using only colored pigments with a high percentage in total formulation

# RecyClass | PRINTING INKS TEST CAMPAIGN

## Next Steps

Production of PE film (Control and Printed films)



Printing of PE film samples



Recycling of printed films (Extrusion)



Production of new films from pellets

Characterization of pellets (DSC, TGA, GC-MS)

Mechanical Characterization of films

Visual Characterization of films

Characterization of films (DSC, TGA, GC-MS)



# RecyClass | PRINTING INKS - EXTRUSION

## General Observations

- ❑ For **NC-binders**:

- ❑ Without pigments: **Sever degradation** within seconds in the extruder
  - ❑ With pigments: Extrudable but some clogging observed for 5wt% of inks



- ❑ For **PU-binders**:

- ❑ Without pigments: Possible to extrude with a very slow process due to clumping and high statics
  - ❑ With pigments: **Impossible to extrude** because flakes are too light and do no flow in the feeder

- ❑ Other observations:



- ❑ Some samples showed a **strong odour**
  - ❑ Samples with HP pigments seems to be easier to extrude than the one with standard pigments
  - ❑ Deinked samples could be extruded and led to pale green pellets

# RecyClass | PRINTING INKS TEST CAMPAIGN

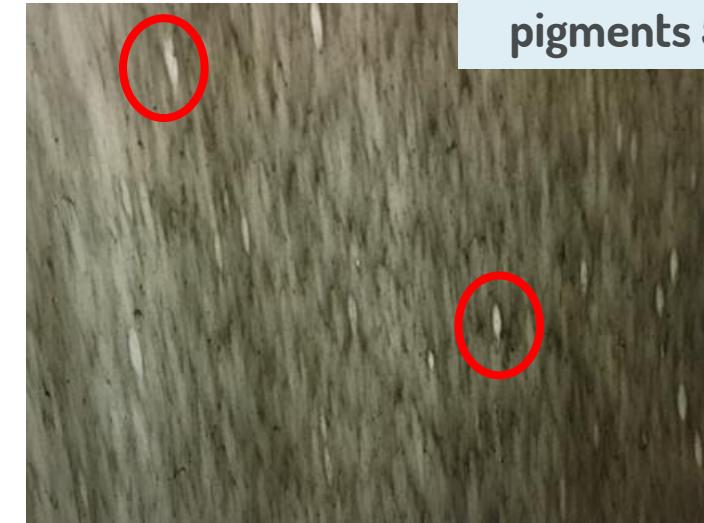
## Visual inspection: pellets & films



**NC-binder 0.7 gsm**  
(ID8)



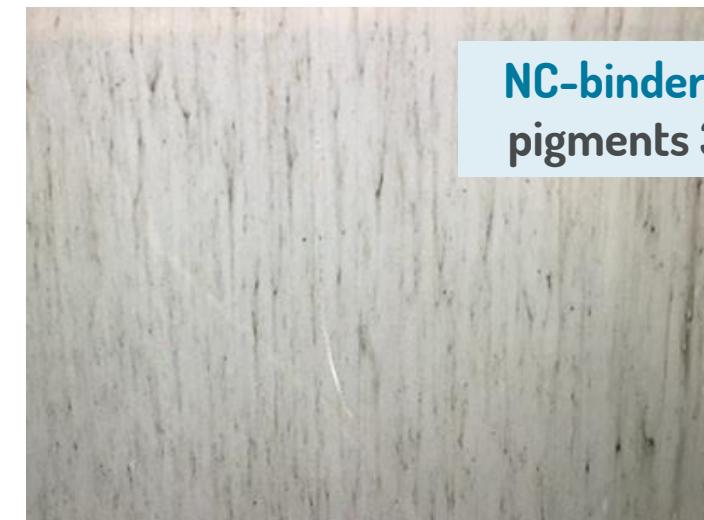
**NC-binder + standard  
pigments 3 & 5 gsm**  
(ID2 and 6)



