

# RecyClass



## Science behind Recyclability

Barrier Technologies used in Plastic Packaging

16 January 2023

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# RecyClass

A stylized, light teal graphic on a dark teal background. It features a chemical structure on the left, consisting of two fused hexagons with internal lines representing bonds. To the right of the chemical structure is a large Erlenmeyer flask, also in a light teal outline, containing a wavy line representing liquid. The overall theme is scientific and related to chemistry or materials science.

## RecyClass Test Campaigns

RecyClass Science behind Recyclability, 16 January 2023

# 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.

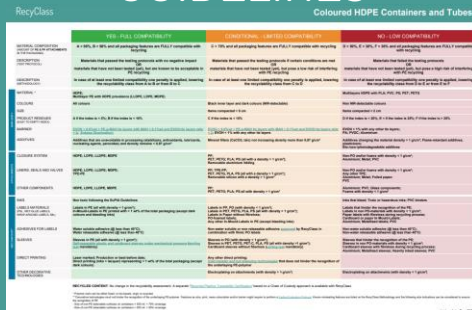
## Why does RecyClass perform test campaigns?

- 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



The image shows a thumbnail of the 'Design for Recycling Guidelines' table. It is a complex table with multiple columns and rows, detailing various packaging features and their corresponding recyclability status. The table is color-coded with green, yellow, and red headers.

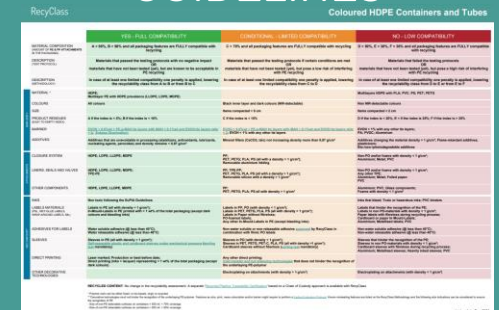
MISSING FEATURE !

## TEST CAMPAIGN



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

## DESIGN FOR RECYCLING GUIDELINES



The image shows a thumbnail of the updated 'Design for Recycling Guidelines' table. It is a complex table with multiple columns and rows, detailing various packaging features and their corresponding recyclability status. The table is color-coded with green, yellow, and red headers.

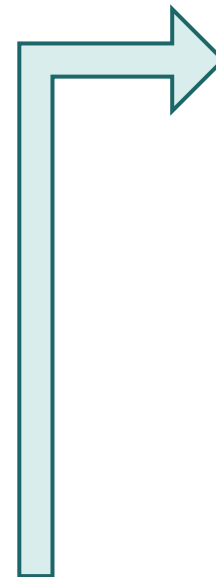
FACT-BASED INFORMATION ✓

# RecyClass | Test Campaigns: Process

	YES - FULL COMPATIBILITY	CONDITIONAL - LIMITED COMPATIBILITY	NO - LOW COMPATIBILITY
MATERIAL COMPOSITION (TOTAL AMOUNT OF PE & AMOUNT OF PP ATTACHMENTS IN THE PACKAGING)	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
DESCRIPTION (TEST PROTOCOL)	Materials that passed the testing protocols with no negative impact OR 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
DESCRIPTION (METHODOLOGY)	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
MATERIAL (METHODOLOGY)	D, PE-LD, PE-HD	Multilayer PE/PP with PP < 5%	Multilayer PE/PP with PP > 5%; Any other polymer (e.g. PET, PVC, etc.)
COLOURS	Light colours; translucent colours	NIR-detectable dark colours (Sorting test)	Non NIR-detectable dark colours
SIZE	> A4 or > 50 x 50 mm once compacted	< A4 format or between 20 x 20 and 50 x 50 mm once compacted (Sorting test)	< 20 x 20 mm
PRODUCT RESIDUES (EASY TO EMPTY INDEX)	A if the index is < 5%; B if the index is < 10%	C if the index is < 15%	D if the index is < 20%; E if the index is < 25%; F if the index is > 25%
BARRIER	Barrier in the polymer matrix; and ADO without additional coatings	< 5% EVOH (in polyolefin combination film); metallized layers without coatings; barrier layer PVC, PVDC; any other barrier layer; foaming agents used as expanding chemical agents; aluminium	> 5% EVOH (in polyolefin combination film); Any other PA; barrier layer PVC, PVDC; any other barrier layer; foaming agents used as expanding chemical agents; aluminium
ADDITIVES	Additives that do not increase the density higher than 0,97 g/cm³	Bi-/oxo-/photodegradable additives; Additives that do increase the density higher than 0,97 g/cm³ (CaCO3, talc, glass fibers, etc.)	Bi-/oxo-/photodegradable additives; Additives that do increase the density higher than 0,97 g/cm³ (CaCO3, talc, glass fibers, etc.)
CLOSURE SYSTEM LINERS, SEALS AND VALVES	D, PE-LD, PE-HD	PP	Metal, aluminium, PVC, PET, PETG, PS, PLA, non PO or foams with density < 1 g/cm³
OTHER COMPONENTS	D, PE-LD, PE-HD	PP, removable aluminium lidding	Metal, aluminium, PVC, PET, PETG, PS, PLA, foiled paper, non PO or foams with density < 1 g/cm³
RISKS	D, PE-LD, PE-HD	PP	Metal, aluminium, PVC, PET, PETG, PS, PLA, paper, foams with density < 1 g/cm³
LABELS	Non-bleeding inks compliant with EuPIA Exclusion Policy	Inks that bleed; Inks non-compliant with EuPIA Exclusion Policy	Inks that bleed; Inks non-compliant with EuPIA Exclusion Policy
ADHESIVES FOR LABELS	Water soluble or water-releasable at less than 60°C	PP, paper labels without fibrous	Metallized labels, any other: paper labels with fibrous
DIRECT PRINTING	Laser marked print; Printed production or expiry date; printing covering < 50%**	Printing covering > 50%**	Adhesives non-soluble in water or non-releasable in water at less than 60°C

RECYCLED CONTENT: No change in the recyclability assessment. A separate 'Recycled Plastic Traceability Certification' based on a Chain of Custody approach is available with RecyClass  
 \*\* Temporary solution

Last update: June 2021



REPORT AST-22-079-part1-EN/2  
AST-22-079

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BELGIUM

PETITIONER:  
Fabrice Di Gregorio

SUBJECT  
Recyclability study of LDPE laminated films

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## Laboratory results reviewed within RecyClass TC

