CIMPA FINAL EVENT

Advancing the circularity of complex plastic films

20 November 2024
14:00-18:00, BluePoint Brussels

Hosted by EuR10

cimpa

Funded by the European Union

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Advancing the circularity of complex plastic films

14:15-14:35 EU's Circular Plastic Strategy: progress and next steps

Laure Baillargeon

Policy Officer,
DG GROW, European Commission

Hosted by EuRIC

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Progress towards circular plastics in the EU: where do we stand?

Ms Laure Baillargeon
Net-zero industries, sustainable and circular products Unit, DG GROW, European Commission

EU action – progress made

- **PPWR – plastic packaging films** ✓

Targets adopted

Recycled content needs

Packaging approx. 6Mt, including a third of food contact?

Films: approx. 2.3 Mt incl. 0.3 Mt food contact?

- **Framework on biobased, biodegradable and compostable plastics** ✓
- **Plastic pellet management regulation** ✓
- **Agricultural plastic films (non-packaging)** ✗

Not yet specific targets or mandatory EPR

By…	Target
2025	10Mt of recycled plastics used in products in EU
2030	All plastic packaging recyclable by design
2030	55% recycling rate for plastic packaging
2030	10% (*25%*) recycled content for contact sensitive, 35%(*65%*) for other
2030	55% CO2 reduction compared to 1990
2035	All plastic packiaging recycled at scale
2040	90% CO2 reduction compared to 1990

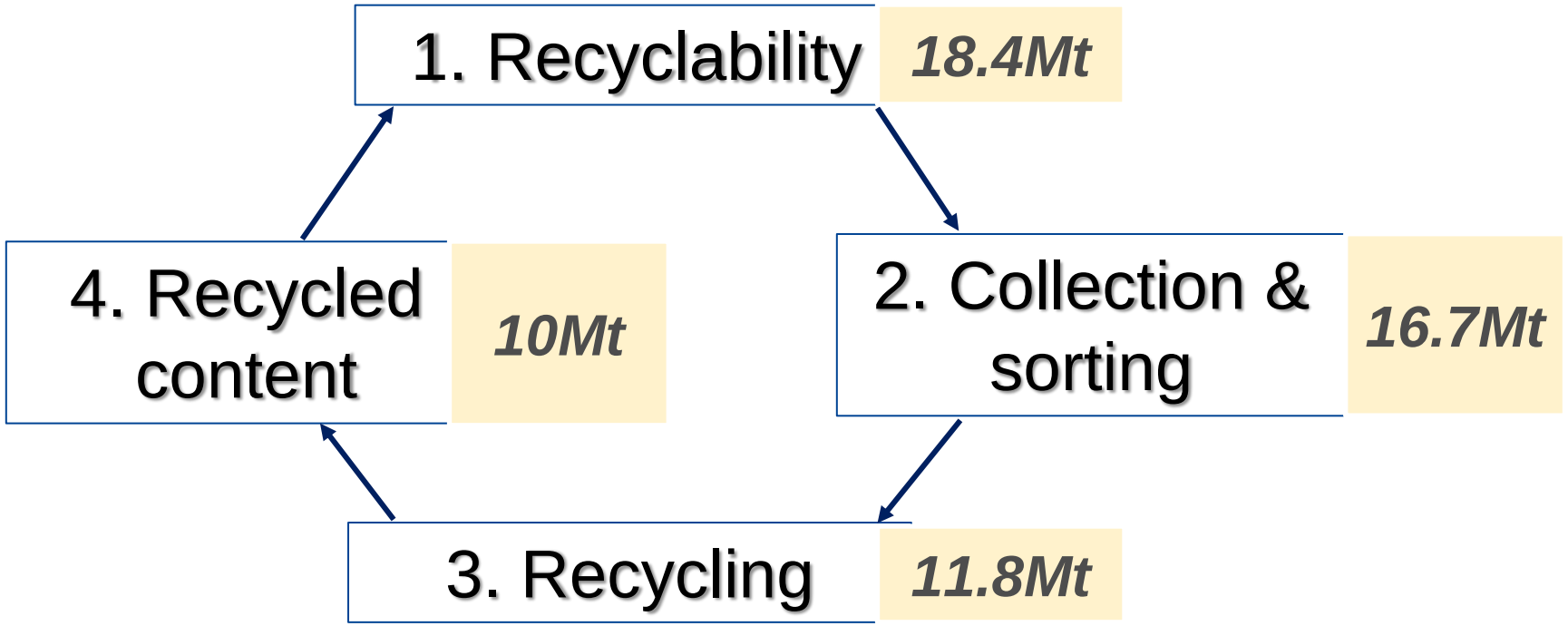
EU action – what's on the horizon?

- **PPWR – secondary legislation**

Recyclability (2028), calculation and verification of recycled content (2026), sustainability criteria for plastic recycling technologies (2026), equivalent conditions for non-EU recycling (2026), possible derogations from or changes to minimum recycled content percentages

- **Circular Economy Act** ("market demand for secondary materials and a single market for waste"**)**
- **Waste Framework Directive revision** (2026)
- **Single-Use Plastics Directive** (2027)

What is happening now? Are we on track?



Source: Circular plastics alliance
Note: 10 Mt for EU-28 (with UK) = 8.8Mt for EU-27

European Commission

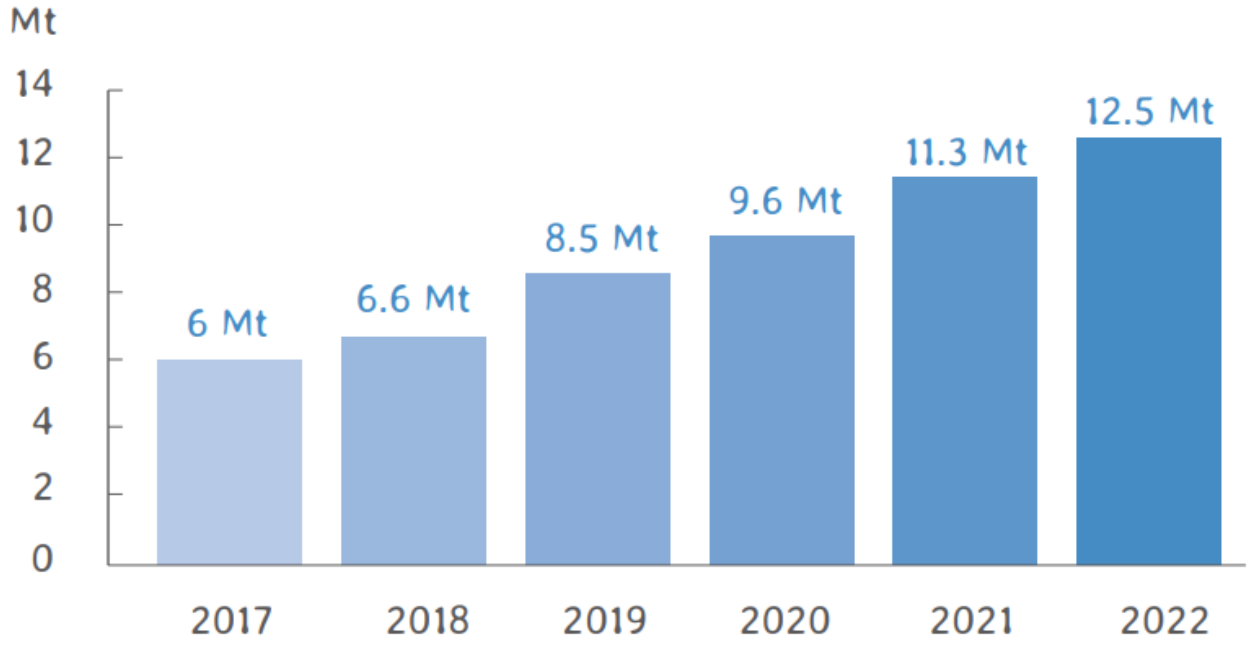
What is happening now?

Recyclability

- No figure but CEN design-for-recycling standards planned by 2025 (incl. packaging and agri films)

Recycling capacities

- Already beyond CPA target



Installed recycling capacities (EU27+3)
Source: Plastics Recyclers Europe

European Commission

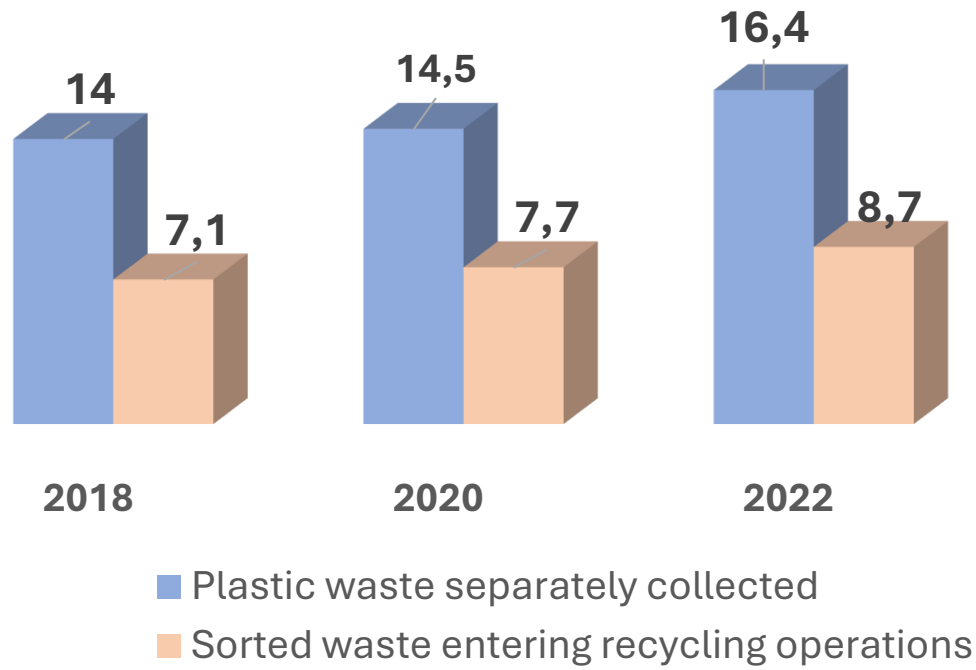
What is happening now?