**NC-binder + standard  
pigments 5 gsm (ID2)**



Gels,  
holes,  
fisheyes

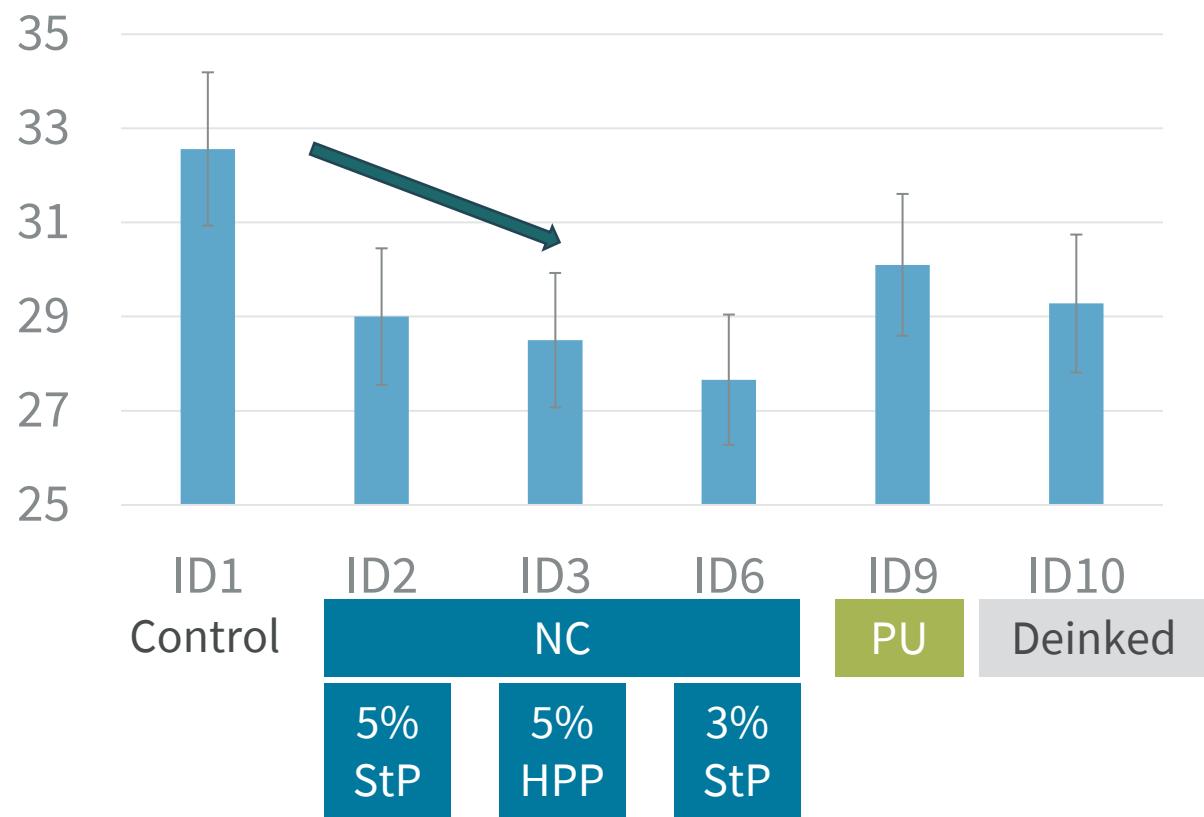


**NC-binder + standard  
pigments 3 gsm (ID6)**

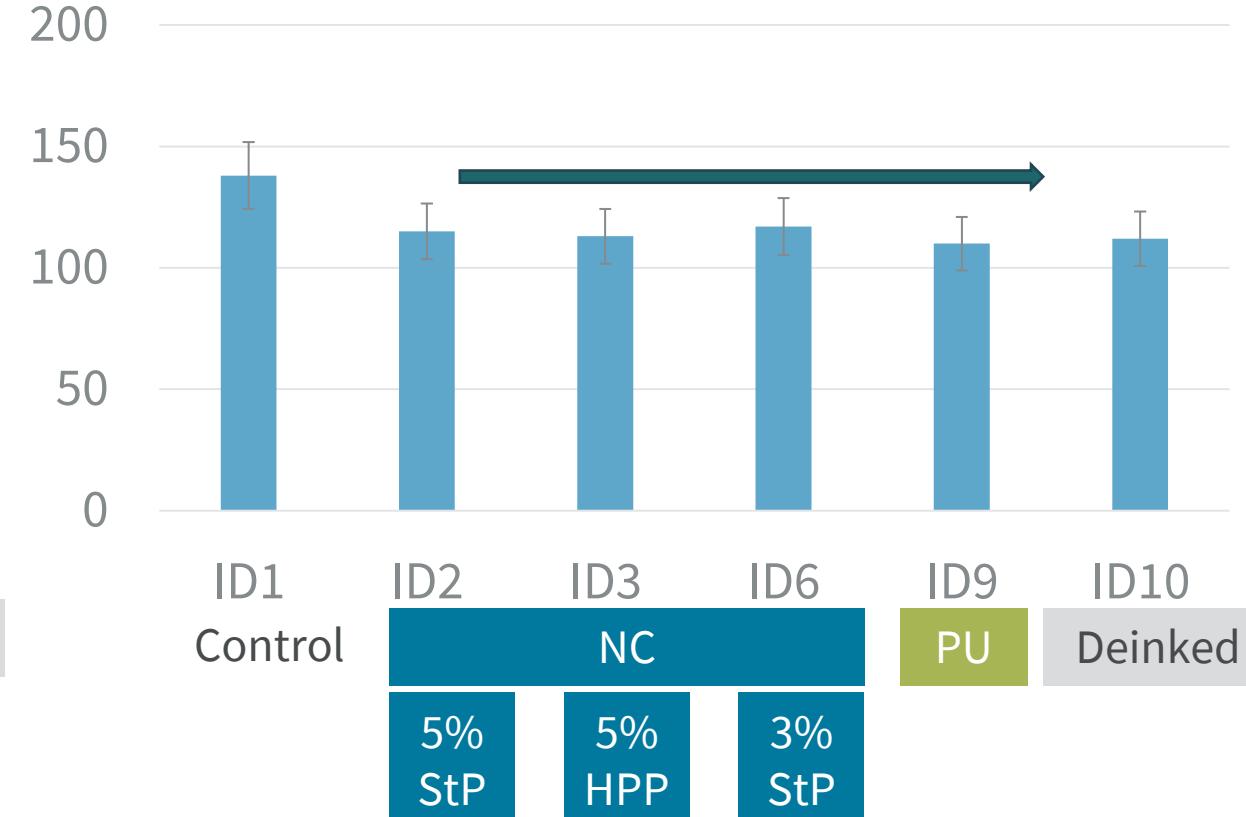
# RecyClass | PRINTING INKS TEST CAMPAIGN