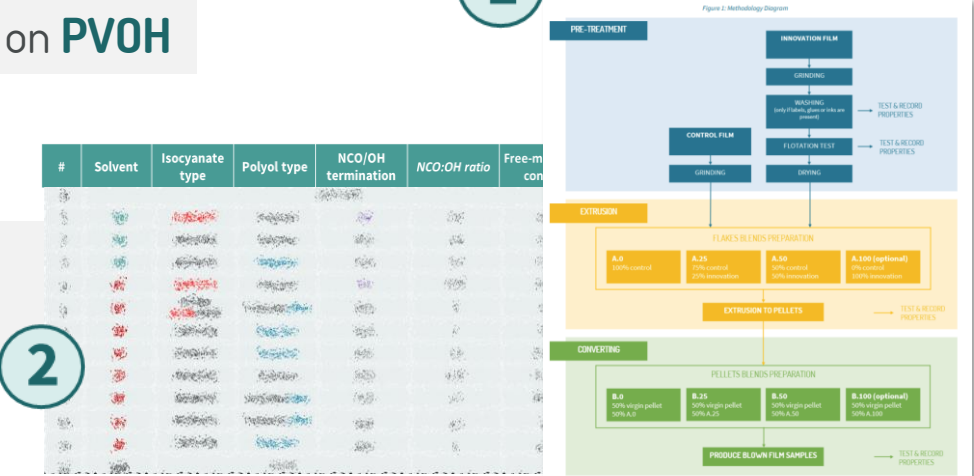
4

## DfR Guidelines updated with findings of the test campaign

Ex: No information on **PVOH**



RecyClass TC defines the scope of the **test campaign**



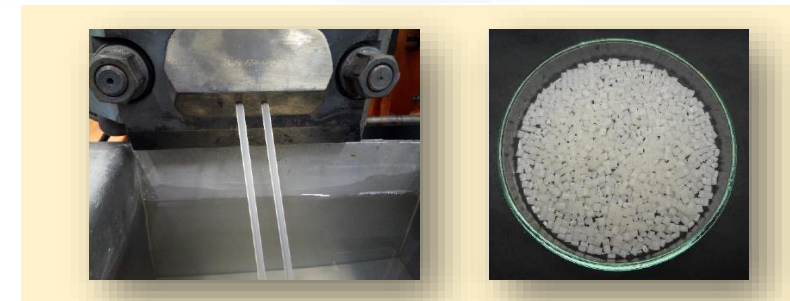
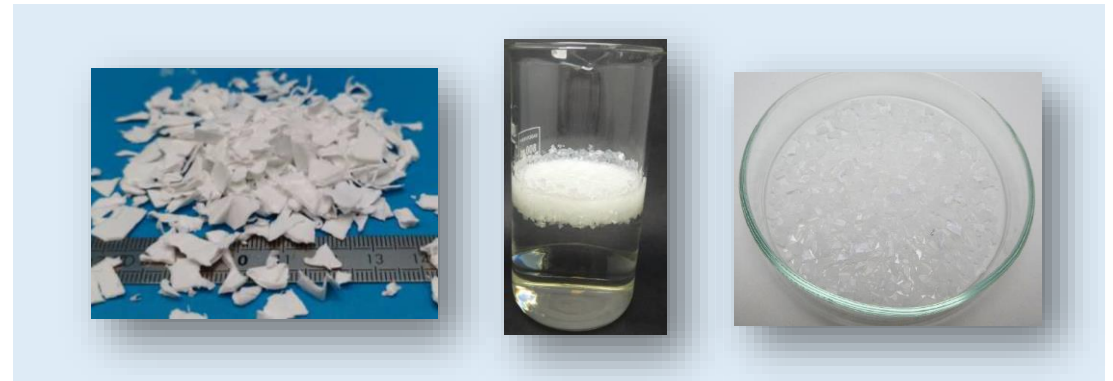
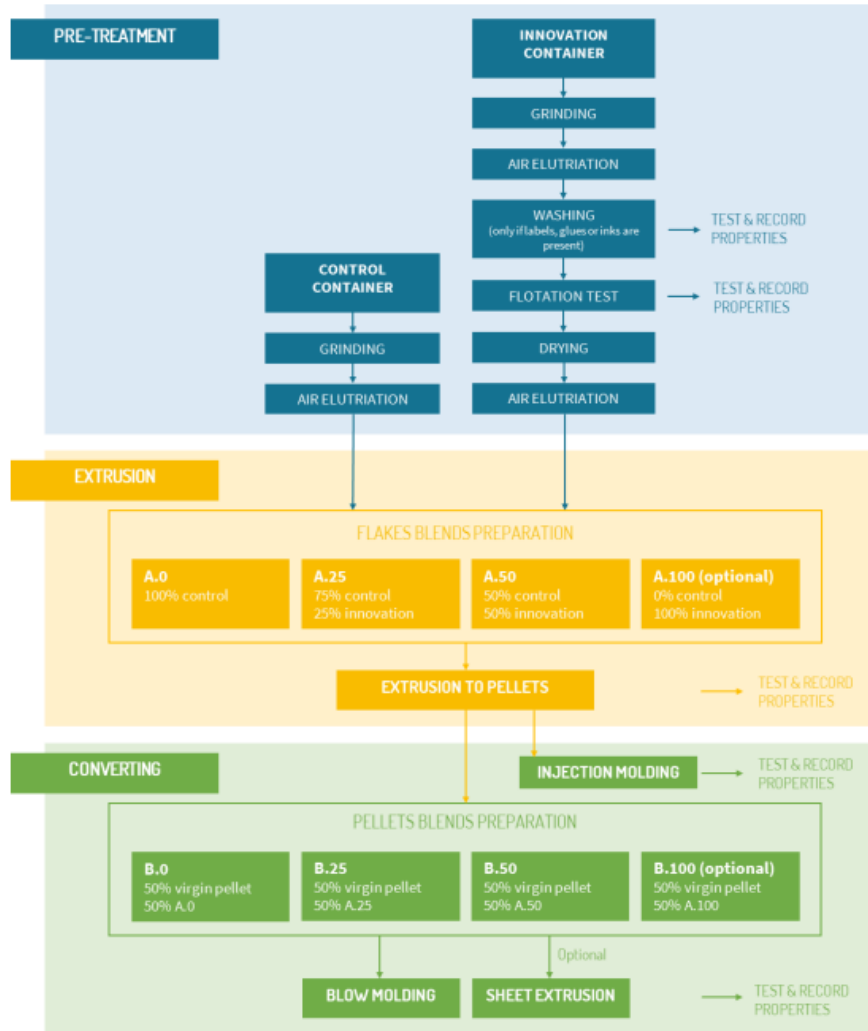
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DIRECT PRINTING			

RECYCLED CONTENT: No change in the recyclability assessment. A separate 'Recycled Plastic Traceability Certification' based on a Chain of Custody approach is available with RecyClass  
 \*\* Temporary solution

Last update: June 2021

# RecyClass | Test campaigns: Laboratory testing

RecyClass Recyclability Evaluation Protocols are used as a reference to perform the tests.



# RecyClass

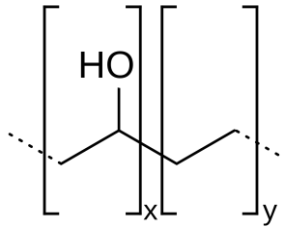
The background features two large, light teal line-art graphics. On the left is a chemical structure of a benzene ring with a fused six-membered ring, possibly representing a polymer repeat unit. On the right is a large Erlenmeyer flask containing a wavy line representing liquid.

## Barrier Technologies in Plastic Packaging

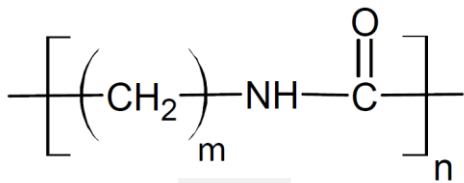
RecyClass Science behind Recyclability, 16 January 2023