Collection & sorting

- Increasing but not sufficiently
- Packaging

70% of waste separately collected

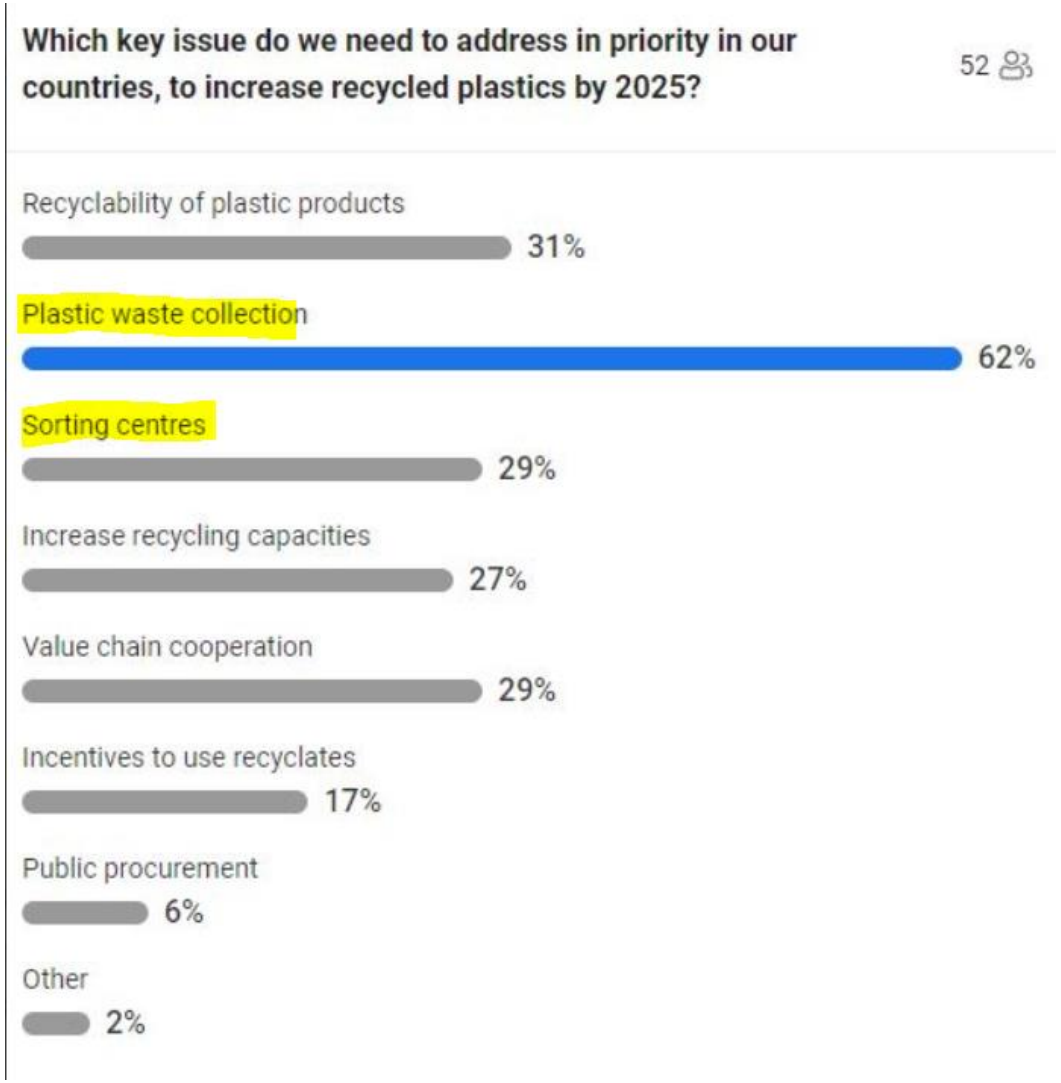
80% of sorted waste to recyclers



Source: Plastics Europe

Collection & sorting as a key bottleneck

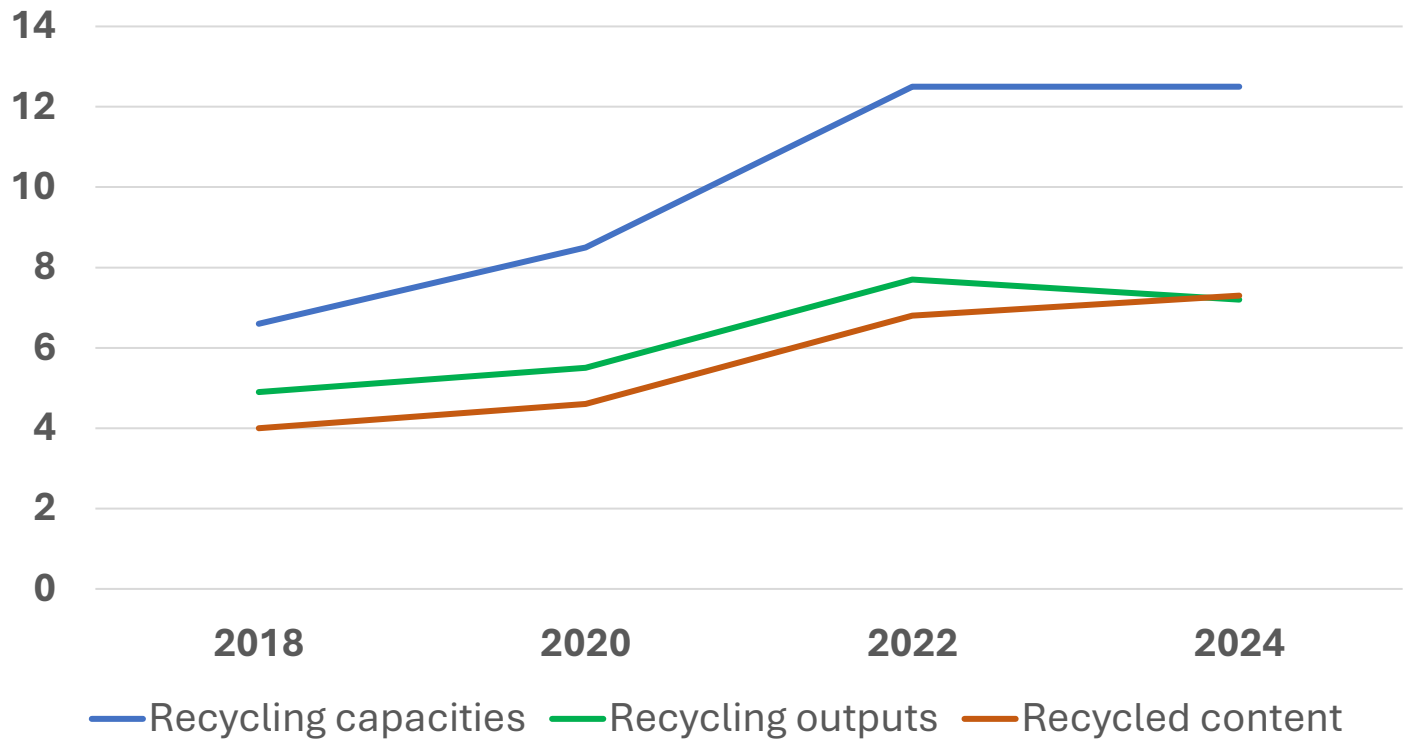
- 2023 JRC study : the highest increase in plastic waste recycling is achieved with **reduced exports of plastic waste** and **increased separate collection for recycling**
- Views of participants at the General Assembly of the Circular Plastics Alliance (CPA, 2022)



What is happening now?

Recycling & recycled content

- Demand for recycled content stagnating
- Widening gap between capacities and outputs
- Crossing of lines for EU production and demand
- Context of declining virgin production

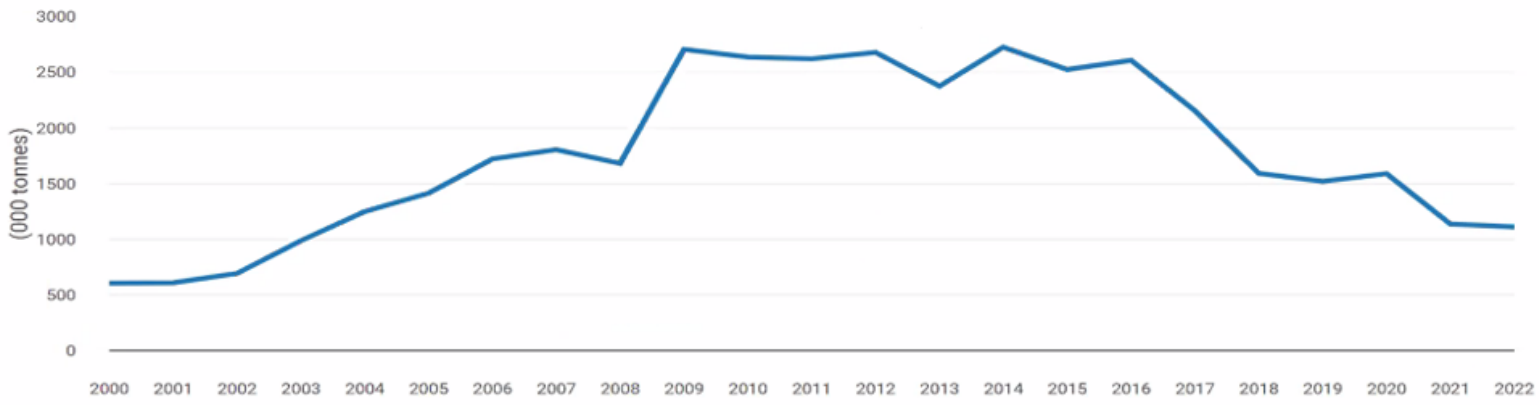


Figures in Mt,
Source: Plastics Europe and Plastics Recyclers Europe

What is happening now?

Export of plastic waste outside the EU continue decreasing

The indicator shows the quantities of plastic waste exported outside EU 27.



Download Share Enlarge

Chart Title: Extra-EU plastic waste trade 2000–2022.

Status: Indicator

Coverage: EU-27, 2000-2022.

Source: the European Environment Agency

What is happening now?

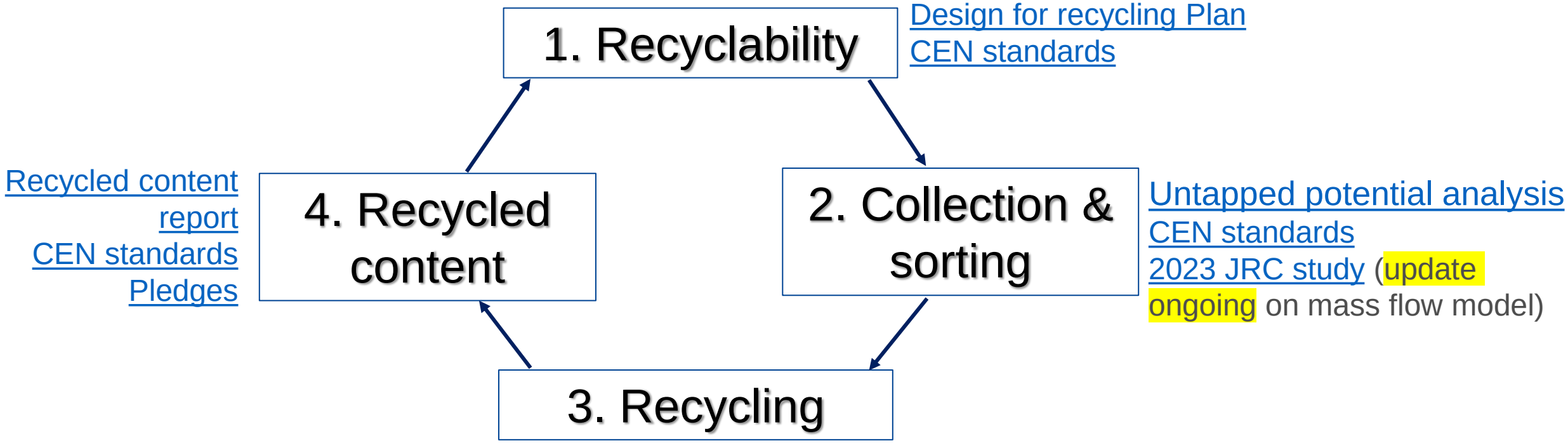
All plastics/ Packaging		
	Baseline	**EU & CPA targets**
Recycled content	2018: 4.0 /1Mt (2%) 2020: 4.6 /1.4Mt (6.6%) 2022: 6.8/ 2Mt (9.7%) 2024: 7.3Mt	10Mt in 2025 (3Mt in packaging?) PPWR targets by 2030 (6 Mt?)
Recycling rate	2018: 32%/ 42% 2020: 35% /46% 2022: 27% / 38%	55% packaging recycling rate by 2030
Recyclability	Not available	100% by 2030

Agricultural plastics		
	Baseline	**CPA target**
Collection rate	2018: 0.7Mt 68%)	2025: 1Mt (100%)
Recycling inputs	2018: 0.39 Mt	2025: 0.7Mt
Recycling outputs	2018:0.2Mt	2025:0.4 Mt

Lessons from the CPA work?

- Work against a target and around the conditions needed to achieve it
- Build from collective knowledge
- Focus on economic conditions (« business case », supply & demand)
- Articulate with the regulatory /policy work
- Compare internationally (e.g. investment framework)
- Multi-stakeholder dimension
- Allow for specialised working groups (by sector, by application/polymer)

Recap of the work done by the CPA



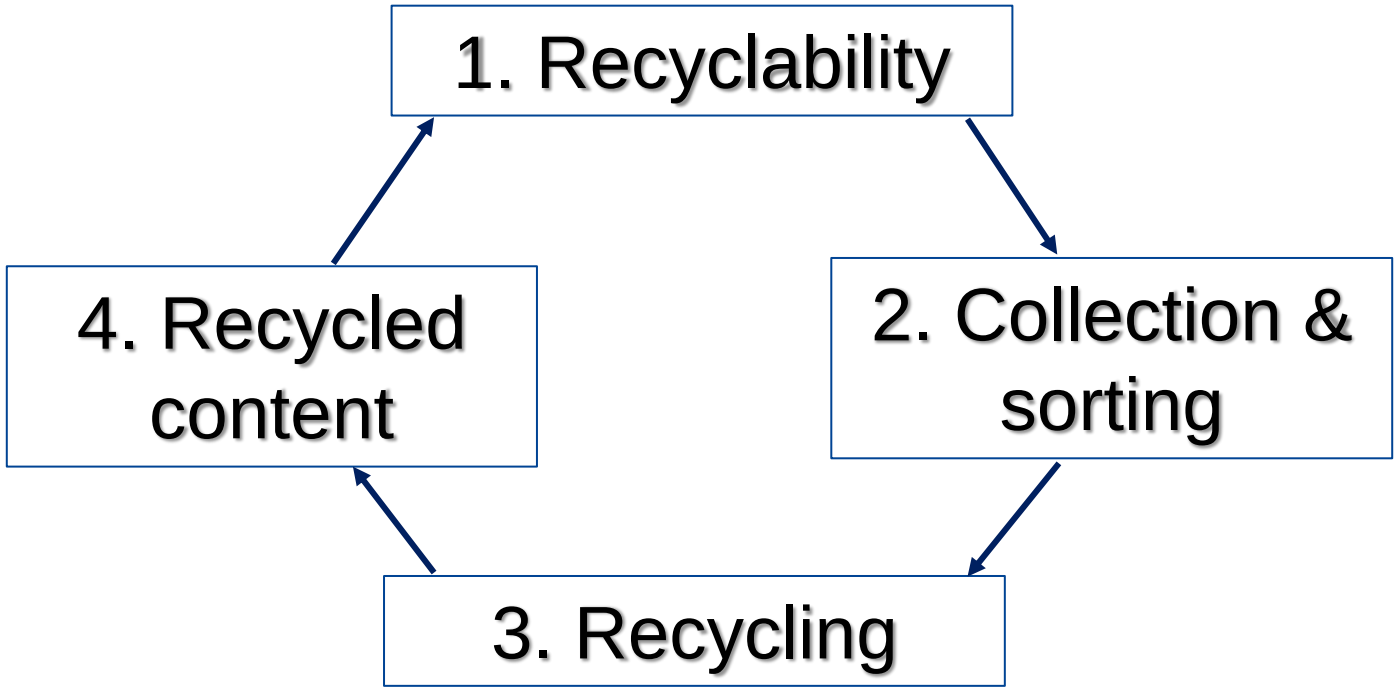
European Commission

Recap of the work done by the CPA

REGULATION

INNOVATION

FINANCE



European Commission

Q&A

Unit GROW I.3
https://ec.europa.eu/growth/industry/strategy/industrial-alliances/circular-plastics-alliance_en
GROW-ENV-RPLASTICS-PLEDGE@ec.europa.eu