## Mechanical characterization

Stress at Max Load MD (MPa)



Elongation MD (%)



# RecyClass | PRINTING INKS TEST CAMPAIGN

## Mechanical characterization



### Thermal characterization

| Sample       | DSC         |
|--------------|-------------|
|              | Tm1 (°C)    |
| ID1 Pellets  | 112,5 ± 0,2 |
| ID1 Film     | 112 ± < 1   |
| ID2 Pellets  | 111,7 ± 0,1 |
| ID2 Film     | 111 ± < 1   |
| ID3 Pellets  | 111,2 ± 0,1 |
| ID3 Film     | 111 ± < 1   |
| ID4 Film     | 111 ± < 1   |
| ID5 Pellets  | 111,6 ± 0,1 |
| ID5 Film     | 111 ± < 1   |
| ID6 Pellets  | 111,7 ± 0,4 |
| ID6 Film     | 111 ± < 1   |
| ID7 Pellets  | 111 ± < 1   |
| ID7 Film     | 111 ± < 1   |
| ID8 Strand   | 110,8 ± 0,1 |
| ID9 Pellets  | 111,4 ± 0,1 |
| ID9 Film     | 111,9 ± 0,1 |
| ID10 Pellets | 111,8 ± 0,1 |
| ID10 Film    | 111,8 ± 0,2 |

### TGA

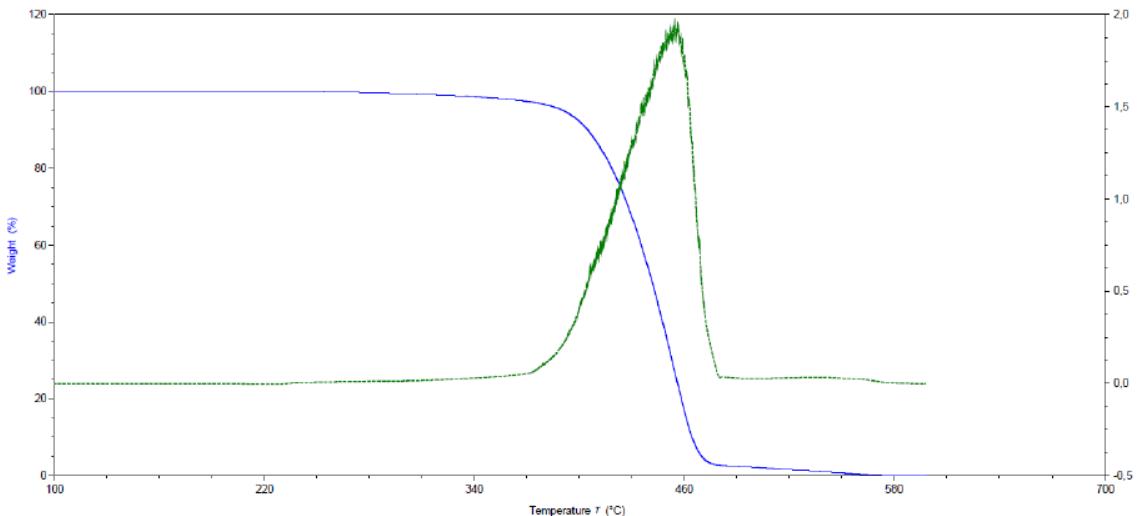


Figure 40.

“Nitrocellulose (NC) is the most commonly used binder resin for flexible plastic packaging printing inks due to its low price and high gloss [44]. However, **NC is vulnerable to thermal degradation starting at 160–185 °C, producing CO<sub>2</sub> and NO<sub>2</sub>, resulting in a brownish color, porosity, and odor in the recyclates** [45,46,47,48,49]. Additionally, some organic pigments were also reported to be thermally unstable under mechanical recycling processes, such as pigment PR 146 and pigment PY 13 [50].”