# Barrier Technologies

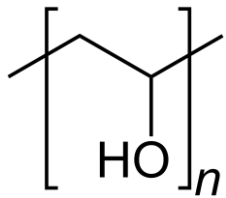
# Organic



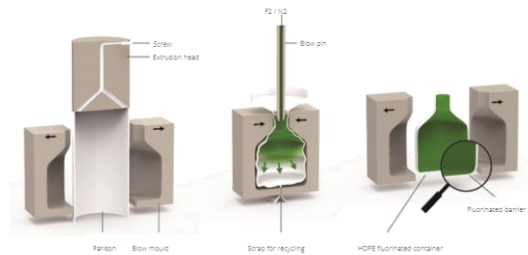
## EVOH



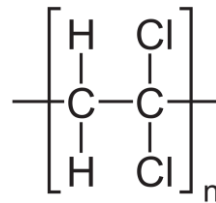
PAs



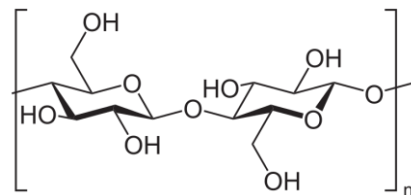
PVOH



## Fluorination

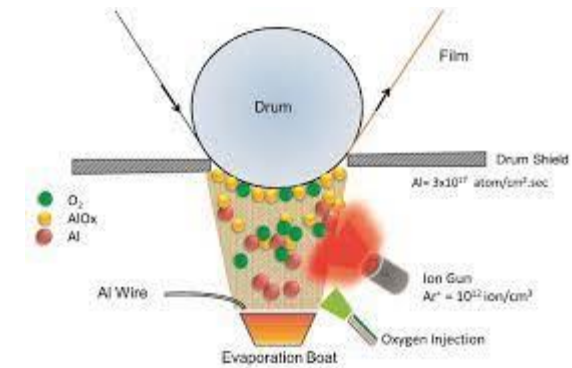


PVDC



## Cellulose

# Inorganic



## Metallisation

## AlO<sub>x</sub> coating

SiO<sub>x</sub> coating

**Internal layer:** EVOH, PVOH, PA, metallisation, AlOx coating, ...

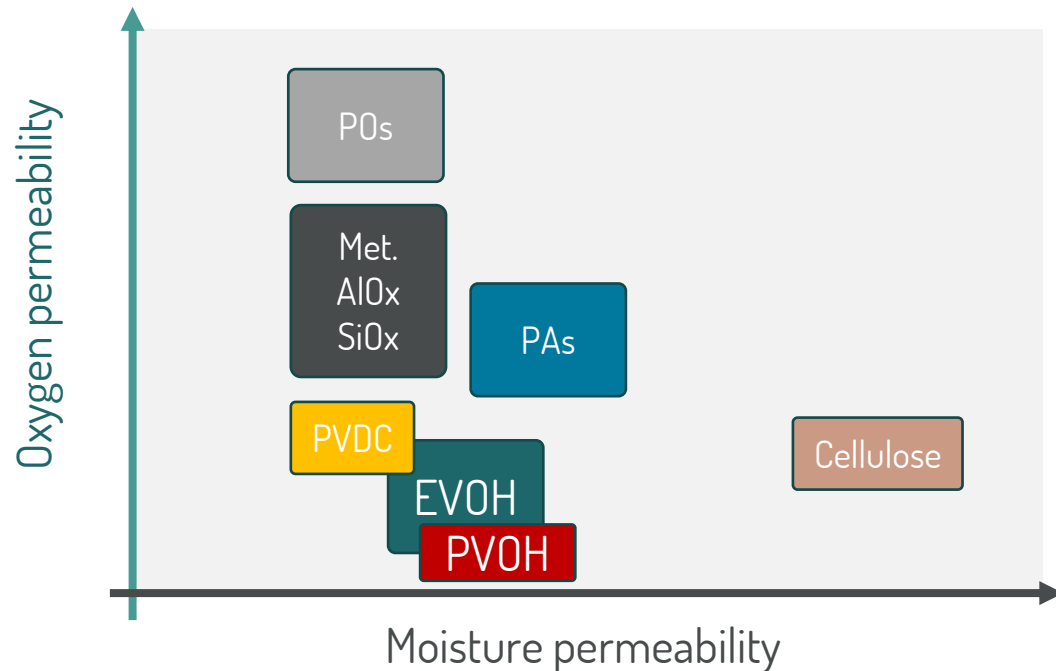
**Surface coating :** Fluorinated layer deposit, SiO<sub>x</sub> coating, ...



# RecyClass | Barrier Specificities

## Barrier properties to:

- Oxygen
- Moisture
- Light
- Aroma



Barrier coating/treatment	Main Advantages
EVOH	Excellent moisture and gas barrier
Polyamides	Aroma/O <sub>2</sub> -barrier with stiffness
PVOH	Excellent oxygen barrier
PVDC	Excellent moisture and gas barrier
Cellulose	Biobased material with good oxygen barrier
Fluorination	Resistance to chemicals
Metallisation	Light barrier
AlO <sub>x</sub>	Transparent, nm scale deposit
SiO <sub>x</sub>	Transparent, nm scale deposit

# RecyClass | Barrier Recyclability & Challenges

**Many parameters** to consider when evaluating the **recyclability** of barrier materials:

**Nature of the barrier material**

**Concentration of the barrier material**

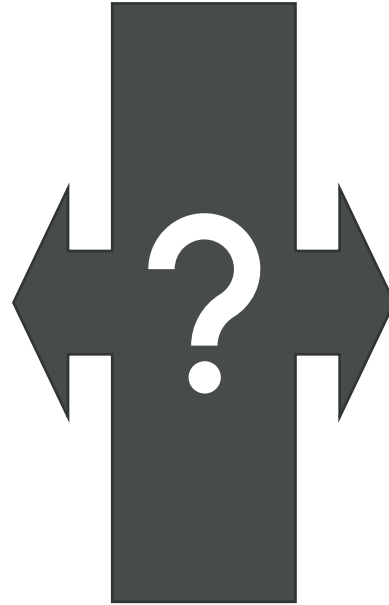
**Presence of tie layers**

**Presence of compatibilizers**

**Presence of a primer**

**Presence of a topcoat**

...



**Yellowing of the recyclate**

**Dark colouration of the recyclate**

**Non-molten materials**

**Filter saturation during pelletisation**

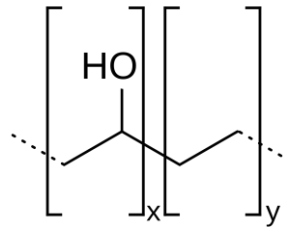
**Increase of volatiles**

**Mechanical properties of recyclate**

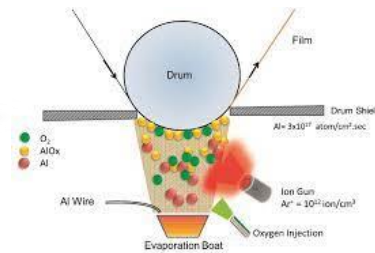
**High gels & specks level**

**Recycling processes** and **properties of the recyclate** can be affected by the barrier system resulting in a low recyclability of the packaging.

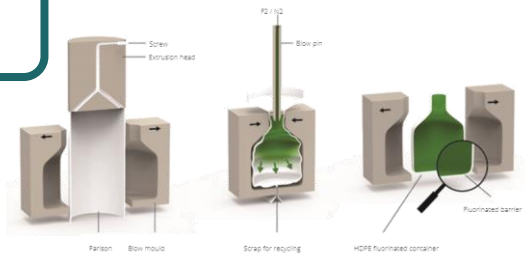
# RecyClass | RecyClass Test Campaigns



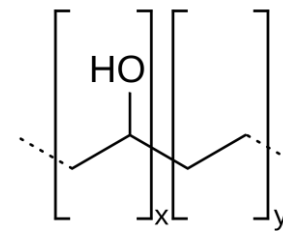
EVOH



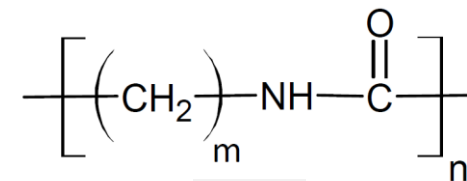
Metallisation



Plasma Fluorination & SiOx



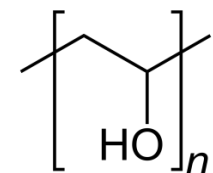
EVOH



PAs



Metallisation



PVOH

# RecyClass

The background features two large, light teal line-art graphics. On the left is a chemical structure of a benzene ring with a side chain. On the right is a laboratory flask containing a wavy line representing liquid.