European Commission

CIMPA FINAL EVENT

20 November 2024
14:00-18:00
BluePoint Brussels

Advancing the circularity of complex plastic films

14:35-15:10 CIMPA's overview: towards the circularity of multilayer plastic films

Céline Chevallier

CIMPA project coordinator, IPC

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a circular
multilayer plastic approach
for value retention of end-of-life
multilayer films

A circular multilayer plastic approach for value retention of end-life multilayer films

CIMPA project, Grant Agreement N° 101003864

CIMPA AT A GLANCE

Grant agreement ID: 101003864

Start date: 1 June 2021

End date: 30 November 2024

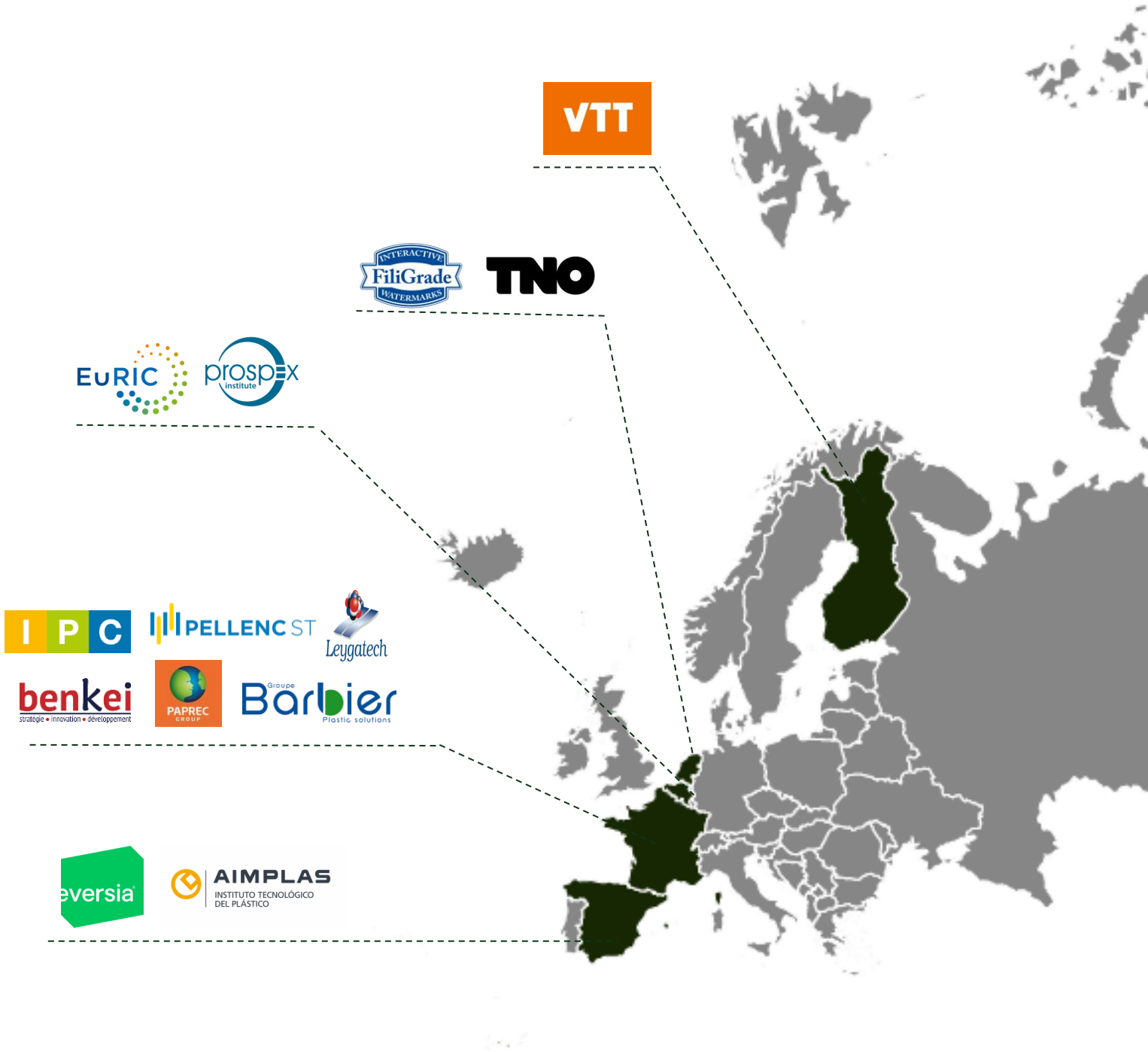
Funded under: H2020-EU.3.5.4.

Overall budget: € 4 984 396,25

EU contribution: € 4 984 396,25

Coordinated by:

CENTRE TECHNIQUE INDUSTRIEL DE LA PLASTURGIE ET DES COMPOSITES, France



To create a value chain for multilayers recycling and reuse in the food and agriculture packaging markets, in a systemic way, considering all aspects of the value chain

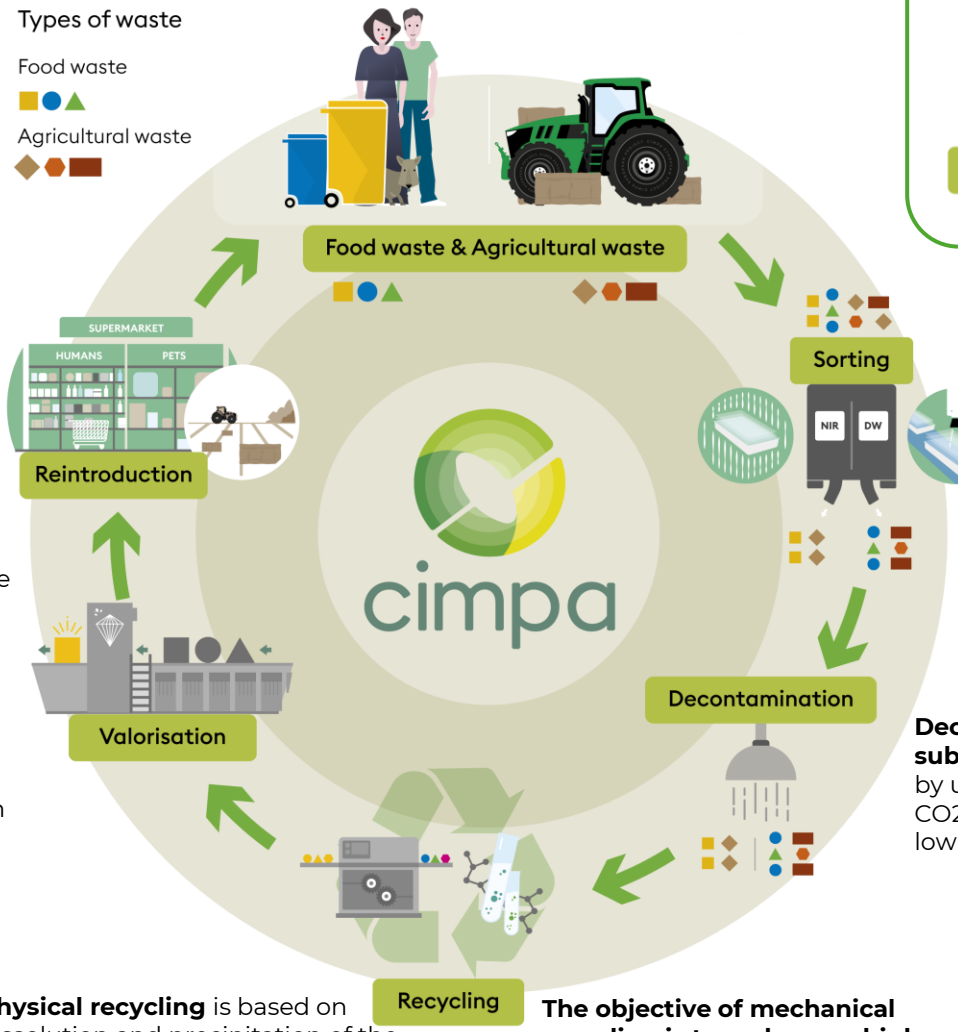
CIMPA Value Chain

Normalization

The recycling processes will be developed according to current European legislation. **Modification of such legislation and standards could be proposed** to increase multilayer films recyclability.

Research

New designs will be proposed including :
Multilayer structures more recyclable
Multilayer compositions including recycled materials



NIR identification relies on inner characteristics of the multilayer films: Composition, transparency, number and thickness of layers... When a combination of NIR, metal detection and Digital Watermarking is used, **up to 99% of sorting efficiency can be expected.**

A novel pilot recycling line with in-line adaptive melt rheology control and additivation will be used **to stabilize and upgrade targetted properties of recycled stream**, such as melt flow properties (targetting e.g. less than ±15% variance in melt flow index for recycled feedstock).

Decontamination will remove toxic and hazardous substances, but also more than 80% reduction of VOCs, by using conventional stripping agents and supercritical CO2 if necessary. The Overall Migration Limit should be low enough to return to food contact applications.

Physical recycling is based on dissolution and precipitation of the polyolefin contained **in the *Multilayer films that cannot be mechanically recycled***. The process uses a low boiling point solvent, and up to 90% recovery of the PO present should be reached.

The objective of mechanical recycling is to make new high gas barrier films. 2 innovative processes will be used : continuous extensional flow mixing and multinanolayering extrusion. Bi-axial stretching can also improve the barrier properties if needed.

Demonstrators in CIMPA project

	Laboratory scale	Pre-production scale	Recyclability & New designs
Mechanical recycling	**Goal :** Make film with suitable properties from multilayer wastes, using mechanical recycling equipments ❖ MNL and METEOR, at IPC, ❖ Biaxial stretching at VTT	**Goal:** Make film with suitable properties from multilayer wastes using industrial equipments ❖ pilot blown film at LEY and BAR	**Goal :** Novel multi-material structures treated according to the CIMPA concept using mechanical recycling equipment with demonstrators produced ❖ MNL and METEOR, at IPC, ❖ VAREX at VTT
Physical recycling	**Goal :** Make film with suitable properties from multilayer wastes, using polyolefins coming from physical recycling ❖ Möbius at TNO ❖ Mini-scale film at VTT		**Goal :** Novel multi-material structures treated according to the CIMPA concept using physical recycling and with demonstrators produced ❖ Möbius at TNO (TRL4) ❖ Mini-scale film at VTT

Details and results available in D5.5
https://cimpa-h2020.eu/

Demonstrators in CIMPA project

*PI : post industrial Recyclates

*PC : post consumer Recyclates

Physical recycling demonstrators, Laboratory scale

Feedstocks

Metallized Films, ***samples, PIR***
From EVERSIA

Household waste from Paprec Sorted by Pellenc ST

Metallized Films, ***PCR***

Physical recycling at TNO

rPO, ***samples***

Upgrading (additivation and stabilization) at VTT

Upgraded rPO, ***samples***

Film production at Laboratory scale at VTT

Hot press, ***samples***

Results

Code	r-PO mix (PLA-0057/-0059)	Virgin polymer		Compatibilizer		Stabilizer		Tensile modulus	Tensile stress at yield	Tensile strain at break
	[wt-%]	*Grade*	*[wt-%]*	*Grade*	*[wt-%]*	*Grade*	*[wt-%]*	*[MPa]*	*[MPa]*	*[%]*
CIMPA-WP4-5	99.85	-	-	-		Irganox 1010	0.15	563.2	4.9	9.2
CIMPA-WP4-6	94.85	-	-	POE	5	Irganox 1010	0.15	400.2	4.4	21.6
CIMPA-WP4-7	94.85	-	-	OBC	5	Irganox 1010	0.15	545.5	5.4	215.1
CIMPA-WP4-8	94.85	-	-	PP-g-MAH	5	Irganox 1010	0.15	382.4	3.9	4.3
CIMPA-WP4-9	97.35	LDPE Lotrène® FD0274	0	OBC	2.5	Irganox 1010	0.15	555.2	13.9	500.0
CIMPA-WP4-10	82.72	LDPE Lotrène® FD0274	15	OBC	2.13	Irganox 1010	0.15	481.2	13.2	299.5
CIMPA-WP4-11	82.72	LDPE Lotrène® FD0274	15	OBC	2.13	IrgaCycle™ PS 031 G	0.15	534.2	11.5	158.5
LDPE ref	-	LDPE Lupolen 2426F	100	-	-	-	-	260	11	300
PP copolymer	-	PP Moplen EP310D HP	100	-	-	-		~900 (generic)	26	500