# RecyClass | VOLATILES

## Control material (PE)

Table 2

| Retention time (min) | Compound (name)  | Compound (CAS No.) | Concentration (mg/kg) |
|----------------------|--|--------------------|-----------------------|
| 3.00                 | Nonane   | 111-84-2           | 0.04                  |
| 3.92                 | Decane, 2,2-dimethyl-                                      | 17302-37-3         | 0.85                  |
| 4.65                 | Decane   | 124-18-5           | 0.86                  |
| 4.87                 | Sulfurous acid, 2-ethylpentadecyl ester                    | -                  | 0.03                  |
| 4.98                 | 2H-Pyran, 2-(2-heptadecyloxy)tetrahydro-                   | 69502-96-1         | 0.11                  |
| 5.50                 | Decane, 2,5,6-trimethyl-                                   | 62108-23-0         | <LOQ                  |
| 6.01                 | Heptadecane, 9-hexyl-                                      | 55124-79-3         | <LOQ                  |
| 6.21                 | 4-Octadecenal  | 56554-98-4         | 0.16                  |
| 6.73                 | Undecane   | 1120-21-4          | 1.02                  |
| 7.11                 | Oxalic acid, cyclohexylmethyl decyl ester                  | -                  | 0.15                  |
| 7.82                 | 1-Hexadecanol, 2-methyl-                                   | 2490-48-4          | 0.37                  |
| 8.20                 | 9-methylheptadecane  | 26741-18-4         | 0.07                  |
| 8.44                 | Cyclohexane, 1,1'(1,5-pentanediyl)bis-                     | 54833-31-7         | 0.02                  |
| 8.76                 | 1-Methylbicyclo[4.4.0]decano(trans)                        | -                  | 0.12                  |
| 8.91                 | Dodecane   | 112-40-3           | 0.83                  |
| 9.05                 | Phytol   | 150-86-7           | <LOQ                  |
| 9.15                 | 2-Butyloxycarbonyloxy-1,1,10-trimethyl-6,9-epidioxydecalin | 108533-24-0        | <LOQ                  |
| 9.29                 | trans-4a-Methyl-decahydronaphthalene                       | 2547-27-5          | 0.42                  |
| 11.02                | Tetradecane  | 629-59-4           | 0.07                  |
| 13.95                | Acetic acid  | 64-19-7            | 0.23                  |

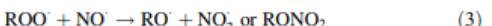
At first, after the ambient temperature reaching around 90 °C, a small part of NO<sub>2</sub> depolymerizes from the O-NO<sub>2</sub> bond, as shown in Eq. (1) [2]:



Afterward, the autocatalytic reaction promotes the formation of peroxy groups according to Eq. (2) [21],



It is known from the previous study [25] that the reverse reaction also exists at this time, i.e.,



Katoh et al. [26] assumed the following reactions, taking O<sub>2</sub> into consideration:



## Sample #2 (NC/St.Pig. 5wt%)

Table 4

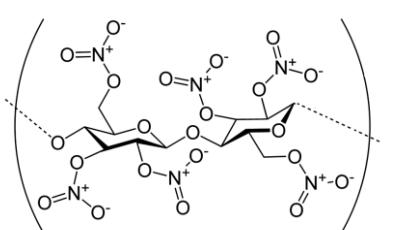
| Retention time (min) | Compound (name)                | Compound (CAS No.) | Concentration (mg/kg) |
|----------------------|--------------------------------|--------------------|-----------------------|
| 2.08                 | Propanal                       | 123-38-6           | 0.37                  |
| 2.44                 | 2-Propenal                     | 107-02-8           | <LOQ                  |
| 2.72                 | Butanal                        | 123-72-8           | 0.75                  |
| 2.99                 | Methyl Alcohol                 | 67-56-1            | 0.21                  |
| 3.48                 | Isopropyl Alcohol              | 67-63-0            | 0.19                  |
| 3.92                 | Heptane, 2,2,4,6,6-pentamethyl | 13475-82-6         | 0.56                  |
| 4.17                 | 2,3-Butanedione                | 431-03-8           | 0.26                  |
| 4.65                 | Decane                         | 124-18-5           | 0.76                  |
| 4.87                 | Dodecane, 2,6,10-trimethyl     | 3891-98-3          | 0.07                  |
| 4.99                 | Hydrogen cyanide               | 74-90-8            | 2.35                  |
| 5.32                 | Benzene, (3-octylundecyl)-     | 5637-96-7          | 0.12                  |
| 6.71                 | Undecane                       | 1120-21-4          | 0.64                  |
| 7.71                 | 1-Butanol                      | 71-36-3            | 1.45                  |
| 8.15                 | 2-Propanol, 1-ethoxy-          | 1569-02-4          | 0.60                  |
| 8.92                 | Dodecane                       | 112-40-3           | 0.23                  |
| 10.86                | 2-Propanone, 1-hydroxy-        | 116-09-6           | 0.35                  |
| 12.25                | Glycolaldehyde dimer           | 23147-58-2         | 0.01                  |
| 13.91                | Acetic acid                    | 64-19-7            | 24.86                 |
| 14.05                | 3-Furaldehyde                  | 498-60-2           | 2.23                  |
| 14.85                | 1,2-Propanediol, 1-acetate     | 627-69-0           | 0.59                  |
| 15.21                | Formic acid                    | 64-18-6            | 40.72                 |
| 15.94                | Propanamide, 2-hydroxy-        | 2043-43-8          | 2.23                  |
| 16.07                | Propanoic acid, 2-methyl-      | 156564-41-9        | 2.97                  |
| 16.11                | 2,6-Dimethylphenyl isocyanate  | 28556-81-2         | 1.27                  |
| 16.45                | R-(+)-1,2-propanediol          | 4254-14-2          | 0.11                  |
| 17.11                | Butanoic acid                  | 107-92-6           | <LOQ                  |
| 17.41                | Silanediol, dimethyl-          | 1066-42-8          | 0.27                  |
| 17.56                | 2-Propenoic acid               | 79-10-7            | 0.21                  |
| 19.36                | 2(5H)-Furanone                 | 497-23-4           | 0.91                  |
| 19.45                | N,N-dimethylacetamide          | 127-19-5           | 0.56                  |
| 20.14                | Formamide                      | 75-12-7            | 0.10                  |
| 22.18                | Hexanoic acid                  | 142-62-1           | 0.51                  |
| 23.14                | 1-Propanol, 2,2'-oxybis-       | 108-61-2           | 0.70                  |
| 23.31                | 1-Propanol, 3,3'-oxybis-       | 2396-61-4          | 0.97                  |
| 24.83                | Levoglucosanone                | 37112-31-5         | 0.24                  |