## Case study: EVOH in rigid HDPE & PP packaging

# RecyClass | EVOH in Rigid Packaging

## RecyClass Test Campaign on EVOH

Stream	EVOH [wt %]	Mol % EVOH	Tie Layer [wt %]	EVOH/Tie layer
HDPE	3	32	3	1
HDPE	6	32	3	2
PP	6	27	3	2
PP	6	32	3	2



	YES - FULL COMPATIBILITY	CONDITIONAL - LIMITED COMPATIBILITY	NO - LOW COMPATIBILITY
MATERIAL COMPOSITION (TOTAL AMOUNT OF PE & AMOUNT OF PP ATTACHMENTS IN THE PACKAGING)	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
DESCRIPTION (TEST PROTOCOL)	Materials that passed the testing protocols with no negative impact OR 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
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MATERIAL *	HDPE; Multilayer PE with HDPE prevalence (LLDPE, LDPE, MDPE)		Multilayers HDPE with PLA; PVC; PS; PET; PETG
COLOURS	All colours	Black inner layer and dark colours (NIR-detectable)	Non NIR-detectable colours
SIZE		Items compacted < 5 cm	Items compacted < 2 cm
PRODUCT RESIDUES (EASY TO EMPTY INDEX)	A if the index is < 5%; B if the index is < 10%	C if the index is < 15%	D if the index is < 20%; E < if the index is 25%; F if the index is > 25%
BARRIER	EVOH < 0.0%wt + PE-g-MAH tie layers with MAH > 0.1%wt and EVOH tie layers ratio <= 2; Enlase (fluorination)	EVOH < 0.0%wt + PE-g-MAH tie layers with MAH > 0.1%wt and EVOH tie layers ratio <= 2; EVOH < 1% with any other tie layers; Plasma Fluorination	EVOH > 1% with any other tie layers; PA; PVDG; Aluminium
	nucleating agents, peroxides) and density remains < 0.97 g/cm³		Bio-/oxo-/photodegradable additives

## RecyClass Recyclability Approvals on EVOH

EVOH [wt %]	Tie layer [wt %]	EVOH/Tie layer	Level of compatibility
4.0	3.0	1.3	Full
3.9	3.9	1.0	Full
3.3	3.3	1.0	Full
3.0	3.0	1.0	Full
4.2	3.0	1.4	Full
3.9	3.0	1.3	Full
4.2	3.0	1.4	Full
4.3	3.3	1.3	Full
4.8	2.2	2.2	Full
4.4	3.2	1.4	Full
4.9	3.8	1.3	Full
5.8	4.4	1.3	Full
4.0	3.0	1.3	Full
4.0	3.0	1.3	Full
4.0	2.0	2.0	Full
3.0	1.4	2.1	Limited
3.0	1.5	2.0	Full
5.0	2.5	2.0	Full
3.0	5.0	0.6	Full

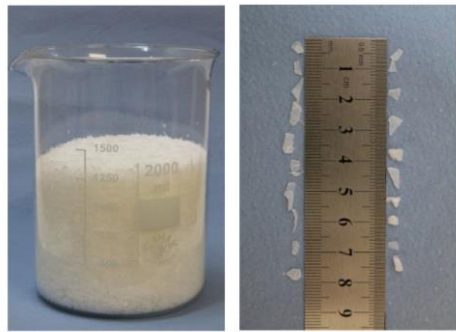
# RecyClass | EVOH in Rigid Packaging – Case study

## Case Study

**Innovation:** HDPE with 6 wt% EVOH and 3% PE grafted with MAH (Tie layers)

**Control material:** One-time processed Hostalen ACP 5831

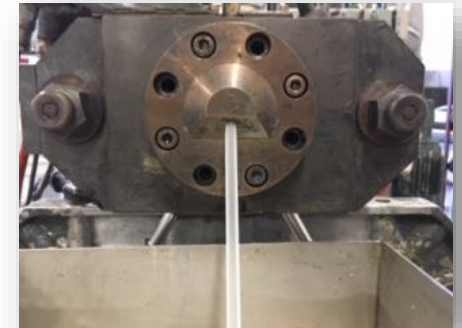
### Flakes of innovation material



### Blends for extrusion

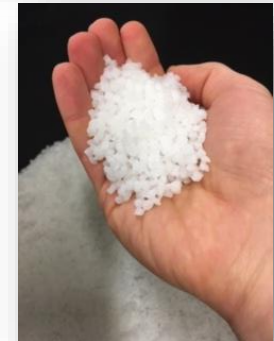
Blend	Control [%]	Innovation [%]
A.0	100	0
A.25	75	25
A.50	50	50

### Extrusion



### Blends for bottle production

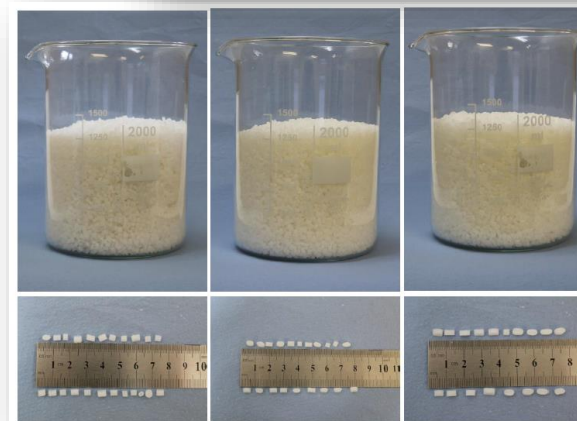
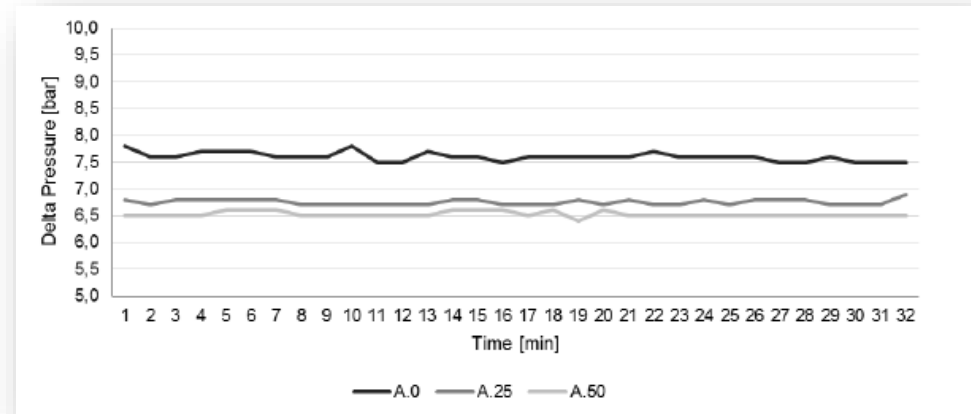
Blend	Virgin [%]	Control [%]	Innovation [%]
B.0	50	50	0
B.25	50	37.5	12.5
B.50	50	25	25



# RecyClass | Extrusion and pellets properties

## Pellets properties

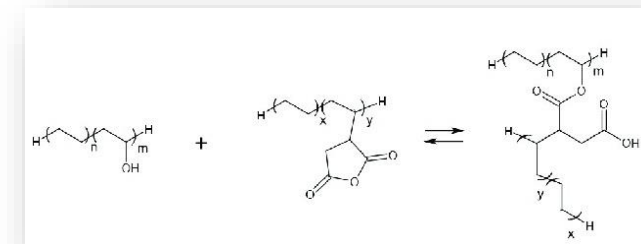
	Standard	Benchmark recommendation	A.0	A.25	A.50
Bulk Density [kg m <sup>-3</sup> ]	EN 15344	> 550	557	568	573
Density [kg m <sup>-3</sup> ]	ISO 1183-1	± 10 for A.25 and A.50 vs. A.0; < 995 (A.50)	935	939 (+ 4 kg m <sup>-3</sup> vs. A.0)	936 (+ 1 kg m <sup>-3</sup> vs. A.0)
Melt Index [dg min <sup>-1</sup> ]	ISO 1133 (190 °C, 2.16 kg)	0.2 – 0.9	0.3	0.3	0.3
Ash Content [wt.-%]	ISO 3451-1	< 2 (A.50)	0.0	0.0	0.0
Filtration	visual inspection	no build-up	no build-up	no build-up	no build-up
Moisture [wt.-%]	moisture analyzer	—	0.05	0.03	0.03
Melting Point [°C]	ISO 11357-3 (DSC)	130 – 140	132	132	133
Impurities	visual inspection	—	none	none	none
Surface Appearance	visual inspection	—	smooth	smooth	smooth
Volatiles [wt.-%]	160 °C, 10 min	± 0.1 % for A.25 and A.50 vs. A.0	0.18	0.18 (± 0.0 % vs. A.0)	0.19 (+ 0.01 % vs. A.0)
PP content [wt.-%]	DSC	< 2 for A.25 and A.50	0.0	0.0	0.0
Delta Pressure [MPa]	during stable run time	< +10 % for A.25 and A.50 vs. A.0	0.76	0.68 (– 10 % vs. A.0)	0.65 (– 14 % vs. A.0)