Can replace virgin material, given that they are mixed PO

Yellow-green tint

Proof of concept achieved

Demonstrators in CIMPA project

*PI : post industrial Recyclates

*PC : post consumer Recyclates

Mechanical recycling, Laboratory scale

Feedstocks

PE/EVOH, PE/PA, PE/PET, ***PIR,***
From Leygatech, Barbier and Eversia

PE/PA and PE/PET families, ***PCR***
Household waste from Paprec Sorted by Pellenc ST

Pretreatment and Decontamination at AIMPLAS

PE/PA and PE/PET families, ***PCR only***

rPE/PA, ***PCR***

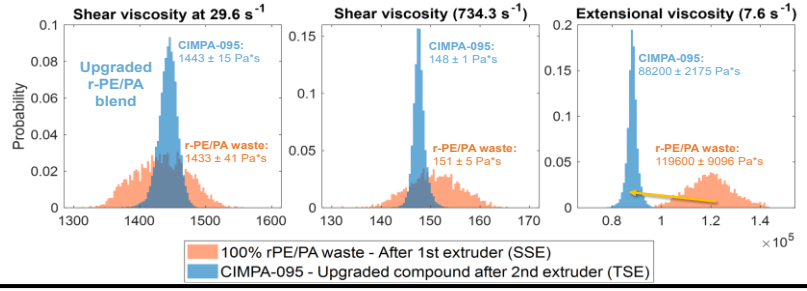
rPE/PET, ***PCR***

Upgrading (additivation and stabilization) at VTT

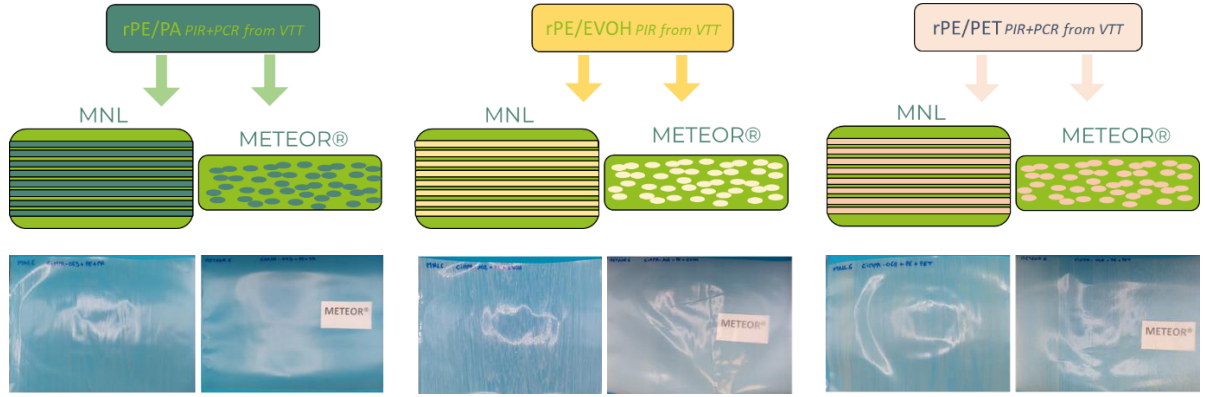
PIR+PCR

Upgraded rPE/PA and rPE/PET, ***PCR***

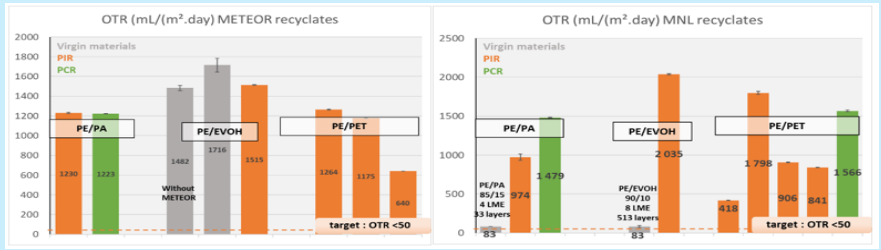
Upgraded rPE/EVOH, rPE/PA, rPE/PET, ***PIR***

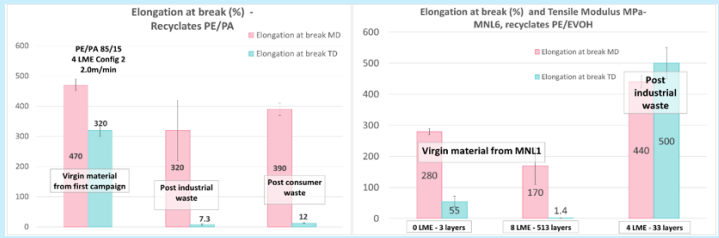


Film production at Laboratory scale at IPC



Results





Poor Oxygen barrier
Decrease in mechanical properties
Can be used in low quality films
Or
Introduction in ML structures

Demonstrators in CIMPA project

*PI : post industrial Recyclates

*PC : post consumer Recyclates

Physical recycling demonstrators, Pre-production scale

Feedstocks

Household waste from Paprec
Sorted by Pellenc ST

Metallized Films, ***PCR***

Physical recycling at TNO

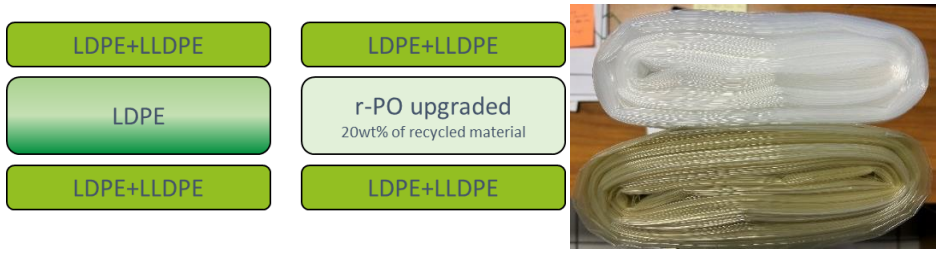
rPO, ***samples***

Upgrading (additivation and stabilization) at VTT

Upgraded rPO, ***samples***

Film production at Pre-production scale at Barbier SAS

Monolayer and multilayer rPO, ***PCR***



Results

Material	Tear Strength MD (N/mm)	Tear Strength TD (N/mm)	Impact resistance (g)
Reference film	58.5	76.9	272.5
10% rPO	75.6	111	208.4

Poor Optical properties
Decrease in mechanical properties
Can be used in food packaging or agriculture films

Demonstrators in CIMPA project

*PI : post industrial Recyclates

*PC : post consumer Recyclates

Mechanical recycling, Pre-production scale

Feedstocks

PE silage, ***PCR,***
From Barbier

PE/PA and PE/PET families, ***PCR***
Household waste from Paprec
Sorted by Pellenc ST

Pretreatment and Decontamination at AIMPLAS

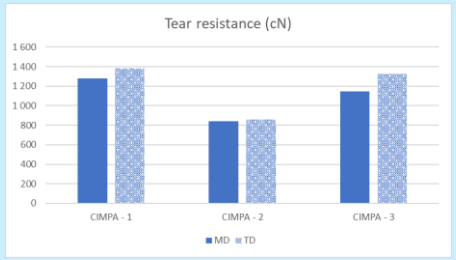
PE/PA and PE/PET families, ***PCR only***

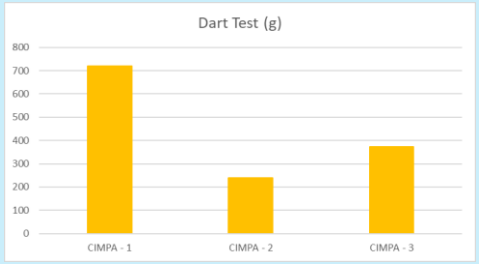
rPE/PA, ***PCR*** rPE/PET, ***PCR*** rPE silage, ***PCR***

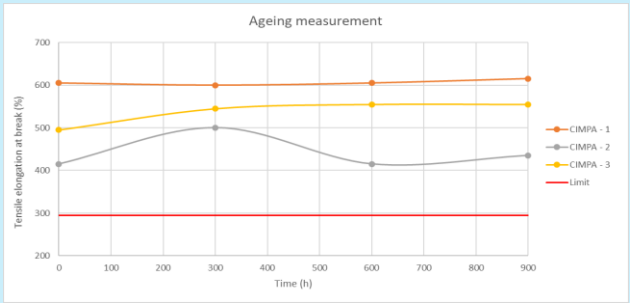
Film production 1st step at industrial lab scale at Barbier

PE	PE	PE
PE + rPE silage 30wt% of recycled material	PE + rPE/PA 30wt% of recycled material	PE + rPE/PET 30wt% of recycled material
PE	PE	PE

Results







Mechanical properties acceptable
Ageing satisfying
Can be used in silage application, medium quality

Demonstrators in CIMPA project

*PI : post industrial Recyclates

*PC : post consumer Recyclates

Mechanical recycling, Pre-production scale

Feedstocks

PE silage, ***PCR,***
From Barbier

PE/PA and PE/PET families, ***PCR***
Household waste from Paprec
Sorted by Pellenc ST

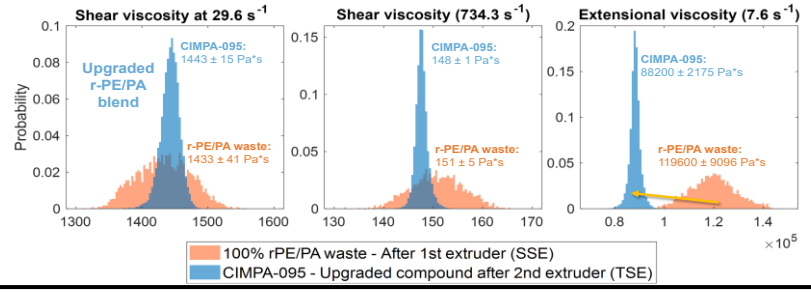
Pretreatment and Decontamination at AIMPLAS

PE/PA and PE/PET families, ***PCR only***

rPE/PA, ***PCR*** rPE/PET, ***PCR*** rPE silage, ***PCR***

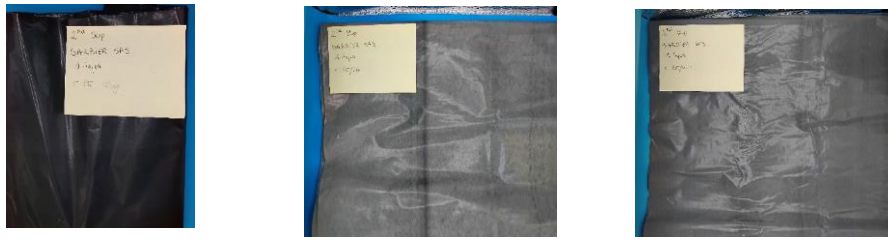
Upgrading (additivation and stabilization) at VTT *PCR*

Upgraded rPE, rPE/PA and rPE/PET, ***PCR***

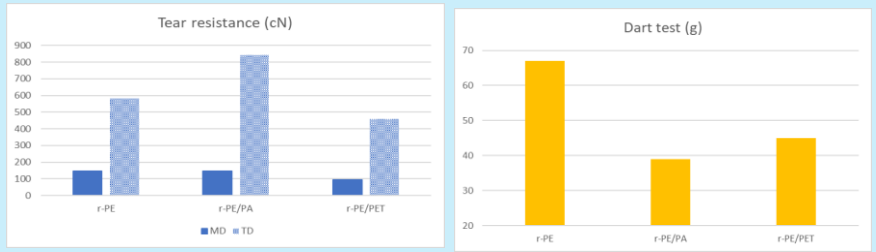


Film production 2nd step at industrial lab scale at Barbier

PE + rPE silage	PE + rPE/PA	PE + rPE/PET
40wt% of recycled material	40wt% of recycled material	40wt% of recycled material



Results



Mechanical properties acceptable for silage applications (but no ageing measured)