## Sample #6 (NC/St.Pig. 3wt%)

Table 6

| Retention time (min) | Compound (name)                        | Compound (CAS No.) | Concentration (mg/kg) |
|----------------------|--|--------------------|-----------------------|
| 2.08                 | Propanal                               | 123-38-6           | 0.21                  |
| 2.44                 | 2-Propenal                             | 107-02-8           | <LOQ                  |
| 2.72                 | Butanal                                | 123-72-8           | 0.33                  |
| 3.00                 | Methyl Alcohol                         | 67-56-1            | 0.13                  |
| 3.93                 | 2,2,7,7-Tetramethyloctane              | 1071-31-4          | 0.35                  |
| 4.18                 | 2,3-Butanedione                        | 431-03-8           | 0.11                  |
| 4.38                 | Decane, 2,6,7-trimethyl-               | 62108-25-2         | 0.01                  |
| 4.66                 | Decane                                 | 124-18-5           | 1.36                  |
| 4.77                 | Octadecane, 3-ethyl-5-(2-ethylbutyl)-  | 55282-12-7         | <LOQ                  |
| 4.87                 | Decane, 2,6,7-trimethyl-               | 62108-25-2         | 0.25                  |
| 4.99                 | Hydrogen cyanide                       | 74-90-8            | 1.71                  |
| 5.33                 | Benzeneacetic acid, 2-tetradecyl ester | -                  | 0.54                  |
| 6.72                 | Undecane                               | 1120-21-4          | 1.03                  |
| 7.72                 | 1-Butanol                              | 71-36-3            | 1.07                  |
| 7.83                 | 1-Hexadecanol, 2-methyl-               | 2490-48-4          | <LOQ                  |
| 8.15                 | 2-Propanol, 1-ethoxy-                  | 1569-02-4          | 0.21                  |
| 8.92                 | Dodecane                               | 112-40-3           | 0.23                  |
| 10.85                | 2-Propanone, 1-hydroxy-                | 116-09-6           | 0.17                  |
| 12.24                | Glycolaldehyde dimer                   | 23147-58-2         | 0.05                  |
| 13.90                | Acetic acid                            | 64-19-7            | 16.15                 |
| 14.04                | Furfural                               | 98-01-1            | 0.88                  |
| 14.83                | 1,2-Propanediol, 1-acetate             | 627-69-0           | 0.32                  |
| 15.33                | Formic acid                            | 64-18-6            | 32.20                 |
| 16.06                | Propanoic acid, 2-methyl-              | 156564-41-9        | 1.72                  |
| 16.44                | (S)-(+)-1,2-Propanediol                | 4254-15-3          | 1.29                  |
| 17.10                | Butanoic acid                          | 107-92-6           | 0.07                  |
| 17.55                | 2-Propenoic acid                       | 79-10-7            | 0.41                  |
| 19.34                | 2(5H)-Furanone                         | 497-23-4           | 0.02                  |
| 19.42                | 1,1-Ethanediol, diacetate              | 542-10-9           | 0.57                  |
| 19.66                | Acetamide                              | 60-35-5            | 0.10                  |
| 20.11                | Formamide                              | 75-12-7            | 0.78                  |
| 23.12                | 1-Propanol, 3,3'-oxybis-               | 2396-61-4          | 0.40                  |
| 23.29                | 1-Propanol, 2-(2-hydroxyprooxy)-       | 106-62-7           | 0.55                  |
| 24.83                | Levoglucosanone                        | 37112-31-5         | 0.84                  |