A.0

A.25

A.50



Chemical reaction between EVOH and PE grafted with MAH (1)

**All properties within benchmark recommendations**



# RecyClass | Bottle production and properties

## Bottle's properties

	Standard	Benchmark recommendation	B.0	B.25	B.50
Bottle Appearance	visual inspection		translucent, no inclusions	translucent, no inclusions	translucent, no inclusions
Bottle Integrity	visual inspection		ok	ok	ok
Bottle Dimension (Height)	direct measurement	± 5 % vs. B.0	241 mm	241 mm (± 0.0 % vs. B.0)	241 mm (± 0.0 % vs. B.0)
Bottle Weight	direct measurement	± 5 % vs. B.0	51.1 g	53.2 g (+ 3.9 % vs. B.0)	51.3 g (± 0.4 % vs. B.0)
Bottle Capacity	direct measurement	± 5 % vs. B.0	1134 mL	1126 mL (− 0.7 % vs. B.0)	1135 mL (+ 0.1 % vs. B.0)
Thickness (top side wall)	direct measurement	≥ 0.3 mm	0.8 mm	0.8 mm	0.9 mm
Thickness (mid side wall)	direct measurement	≥ 0.3 mm	0.9 mm	0.9 mm	1.0 mm
Thickness (bottom side wall)	direct measurement	≥ 0.3 mm	1.0 mm	1.0 mm	1.1 mm
Thickness (shoulder)	direct measurement	≥ 0.3 mm	0.8 mm	0.7 mm	0.8 mm
Thickness (base corner)	direct measurement	≥ 0.3 mm	0.3 mm	0.3 mm	0.3 mm
Top Load	ASTM D2659	< 5 % decrease vs. B.0	9.3 kg	10.6 (+ 12.3 % vs. B.0)	9.7 (+ 4.1 % vs. B.0)
Drop Impact	ASTM D2463 (method B)	< 95 % vs. B.0	2.08 m	2.40 m (+ 15.4 % vs. B.0)	2.64 m (26.9 % vs. B.0)
Additional Observations	visual inspection of the tool	No more than for B.0	none	none	none



## Mechanical properties

	Standard	B.0	B.25	B.50
Stress at Yield [MPa]	ISO 527-2	23.6	24.4	23.6
Stress at Break [MPa]	ISO 527-2	12.0	12.4	11.8
Elongation at Yield [%]	ISO 527-2	13.1	13.6	13.2
Elongation at Break [%]	ISO 527-2	111.9	102.4	229.0
Strength [MPa]	ISO 527-2	23.6	24.4	23.6
Elongation at Strength [%]	ISO 527-2	13.1	13.6	13.2



B.0

B.25

B.50

All properties within benchmark recommendations



# RecyClass | Overall results

## Conclusions

EVOH up to 6 wt% in presence of 3 wt% PE grafted with MAH is ***fully compatible with natural and coloured HDPE recycling*** due to:

- ✓ Stable extrusion process
- ✓ No presence of filter saturation or build ups
- ✓ No visible yellowing of recyclates
- ✓ All pellets' properties are within the recommended benchmarks
- ✓ Stable bottle production process
- ✓ All bottle's properties are within the recommended benchmarks
- ✓ All mechanical properties are within the recommended benchmarks



YES - FULL COMPATIBILITY	
MATERIAL COMPOSITION (TOTAL AMOUNT OF PE & AMOUNT OF PP ATTACHMENTS IN THE PACKAGING)	A >= 95%, B >= 90% and all packaging features are FULLY compatible with recycling
DESCRIPTION (TEST PROTOCOL)	Materials that passed the testing protocols with no negative impact OR materials that have not been tested (yet), but are known to be acceptable in PE recycling
DESCRIPTION (METHODOLOGY)	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
MATERIAL *	HDPE; Multilayer PE with HDPE prevalence (LLDPE, LDPE, MDPE)
COLOURS	Natural (clear)
SIZE	
PRODUCT RESIDUES (EASY TO EMPTY INDEX)	A if the index is < 5%; B if the index is < 10%
BARRIER	EVOH < 6.0%wt + PE-g-MAH tie layers with MAH > 0.1%wt and EVOH tie layers ratio <= 2; Enkase (fluorination)
ADDITIVES	Additives that are unavoidable in processing (stabilizers, antioxidants, lubricants, nucleating agents, peroxides) and density remains < 0,97 g/cm³

## Other barrier combinations are welcomed to be tested:

- ☐ % of EVOH
- ☐ % and type of tie layers
- ☐ Compatibilizers
- ☐ Different ratio EVOH/Tie layers

# RecyClass

The background features two large, light teal line-art graphics. On the left is a chemical structure of a benzene ring with a fused six-membered ring, possibly representing a polymer repeat unit. On the right is a large Erlenmeyer flask containing a wavy line representing liquid.

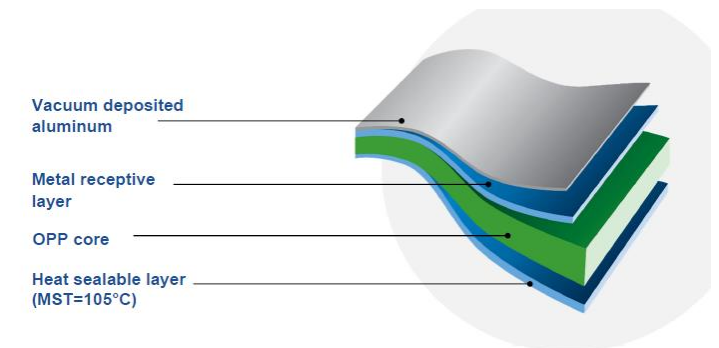
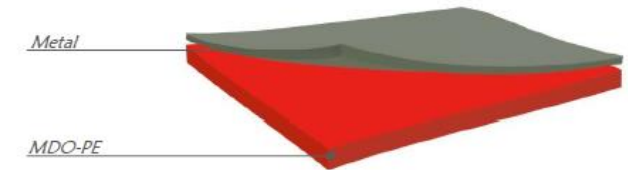
## Case study: Metallisation in flexible HDPE & PP packaging