Processability of the materials checked

Demonstrators in CIMPA project

*PI : post industrial Recyclates

*PC : post consumer Recyclates

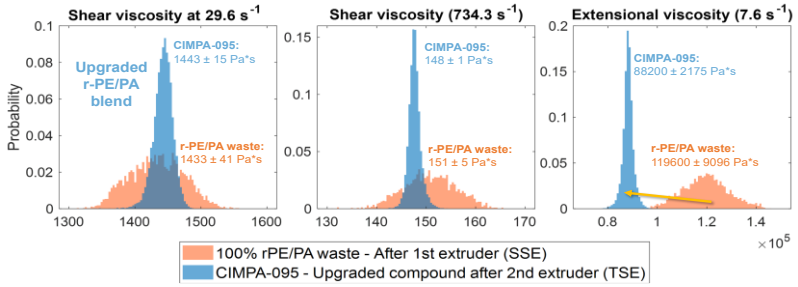
Mechanical recycling, Pre-production scale

Feedstocks

PE/EVOH, PE/PA, PE/PET, ***PIR,***
From Leygatech and Barbier

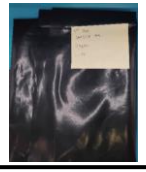
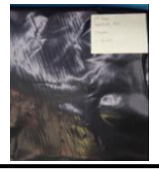
Upgrading (additivation and stabilization) at VTT

Upgraded rPE, rPE/PA and rPE/PET, ***PCR***



Film production 3rd step at industrial lab scale at Barbier

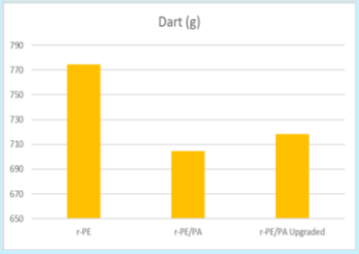
LLDPE	LLDPE	LLDPE
LDPE	PE + non upgraded rPE/PA 40wt% of recycled material	PE + upgraded rPE/PA 40wt% of recycled material
LLDPE	LLDPE	LLDPE

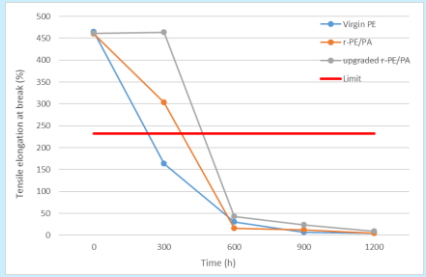




Film production 3rd step at industrial lab scale at Leygatech

$PE+TiO_2$	$PE+TiO_2$	$PE+TiO_2$
Tie	Tie	Tie
EVOH	EVOH	EVOH
Tie	Tie	Tie
$PE+TiO_2$	$PE+TiO_2$+ 10wt% CIMPA r-PE/EVOH	$PE+TiO_2$+ 10wt% non-CIMPA recyclate
Corona-treated side	*Corona-treated side*	*Corona-treated side*

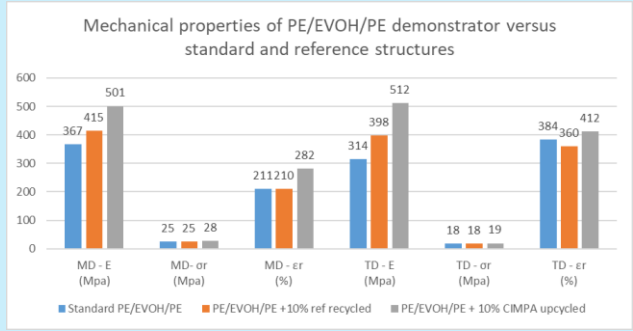

Results





Effect of upgrade seen
Ageing checked
Can be used in silage

Good mechanical properties
Good barrier
Can be used in the original application



Demonstrators in CIMPA project

Physical recycling, Recyclability demonstration and new designs

Feedstocks

Met Films, ***samples, PI (new film)***

From EVERSIA BOPE met

Physical recycling at TNO (TRL4)

rPE, ***samples***

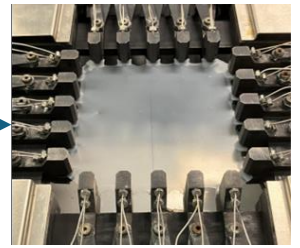
Upgrading (additivation and stabilization) at VTT

Upgraded rPE, ***samples***

Film production at Laboratory scale at VTT

Hot press, ***samples***

Orientation at VTT



Results

Sample	Virgin LLDPE (%)	rPO from TNO (%)	Stabilizer (%)	thickness (µm)	Modulus (MPa)	Strain at break	Elongation at break (%)
CIMPA WP4-12	0	99.85	0.15	41	601	14.6	163
CIMPA WP4-13	10	89.85	0.15	47	426	2.36	96.8
CIMPA WP4-14	20	79.85	0.15	56	423	7.49	309.5

Poor Optical properties
Decrease in mechanical properties
Can be used in food packaging or agriculture films

Demonstrators in CIMPA project

*PI : post industrial Recyclates

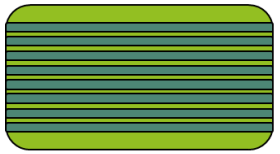
*PC : post consumer Recyclates

Mechanical recycling, Recyclability demonstration and new designs

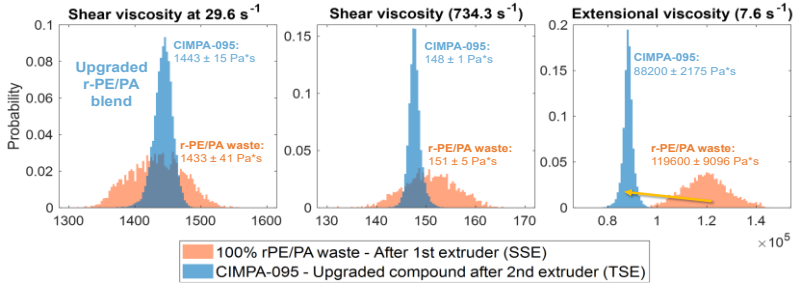
Feedstocks

PE/PA MNL Structure
From IPC

MNL virgin PE/PA



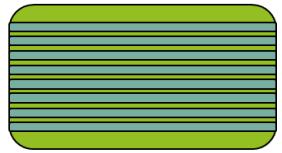
Upgrading (additivation and stabilization) at VTT

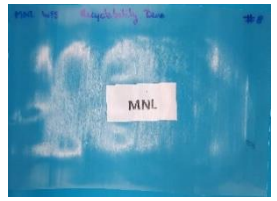


rPE/PA *upgraded at VTT*

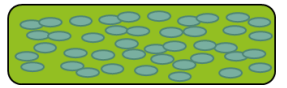
Film production at Laboratory scale at IPC

MNL r-PE/PA

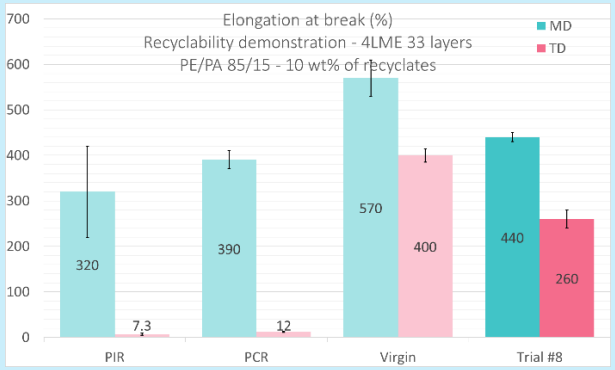


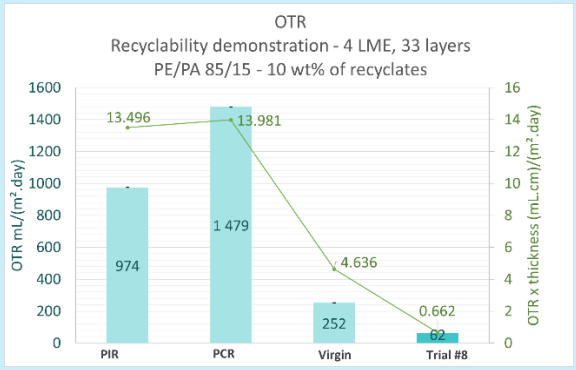


METEOR®



Results





Poor Oxygen barrier

Decrease in mechanical properties

Can be used in low/medium quality films

Or

Introduction in ML structures

Conclusion on demonstrators work

Processability of recycled material demonstrated
Interest of **upgrading** demonstrated

Introduction of recyclates = decrease of **mechanical properties**
Limited amount needed (10-20wt.%, fit with **PPWR targets**)

Physical recycling
The output is a mix of PO (PP, LDPE, LLDPE, HDPE) : more rigid films.
Optical properties can be improved with fine tuning of the process

Mechanical recycling (innovative processes)
Properties not good enough by their own
Adaptation to industrial multilayer process

PCR are compliant with agricultural standards, but optical properties impacts the use on food packaging
PIR can be used in both agricultural films and food packaging applications

Transversal work

Definition of industrial specifications

Consumer and stakeholder engagement

Understand the needs and constraints of the value chain on a technical and economical approach

Circularity-by-design strategies

Food contact assessment and compliance to agriculture standards

Design the right structures to be produced in other WPs according to previous specifications and verify their compliance with their use case.

LCA and LCC analysis

Legislative/ normative compliance

Ensure the relevance of the solutions

Circular and compliant multilayer film for food and agricultural industries

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Do you have any questions? Follow the project updates https://cimpa-h2020.eu/

This project has received funding from
the European Union's Horizon 2020 research and innovation programme
under grant agreement N° 101003864.

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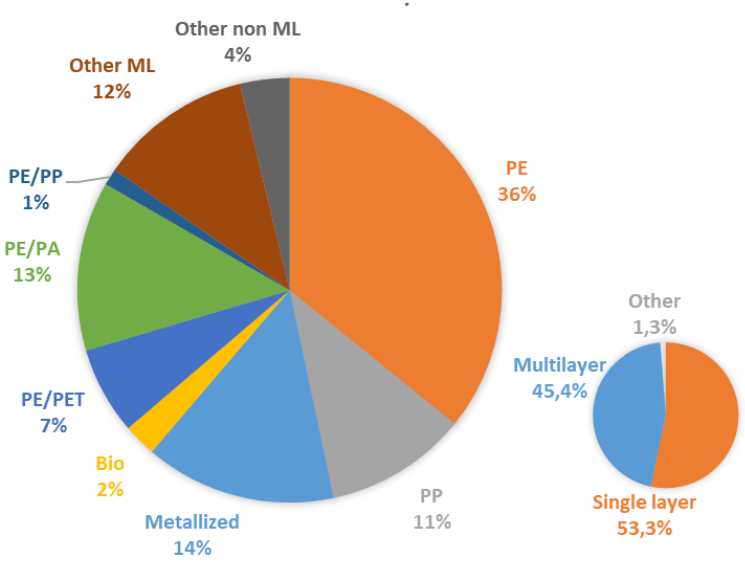
WP2 – Fast and Efficient Sorting for Multilayers

Speakers :
Marien De Lint – Filigrade
Raphael Josselin Verdier – Pellenc ST

CIMPA project, Grant Agreement N° 101003864

Sorting Multilayers in Packaging Waste

Step 0 : Lab Characterization



Characterization of post-consumer packaging waste using Infrared (NIR)

Step 1: Analyze the benefits and difficulties of each technology **alone**

Near InfraRed (NIR)

Watermarking (DW)