## Nitrocellulose structure



# RecyClass | VOLATILES

| ID | Description          | Coating weight     | Substance identification (in mg/kg or ppm) |              |                  |          |           |              |              |                           |
|----|----------------------|--------------------|--|--------------|------------------|----------|-----------|--------------|--------------|---------------------------|
|    |                      |                    | Butanal                                    | Decane       | Hydrogen cyanide | Undecane | 1-Butanol | Acetic Acid  | Formic Acid  | Propanoic acid, 2-methyl- |
| 1  | Unprinted PE         | n.a.               |  | 0.86         |                  | 1.02     |           | 0.23         |              |                           |
| 2  | NC/standard pigments | 5%                 | 0.75                                       | 0.76         | 2.35             | 0.64     | 1.45      | <b>24.86</b> | <b>40.72</b> | 2.97                      |
| 3  | NC/HPP               | 5%                 | 3.13                                       | <b>11.9</b>  | 6.92             | 6.28     | 3.81      | <b>15.98</b> |              | 6.78                      |
| 4  | PU/standard pigments | 5%                 |  |              |                  |          |           |              |              |                           |
| 5  | PU/HPP               | 5%                 |  | <b>11.36</b> |                  | 8.89     |           |              |              |                           |
| 6  | NC/standard pigments | 3%                 | 0.33                                       | 1.36         | 1.71             | 1.03     | 1.07      | <b>16.15</b> | <b>32.2</b>  | 1.72                      |
| 7  | PU/HPP               | 7%                 | 7.98                                       |              |                  |          |           |              |              |                           |
| 8  | NC-binder            | 1.25%              | 1.93                                       |              |                  |          |           |              |              |                           |
| 9  | PU-binder            | 1.25%              |  | 7.6          |                  | 5.27     |           | 6.4          |              |                           |
| 10 | Deinked sample 6     | 3% before deinking |  | 8.33         |                  | 4.18     |           |              |              |                           |