# RecyClass | Metallisation study context

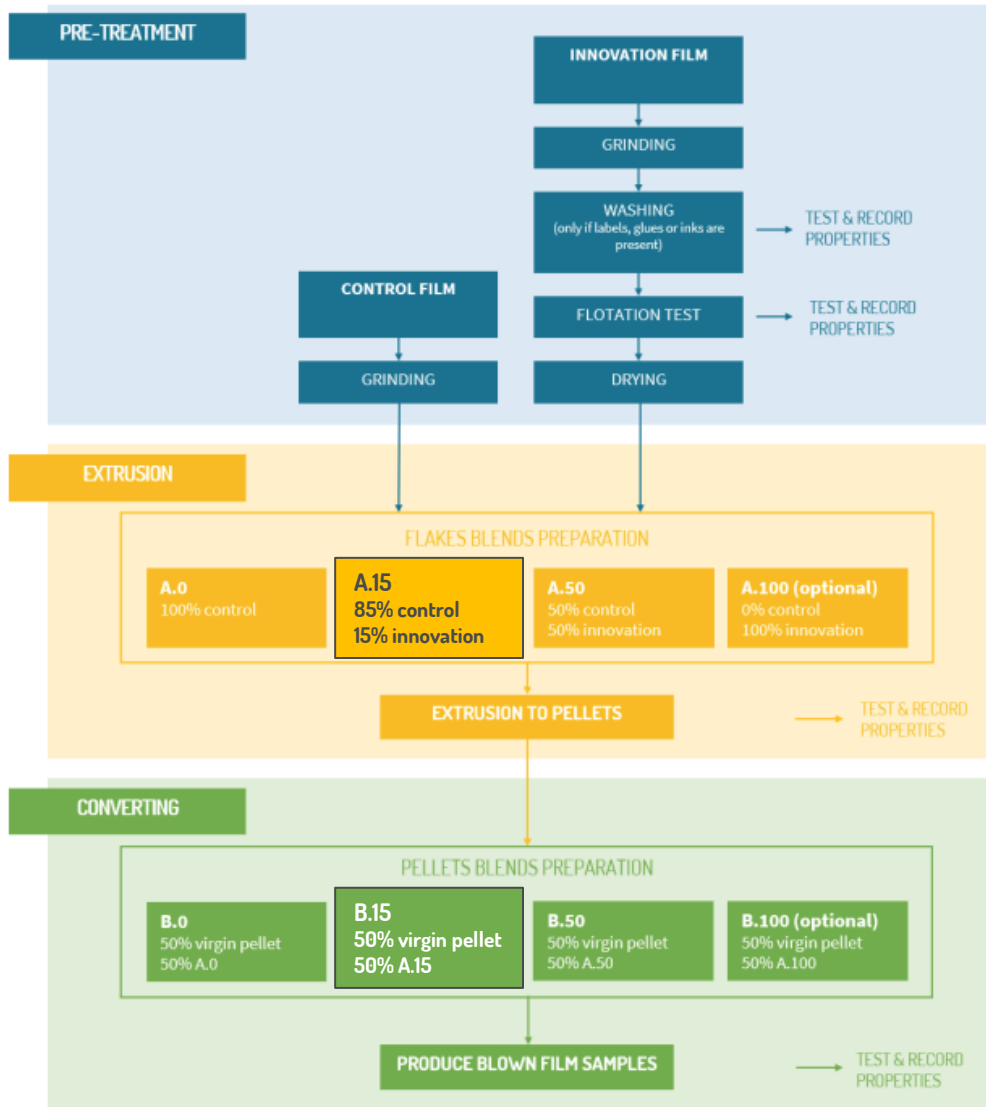
**RecyClass** studied met-MDOPE and met-BOPP (tested by Aimplas) to provide **new recommendations** on PE Films and PP Films Design for Recycling Guidelines.

## Samples evaluated

Innovation	Thickness [μm]	Optical Density	Adhesive [g/m <sup>2</sup> ]	Control material
met MDO-PE	20	2.4-2.7	-	R-310E DOW
Laminate met MDOPE	70	2.4-2.7	1.7	R-310E DOW
met-BOPP	18	2	-	Mono BOPP film
Laminate met-BOPP	35	2	2.2	Mono BOPP film



# RecyClass | Recyclability Evaluation Protocol



Protocol slightly adapted to align RecyClass and COTREP evaluations

1



2

## Pellet properties

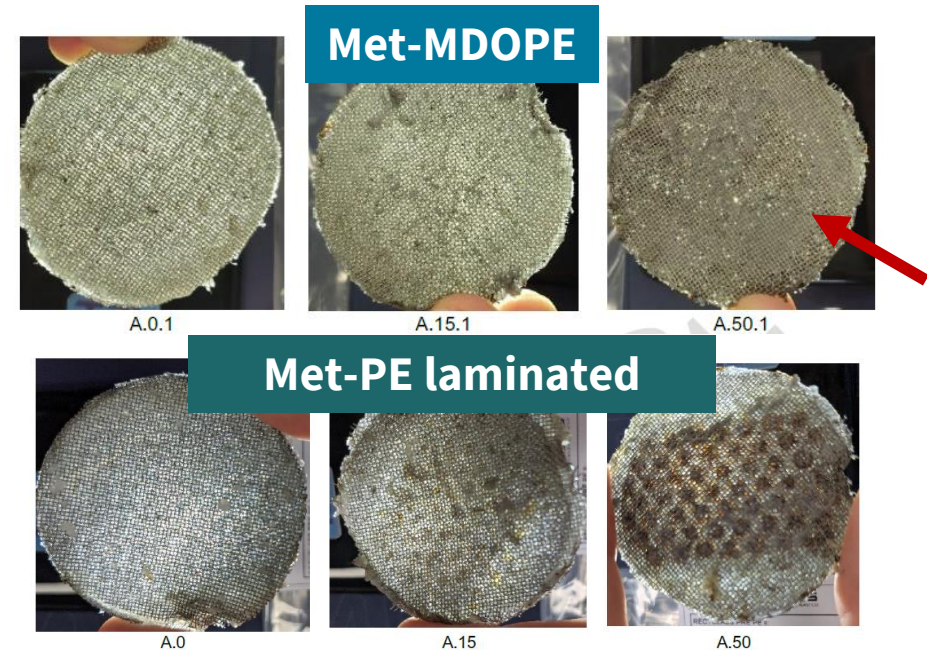
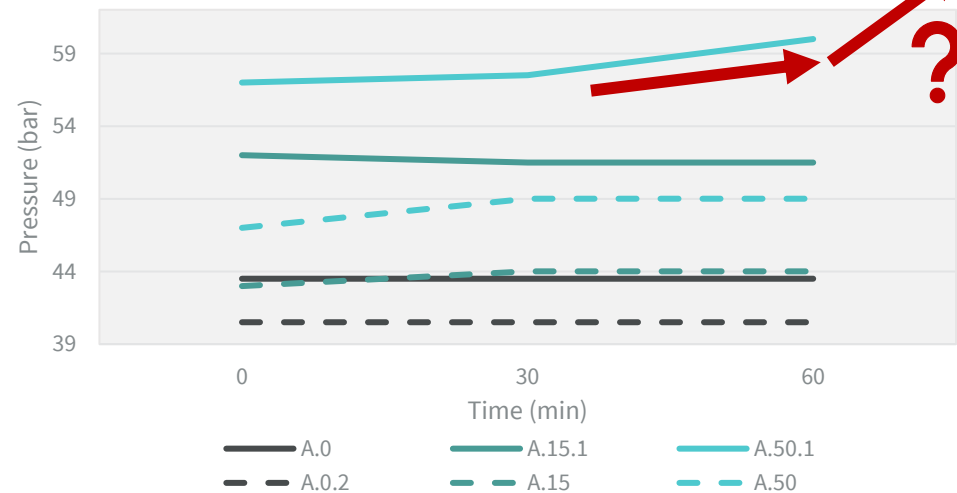
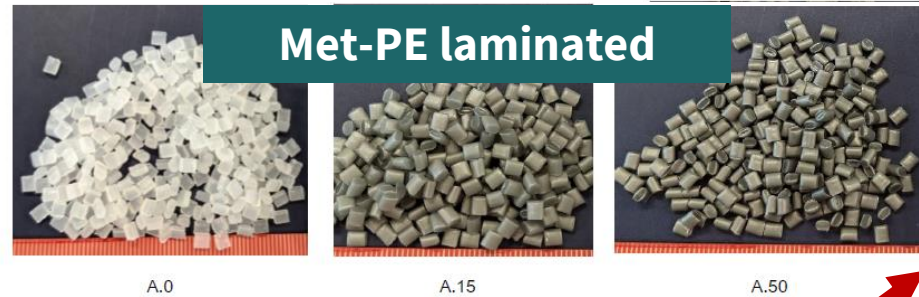
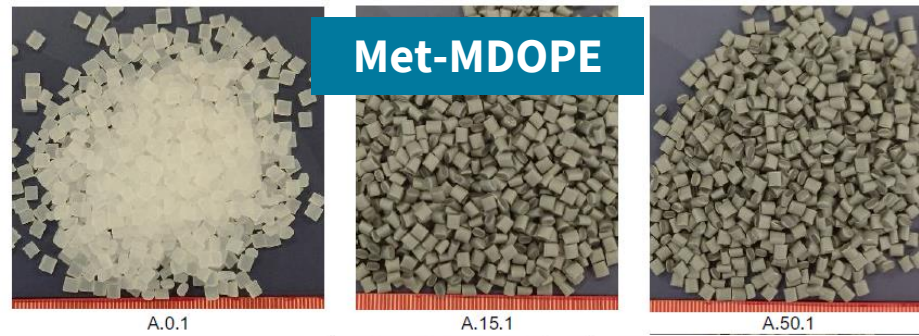
- Melt Flow Index
- Ash content
- Colouration