Step 2: Sorting Multilayers with NIR and Watermarking **combined**

Step 1 : NIR-Based Detection

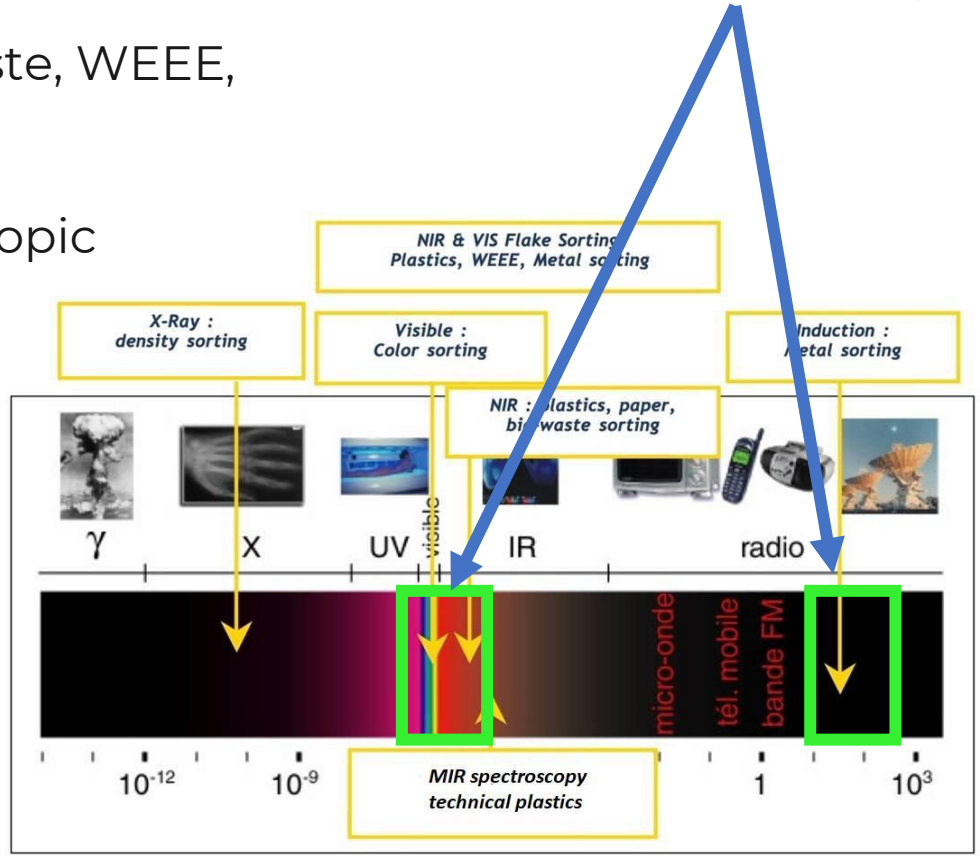
Pellenc Optical Sorter Mistral+ Connect

A multi-purpose optical sorter:
sorting of plastics, paper, cardboard, CDW, biowaste, WEEE, color sorting…

Combines two spectral domains for the spectroscopic detection:

- VIS (Color detection)
  → 400 to 750 nm
- NIR (Organics and polymer detection)
  → 1000 to 2500 nm

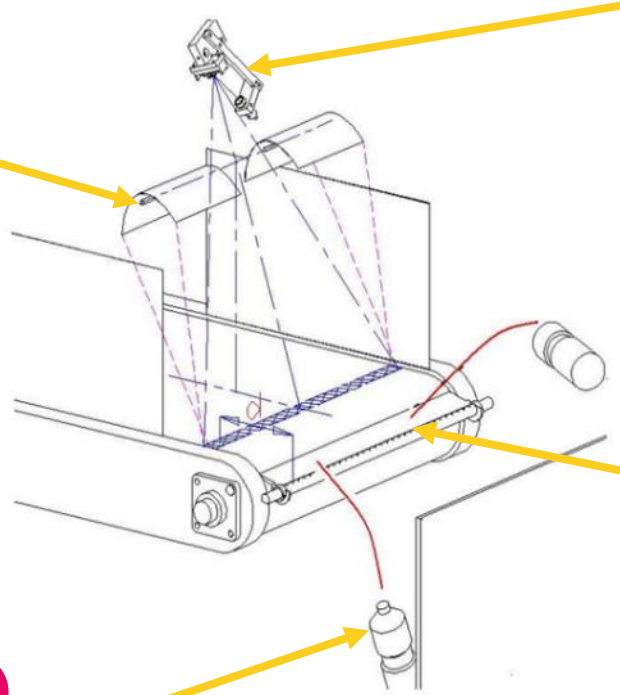
+ Induction detector



NIR Sorting Basics

1. Halogen reflectors create a 2cm-wide focused line of detection

2. Each product is analyzed by our spectrometer



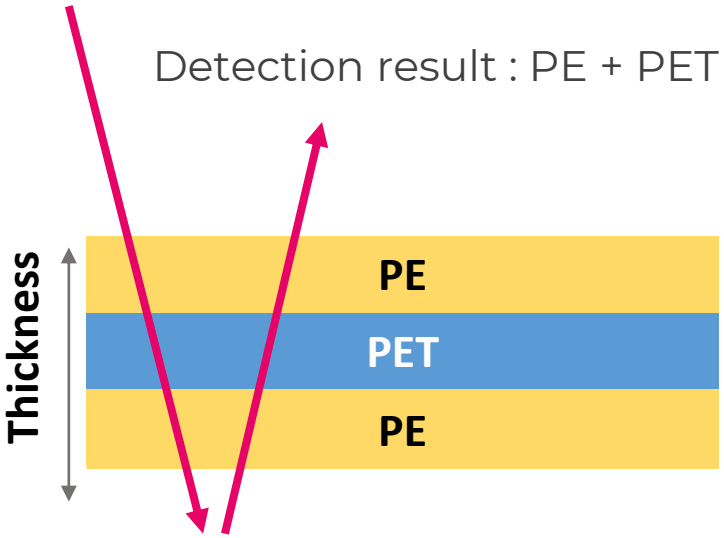
3. Each object's spectrum is computed and compared to our database

4. The PC triggers the solenoid valves

5. Objects are blown upwards, downwards or not blown

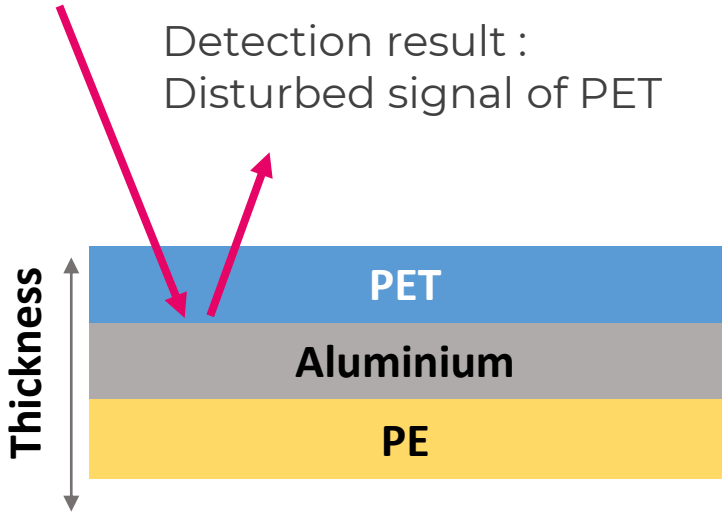
Multilayer Detection Limitations

Detection result : PE + PET



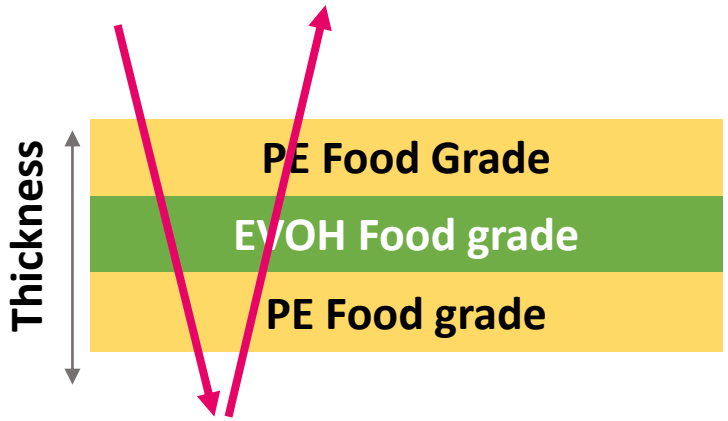
→ NIR Detection OK
→ Same for PE/PA structures

Detection result :
Disturbed signal of PET



→ NIR detection disturbed, the film will be sorted with all metallized films

Detection result : PE Only



→ EVOH not detected
→ Food grade sorting impossible

NIR Takeaways

- High reliability of distinction of PE/PA and PE/PET Structures from mono-material structures.
- Good sorting efficiency on these categories : >90%
- All metallized films were gathered in one “family” of multilayers thanks to Mistral+ induction sensor.
- NIR detection has intrinsic detection limits

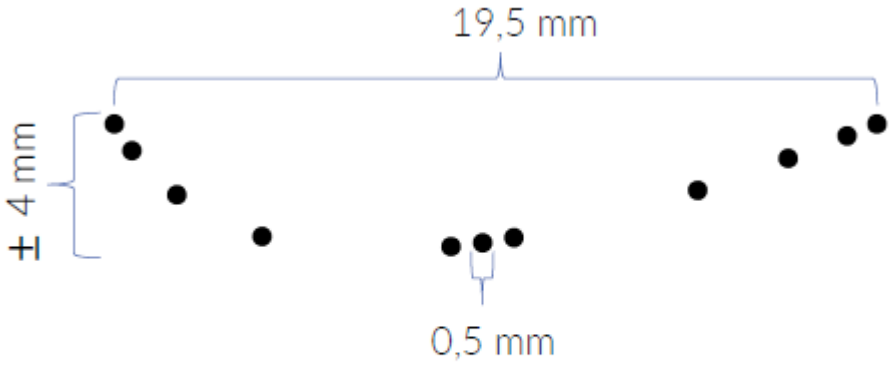
Digital Watermarks (DW) Detection

Basics of Curvcode Digital Watermarks

- Code is always 19,5 mm wide
- Nearly invisible in 3D and 2D
- CurvCode does not need, store or use any sensitive brand-owner data!

Applications targeted :

- **Type of material:** PET, PP, HDPE, paper laminate, multilayer, cardboard, etc
- **Food, non-food and hazardous**
- **Color:** transparent, white, black, carbon black, other colors
- **Layers**: single, multilayer composition



Code for: PET, neutral transparent, single layer, food

2D CurvCode for PRINT

This design contains 55 CurvCode markers with large range of visibility to human eye.

However, machine detection rates of different types of CurvCode markers are similar!

Examples: CurvCode Packaging

rPET
TRANSPARENT
SINGLE LAYER
FOOD

PAPER
SINGLE LAYER
FOOD

PE-EVOH-PE
MULTI LAYER
FOOD

rPET
BLACK CARBON
SINGLE LAYER
NON-FOOD

PVC + ALU
MULTI LAYER
HA**ZARDOUS**

Digital Watermark Detection Takeaways

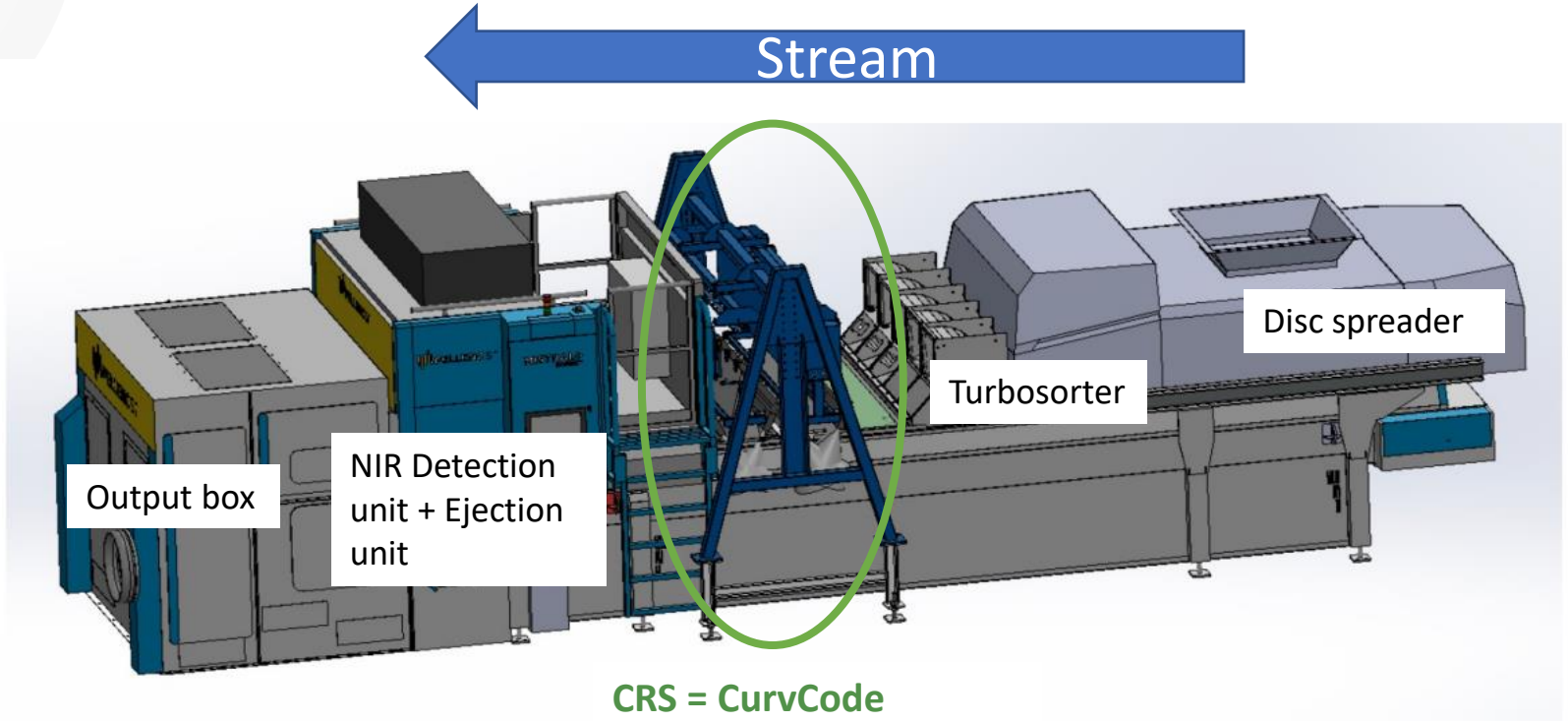
- CurvCode enables cost-effective application of 2D digital watermarks to multilayer packaging using common printing techniques.
- No false positives: Curvcode Reading System does not attempt to blow any unmarked packaging
- Results :