Probably related to HPP and/or PU



Probably related to the presence of Nitrocellulose



Probably related to standard pigments

Too low concentrations

# RecyClass CONCLUSIONS – 1st STUDY

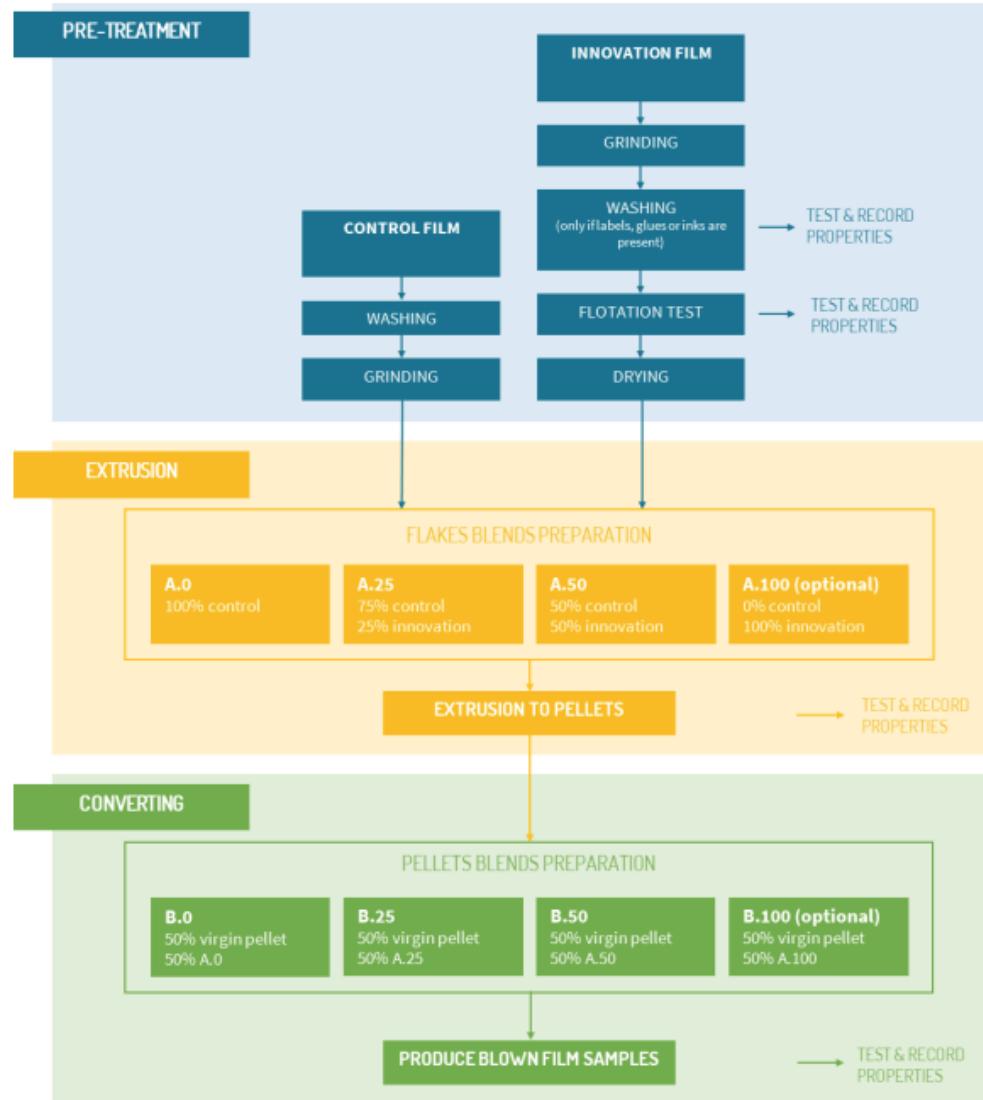
## RECYCLASS CONCLUSIONS

- NC based inks **more detrimental than PU** due to low thermal stability
- **Confirmation of results** obtained by PrintCyc
- **High amount of specific volatiles** for NC based inks compared to PU
- Difficult to evaluate the impact on mechanical properties
- A **threshold between 3 and 5% of inks** was visible for the formation of fisheyes

## COMMENTS

- **To be confirmed with standard procedures** for testing
- What about **NC/PU combinations?**

# RecyClass | STANDARD RECYCLASS TEST



## 3 Samples to be tested:

- Full PU binder
- PU/NC (30/70) combination
- PU/NC (70/30) combination

Full PE as control material, same material to be used for the printing

**Representative of a 5wt% full ink coverage**

Transparent PU/NC varnish  
White PU Ink  
PE Film

# RecyClass



## Printing Inks in Flexible PP Packaging

–  
New PrintCYC project

10% PCR  
in all packaging by  
2030

Do you ever want to reuse  
recycled resins from printed  
packaging films?

Resin quality sufficient for  
closed loop scenarios?



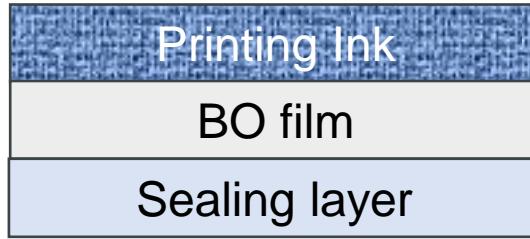
# Nominate the technical targets

Outlook

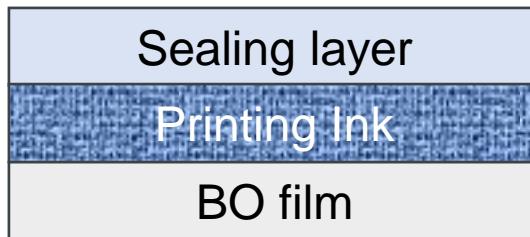
## *Inks – recycling compatible today?*

### Printing options

Surface printing



Interlayer printing



### Offerings Inks

**Circular use of inked waste requires new print solutions:**

**1** **Washability** of inks before regranulation  
→ Uncoloured resins

**2** **Heat resistance** of components, binders / pigments  
→ Coloured resins



### Resin requirements

**Resin quality level:**

**No contamination**

Contamination

**Uncoloured**

Coloured

**Defect-free**

Defects



**Cost comparable** to virgin

Cost higher than virgin

*Of interest: Printing of ink systems – Washing / Deinkability of packaging films – Resin quality*