3

## Film properties

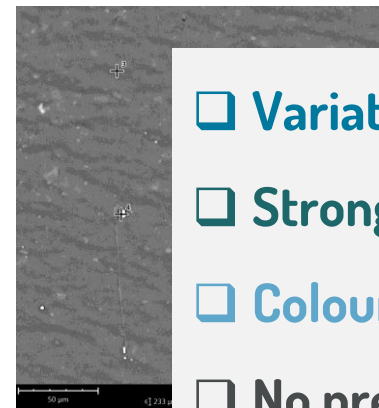
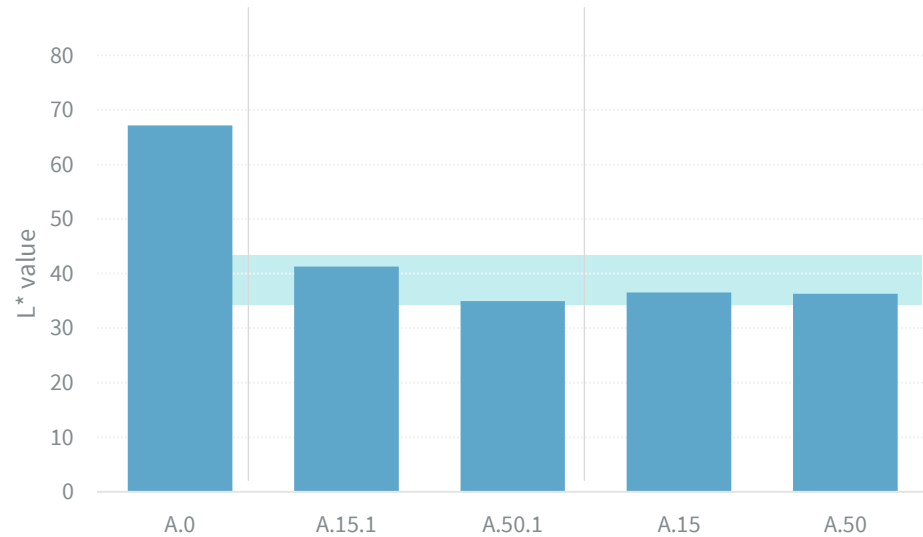
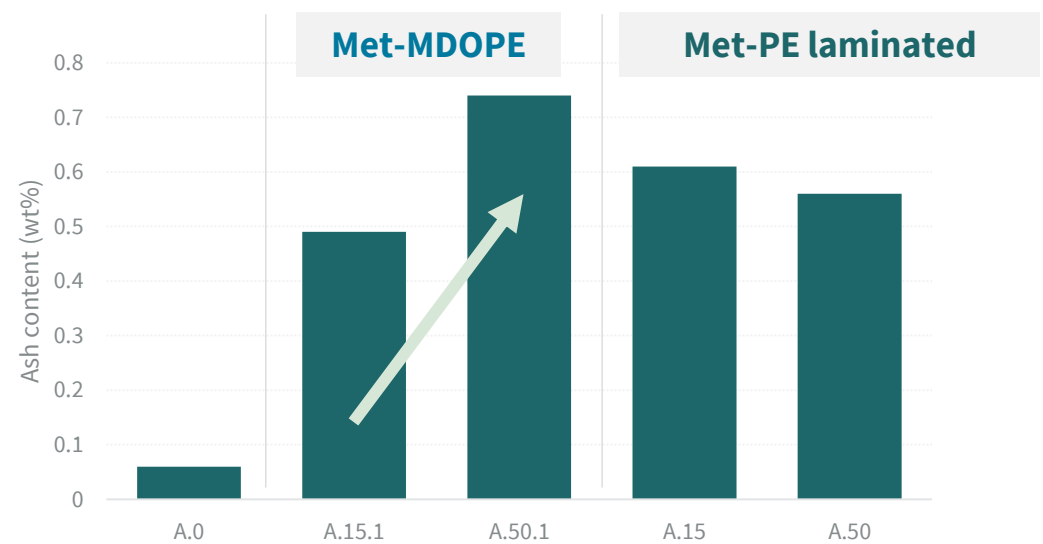
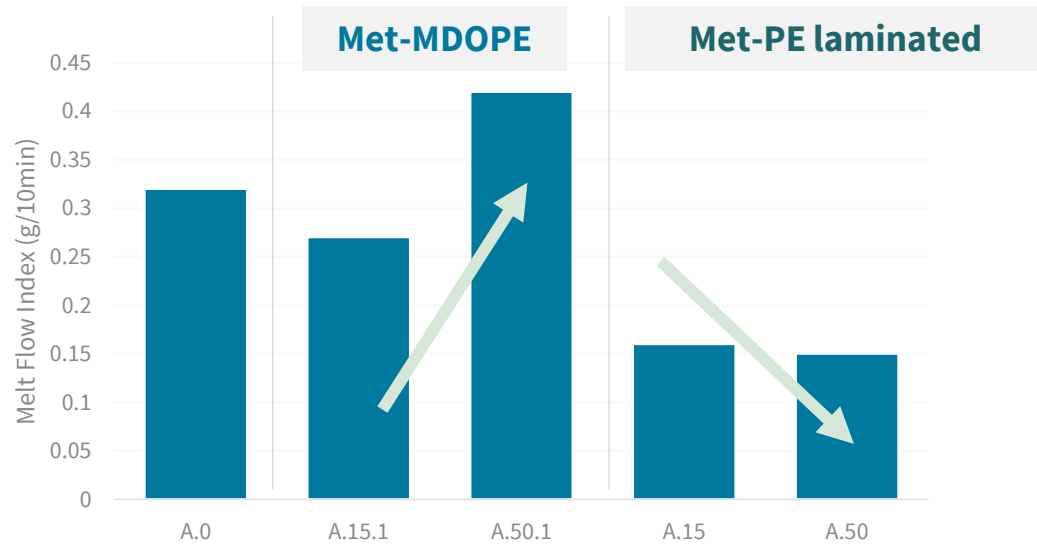
- Tensile properties
- Dart impact
- Visual aspect

# RecyClass | Extrusion & pelletisation



- ☐ Colouration of the pellets
- ☐ Pressure increase
- ☐ Build-ups & Saturation of the filters