(Belt speed At 3 m/s)	#1 Porsi	#2 Boqueron	#3 Cauliflower
Detection rate	100 %	100%	100%
(Baseline) sorting efficiency	87%	93%	90%
Industrial sorting efficiency	Not good enough		

Comments: sorting efficiency is **almost good enough**, but in optimal conditions.
=> Combination with NIR is necessary to achieve better and robust results

Step 2: Combining NIR and DW

Combined Sorting Prototype



CRS = CurvCode Reading System DW

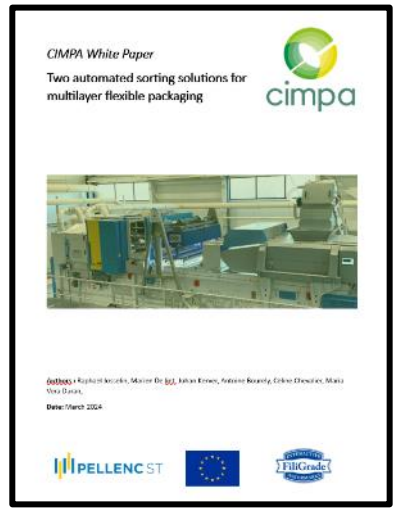
✓ **CRS** is designed to be easily implementable above conveyor belts in MRFs

Strong Sorting Results Achieved

(Belt speed At 3 m/s)	#1 Porsi	#2 Boqueron	#3 Cauliflower
(Baseline) Detection rate	100 %	100%	100%
(Baseline) Sorting Efficiency	98 %	98%	97%
(Industrial) Sorting Efficiency	~90% sorting efficiency in one step		

- Sorting efficiencies are significantly **better** using NIR+DW mode compared to DW alone.
- **In November 2023, a cascaded series of tests yielded efficiency and purity levels of 99%+ in several sorting steps.**

White Paper released in March 2024


CIMPA White Paper

Two automated sorting solutions for multilayer flexible packaging

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PELLENC ST

Future of NIR + DW Prototype

→ Filigrade and Pellenc ST are still working together. The goal is to achieve predictable and robust sorting performance under dirty/soiled conditions.

→ This technology enables new opportunities, beyond CIMPA **:**

- Negative sorting (removing unwanted materials from waste-stream). Ie. Toxic products
- Captive value chains (hospitals, food-service, airports, etc)
- High-value luxury branded (physical) goods (product authentication and counterfeit-protection using CurvCode technology)
- …

How to unlock NIR + DW sorting solution

→ Value chains need to agree on common standards for adopting digital watermarking technologies

→ Legal and regulatory frameworks are needed to use these new technologies

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multilayer films

Thank you for your listening

Any questions ?

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the European Union's Horizon 2020 research and innovation programme
under grant agreement N° 101003864.

CIMPA FINAL EVENT

Advancing the circularity of complex plastic films

20 November 2024
14:00-18:00
BluePoint Brussels

COFFEE BREAK

15:30 -16:00

Hosted by EuR1C

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Funded by the European Union

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CIMPA Decontamination Solutions

Final Event

Brussels, November 20th.

CIMPA project, Grant Agreement N° 101003864

Waste decontamination

One of the great limitations of placing **recycled plastic** materials on the market is the possibility that they present certain amounts of **polluting substances** that may cause alterations in the properties of the plastics, **safety** issues and rejection by consumers (bad **odors**).

Advantages for multi-layer recycling:

- ✓ Increase consumer acceptance of recycled plastics.
- ✓ Eliminate, or reduce, the presence of substances that may imply certain limitations or safety issues.
- ✓ Obtain a high-quality recycled material for close or open-loop applications.

Decontamination in CIMPA:

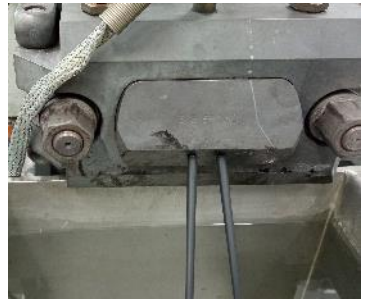
1. Multiple-step decontamination of pre-consumer and post-consumer multilayer films.
2. Develop of a custom decontamination strategies in term of process conditions, according to the type of material.
3. Use of specific stripping agents to maximize volatile removal.

Pilot testing in CIMPA

Process of devolatilization of agricultural film (post-consumer)

Shredding and initial washing → Re-grinding and second washing + drying → Decontamination in TSE → Decontamination in tandem → Testing (VOCs)




Waste decontamination

Post-consumer decontamination

Methodology:

Decontamination of the following samples:

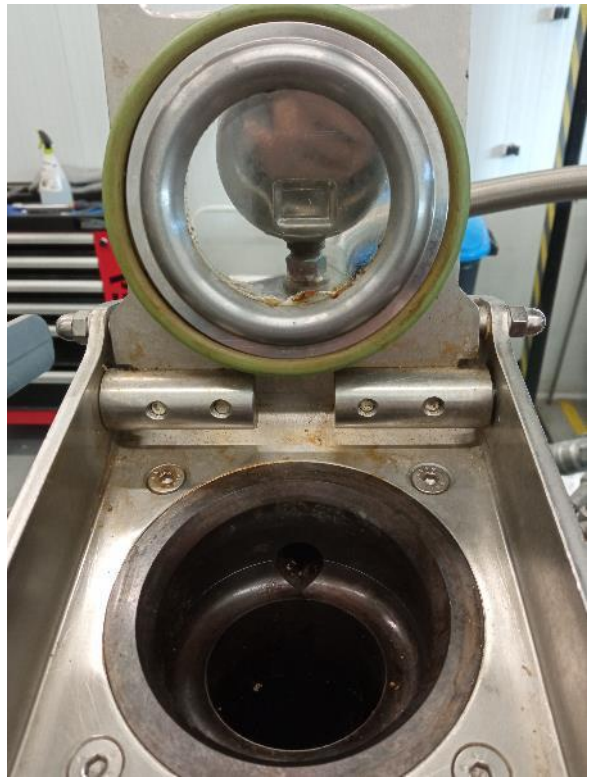
- PE/PET (Pellenc)
- PE/PA (Pellenc)
- Monolayer PE silage films (PAPREC – Barbier)

Twin-screw extruder with L/D ratio up to 56, with and without ScCO2.

One-step additivation: stabilizer and acid scavenger.

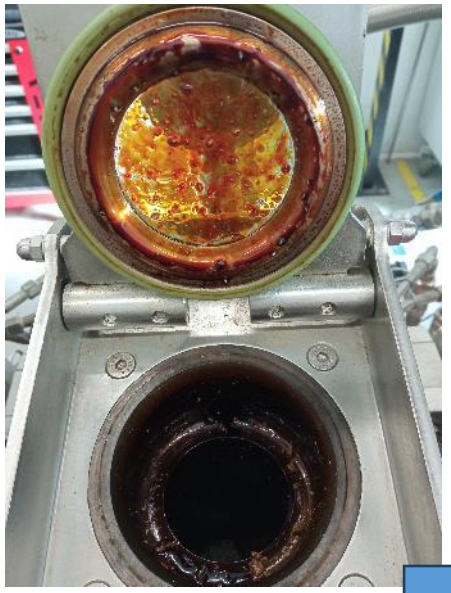
Waste decontamination

Post-consumer decontamination

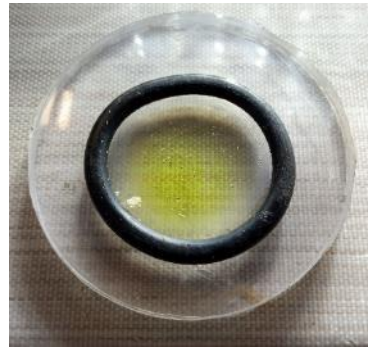


Before starting

At the end of process



TSE



Tandem

Sumary and results

The aim is to reduce the VOCs content, reduce odor and improve the mechanical properties of the material.

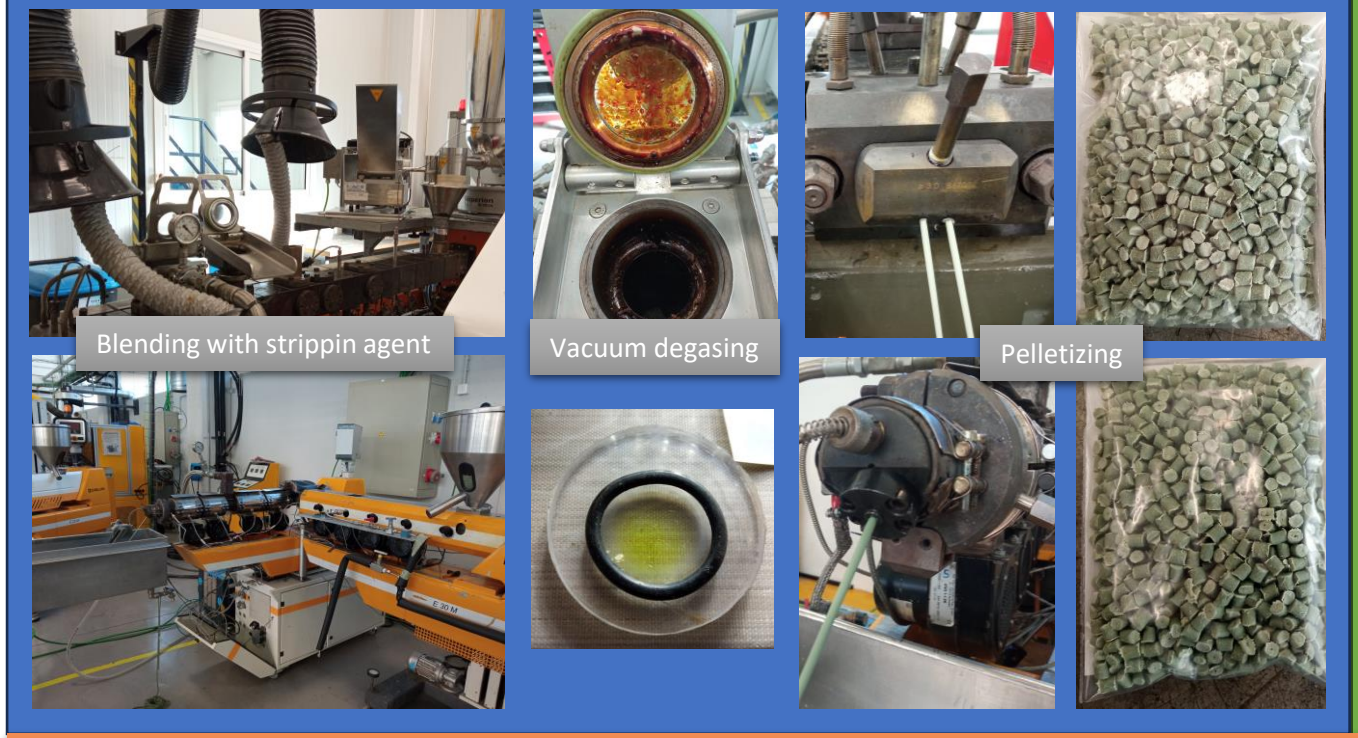
Different strategies have been assessed on pre-treated materials (pre-consumer and post-consumer), studying the efficiency of different stripping agents, process conditions, equipment in the TVOC reduction of each tested materials.