# Scope of action

Deinkability

## Use cases

### Collaboration partners:

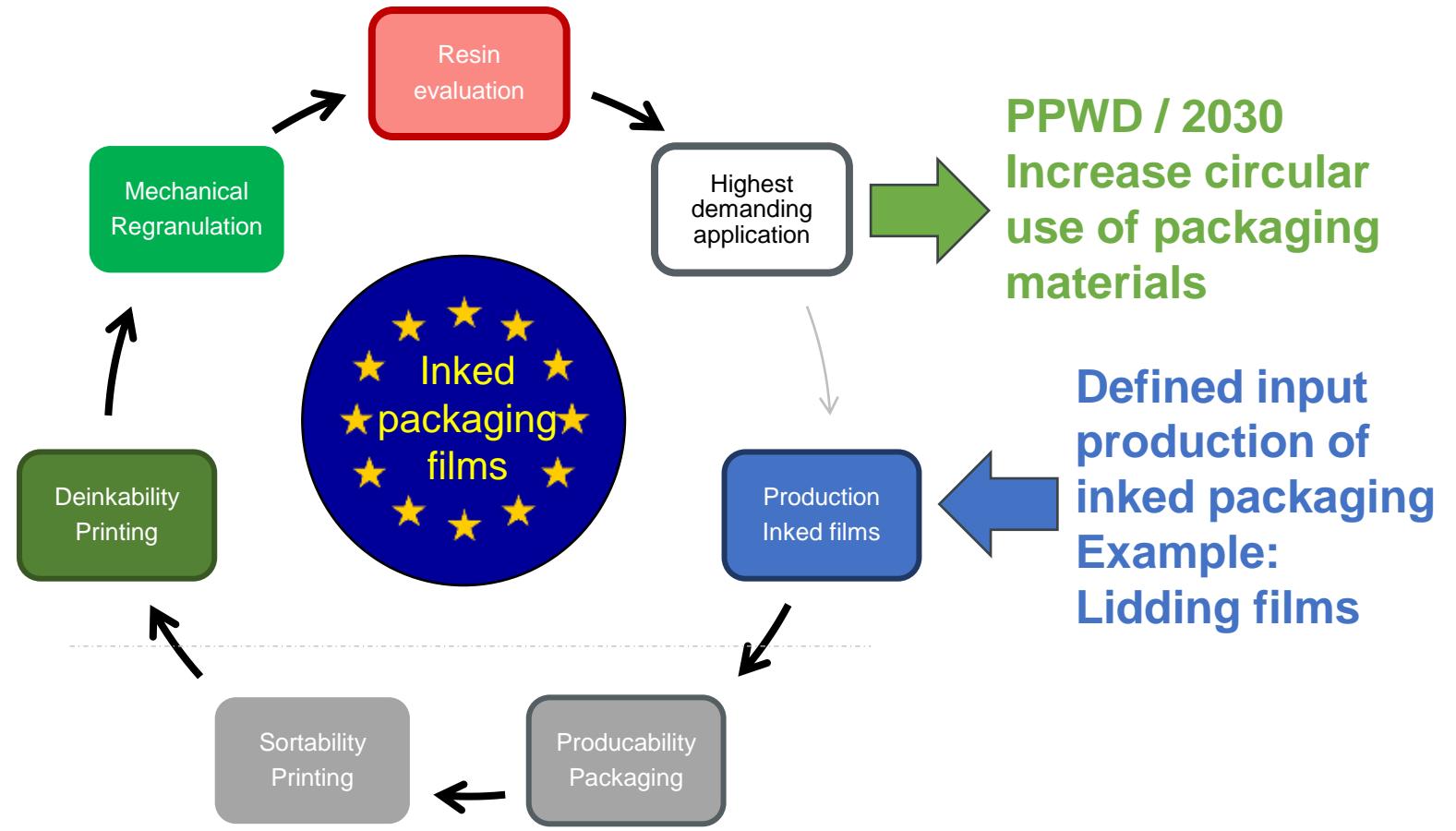
- ✓ HuberGroup
- ✓ Siegwerk
- ✓ Taghleef
- ✓ Südpack
- ✓ Prezero
- ✓ InnoPlastics

### Coordination and Sustainability:

Akk innovation

### Cooperation services:

- Pacoon / PrintDesign
- Realcycle / Sortability
- Interzero / Sortability
- Sqts / Resin tests
- N.N. / Ecofootprint
- Universities
- Platform centers



### Guidance

#### Circular use of printing inks :

#### What's short term / long term realizable?

##### Directive 94/62/EC (PPWD)

By 2030

Inked plastic packaging to be recyclable, reusable or compostable

##### *Inks / Printing recyclable today?*

Guidance product printing

10% PCR in contact packaging

30% PCR in other packaging

##### *Resins from inked packaging waste - quantity, safety sufficient?*

Guidance safety for circularity

Increase the mechanical recycling quota to 55% for plastic packaging.

##### *Linked films incinerated today – cleaned & recycled tomorrow?*

Guidance new technologies

2023

**Recycler**  
Sorting  
Washing  
cold  
Quality  
Ecofootprint

2025

**Recycler**  
Sorting  
Washing  
hot / deinking  
Quality  
Ecofootprint

2030

**Recycler**  
Sorting  
Washing  
others  
Quality  
Ecofootprint

Guidance by Commission – Recyclable – Ceflex – Cradle-to-cradle

**Brandowner**  
Inks  
Printing  
Packaging  
Safety

**Brandowner**  
Inks  
Printing  
Packaging  
Safety

**Brandowner**  
Inks  
Printing  
Packaging  
Safety



# Interested? Let's collaborate!

Together for  
circular & sustainable  
plastic packaging

**Responsible for future**

[www.akk-innovation.de](http://www.akk-innovation.de)  
Contact to: [annett.kaeding@akk-innovation.de](mailto:annett.kaeding@akk-innovation.de)



# KEY TAKEAWAYS

- ✓ Printing Inks are **complex elements** present on most plastic packaging.
- ✓ **Inks**, due to their **binders and pigments**, can have a **significant negative impact on recyclability**.
- ✓ **Polyurethane (PU)** inks are **more thermally stable** than Nitrocellulose (NC).
- ✓ **NC inks** lead to **degradation** during recycling, with volatiles release.
- ✓ **De-inking is not implemented at scale** in European recycling plants.
- ✓ By end of 2023, RecyClass will deliver **new recommendations on compatibility of NC based inks with films recycling**.

# RecyClass

## Questions & Answers

Use the Q&A box in the top-right corner of your screen

# RecyClass



## Thank you for participating!

Sign up for the next session  
**26 October 2023**

[RecyClass.eu/events](https://RecyClass.eu/events)