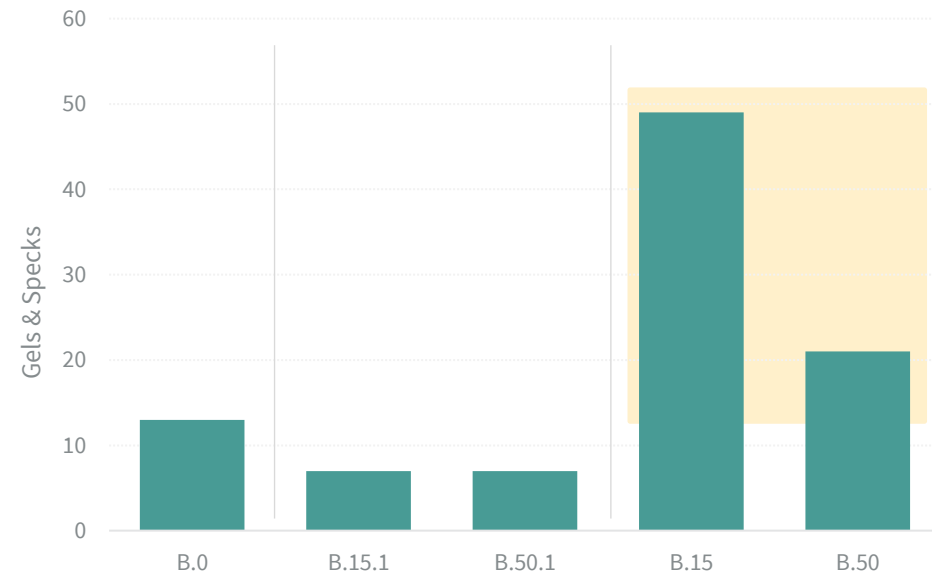
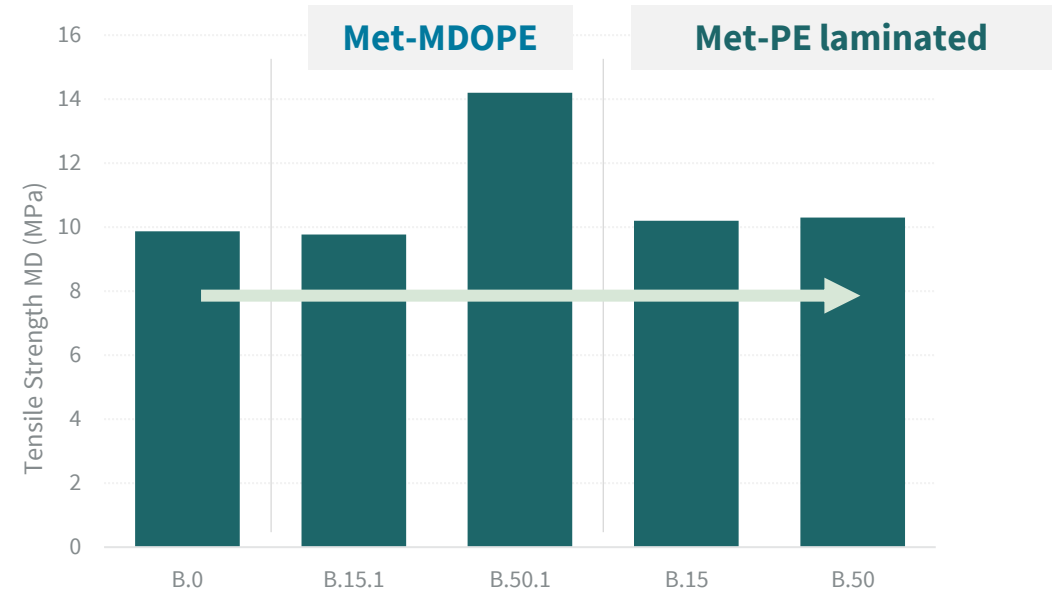
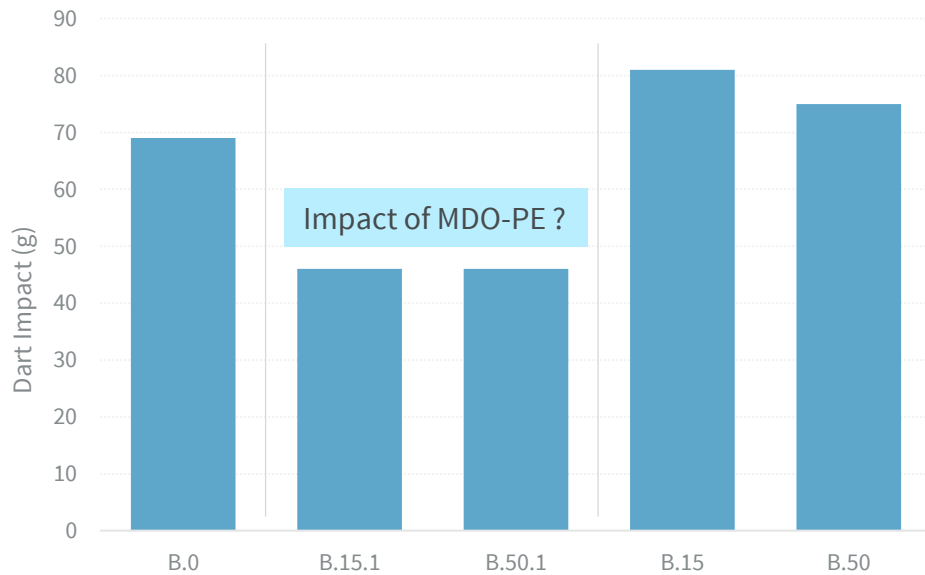
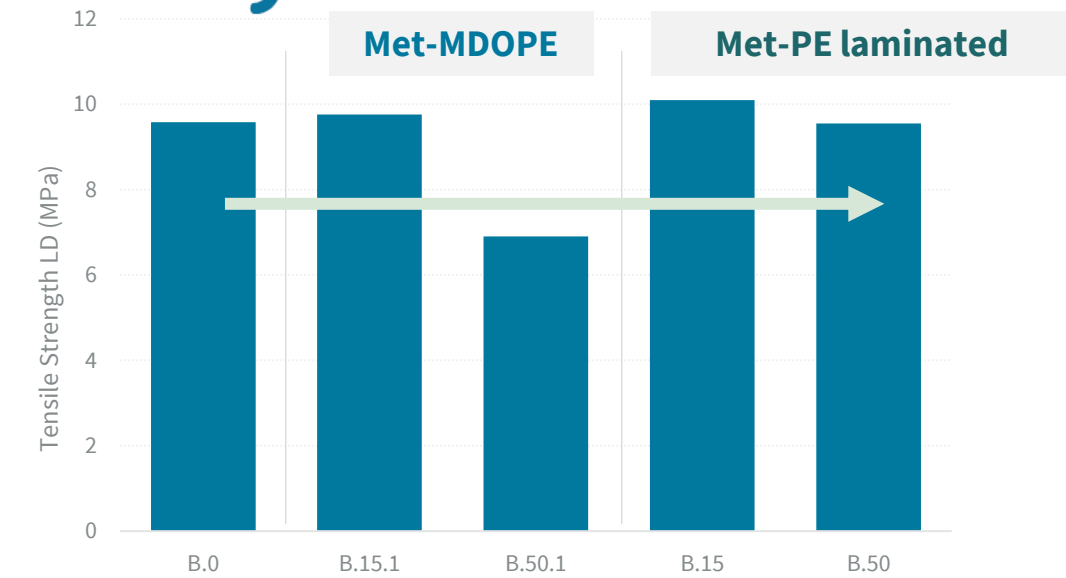
# RecyClass | Pellet properties



- ☐ Variations of the MFI
- ☐ Strong increase of ash content
- ☐ Colouration of pellets
- ☐ No presence of Al found in pellets

Si	3.87	5.35	Si	10.92
C	2.64	1.56	C	3.18

# RecyClass | Film properties





# RecyClass | Overall results

- Similar results obtained for met-MDOPE and met-BOPP films and laminates
- Positive results obtained for:
  - Pellet properties
  - Film processability
  - Film mechanical properties (except dart impact)
- Main deviations observed:
  - Increase of pressure during extrusion
  - Build-up on filters, up to saturation after 60-90 minutes
  - Increase of film haze
  - Small increase of gels & specks in the presence of laminating adhesive



## KEY TAKEAWAYS

- ✓ **RecyClass Recyclability Evaluation Protocols** are developed by the plastic value chain to assess packaging technologies against recyclability in a reliable way
- ✓ **Almost 200 tests contributed to develop fact-based, standardized** design for recycling criteria
- ✓ **Balancing packaging functionality & recyclability** is key for the plastic packaging market
- ✓ **Innovative barrier technologies** are a must for the market & the industry can use RecyClass Protocols to evaluate such developments in a reliable manner

# RecyClass

The background features two large, light teal chemical structures. On the left is a benzene ring, and on the right is a flask containing a wavy line representing a liquid. These structures are faint and serve as a decorative backdrop for the text.

## Questions & Answers

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

# RecyClass

The background features two large, light teal chemical structures. On the left is a benzene ring, and on the right is a flask containing a wavy line representing a liquid. The entire graphic is set against a dark teal background.

## Thank you for participating!

Sign up for the next session  
**5 July 2023**

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