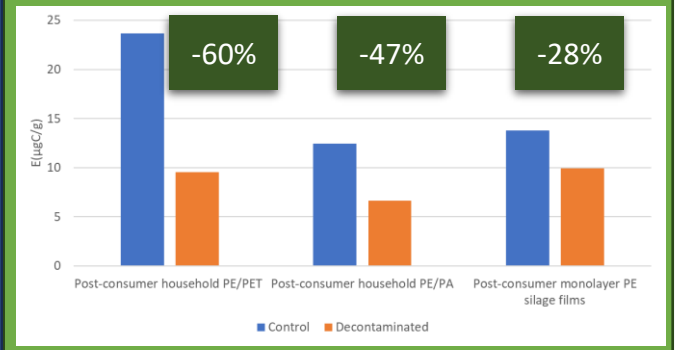
Process

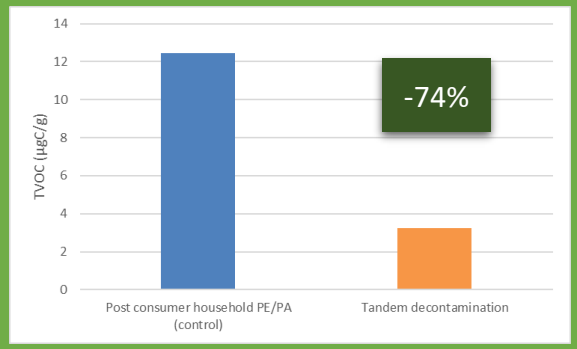
Results

Conventional devolatilization: TSE

Special devolatilization: Tandem SSE







With both process VOC content is **below target of 10µgC/g**

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VAREX: In-line rheology control and upgrading of multi-layer recyclates

VTT

Final event of CIMPA project

Brussels, 20th November 2024

Dr. Ilkka Rytöluoto (VTT)

CIMPA project, Grant Agreement N° 101003864

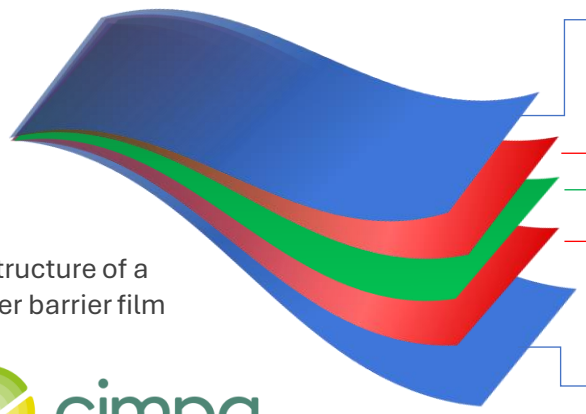
Challenges in multi-layer (and *multi-material*) plastics upgrading

In CIMPA:

Multi-layer plastic waste
(sorted, washed, shredded & decontaminated)

→ Mechanical recycling
→ Solvent-based physical recycling

→ **Recycled plastics** (or polymers)



Typical structure of a multi-layer barrier film

- **PE, PP** (moisture/chemical barrier)
- **Tie layer** (adhesion)
- **EVOH, PA** (oxygen barrier)
- **Tie layer** (adhesion)
- **PE, PP** (moisture/chemical barrier)

After mechanical recycling:

→ **Recycled multi-material blend**

"Heterogeneity challenge"

Significant quality variation within and between material batches.
(e.g., MFI and melt flow properties)

Pre-determined (fixed) additivation may be insufficient for compensating batch fluctuation issues!

"Multi-material challenge"

Incompatibility of different polymeric components.
(Need for compatibilizers and other additives)

VAREX upgrading of multi-layer recyclates

VTT's VAREX is an advanced mechanical recycling pilot line with adaptive in-line viscosity control for stabilizing and upgrading the rheological and final properties of recycled multi-layer and multi-material films.

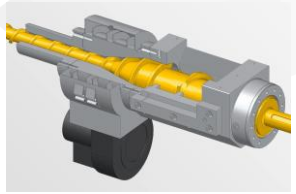
Advantages for multi-layer recycling:

- ✓ Match the material specifications and rheological properties for conversion.
- ✓ Counteract the detrimental effects of feedstock quality variations and polymer degradation by smart additivation.
- ✓ Significant increase in recycling rates and enhance the circularity of plastic packaging.

VAREX process at TRL5–6 in CIMPA:

1. Adaptive stabilization of **physically recycled** polyolefins (r-POs) recovered from complex multi-layers.
2. **Compatibilization** of multi-material polymer blends (e.g. r-PE/PA) for **mechanical recycling**.
3. Tailoring **melt-flow properties** to ensure processability of upgraded recyclates back into **prototypes**, **demonstrators** and **high-value products.**

VAREX extrusion line components



Polymer in (Feeder 3)

- Plastic waste
- Recycled polymer

Single screw extruder (NGR E:GRAN)

Melting, filtration and feeding of plastic waste

Screen exchanger/ Melt filtration unit

1st in-line elongational rheometer

MFI_{in}

Adaptive software controller

- Process values from the extrusion line to controller
- New feeder set points from controller to extruder

Twin-screw extruder

F_3

2nd in-line elongational rheometer

Upgraded plastic

Stabilized recycled plastic with upgraded rheological properties

$\eta_{shear} + \eta_{ext}$

Shear and extensional viscosity properties

F_1

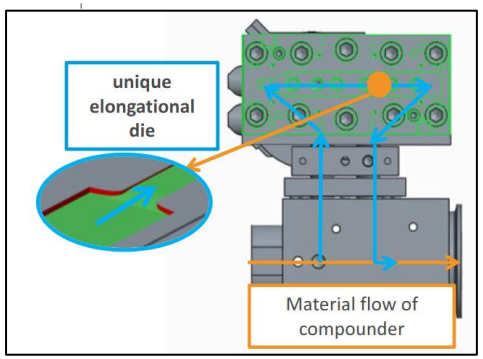
F_2

Feeder 1

Feeder 2

Feeder 3...

Virgin polymers, additives, stabilizers, compatibilizers etc.



+ In-line spectroscopy

Process values:

MFI_{in} Input material MFI/viscosity

F_1 F_2 Feeder set points

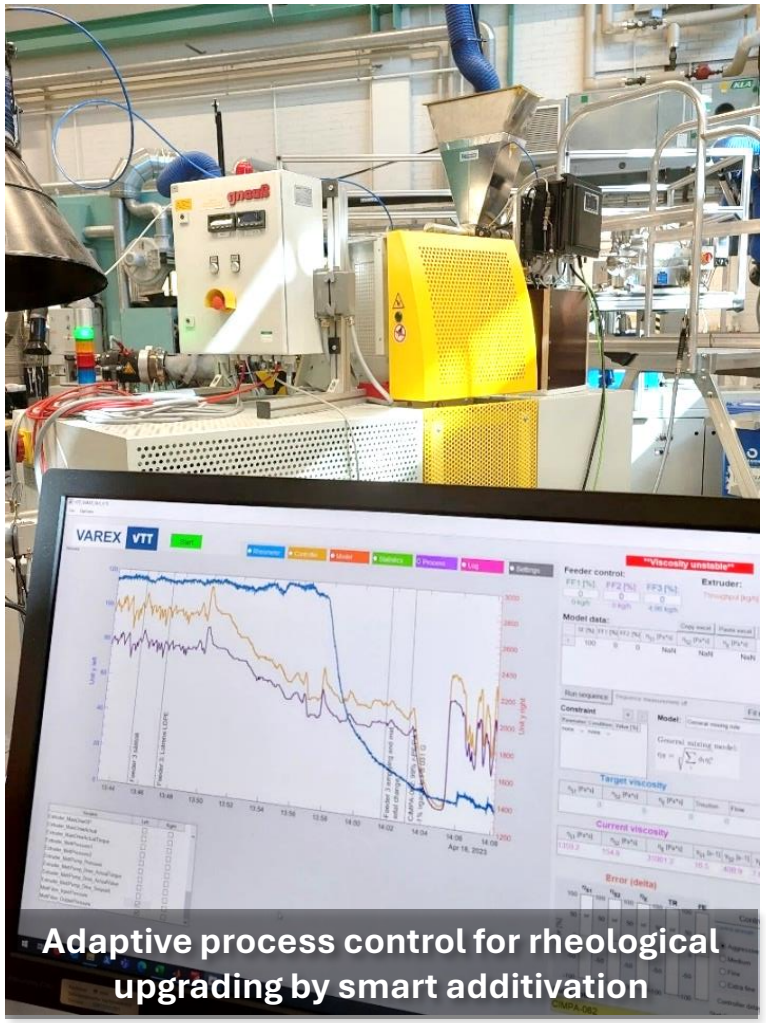
$\eta_{shear} + \eta_{ext}$ Measured shear and extensional viscosities (+MFI)

Signals and material flow:

- Process values
- Bi-directional communication between extruder and controller
- Material flow

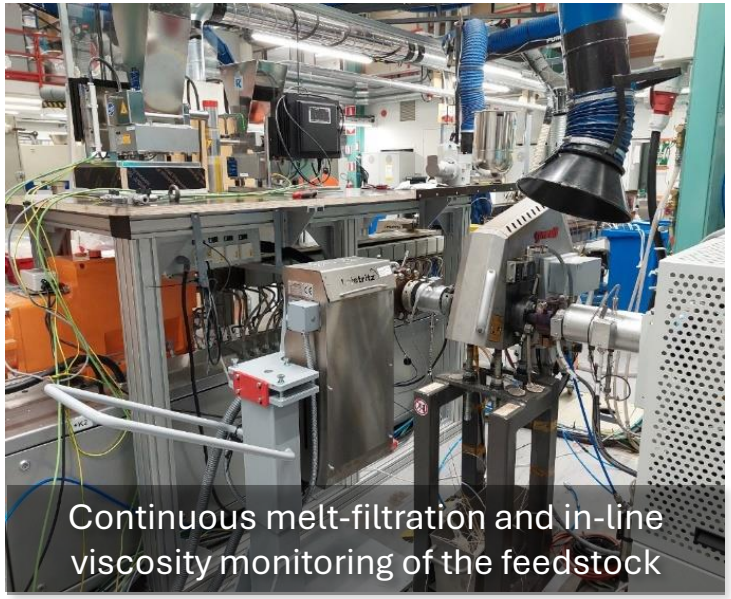
VAREX pilot extrusion line with in-line rheology control

Feeding of multi-layer plastic film waste



Adaptive process control for rheological upgrading by smart additivation

Extrusion and pelletizing for downstream processing



Continuous melt-filtration and in-line viscosity monitoring of the feedstock

Rheology upgrading of recycled multi-layers in CIMPA

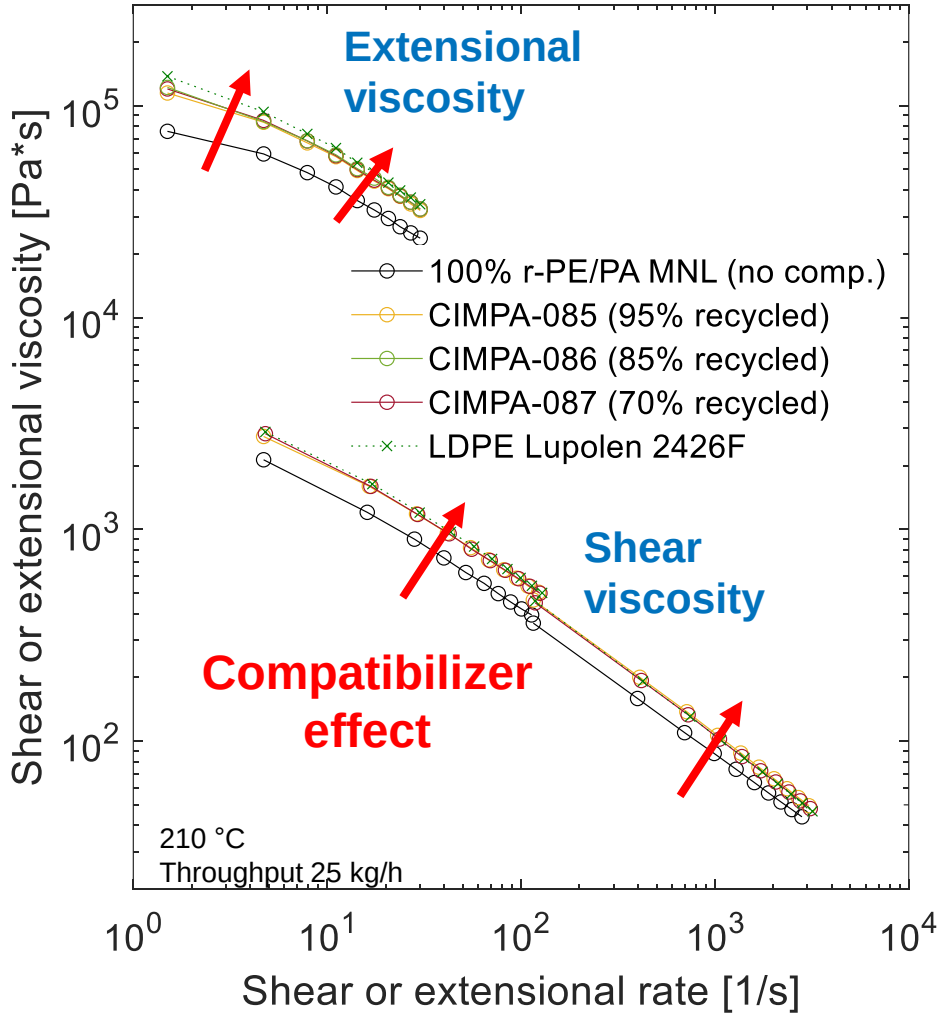
CIMPA feedstocks for upgrading
(up to 100+ kg scale at TRL 6).

Post-consumer r-PE/PA, r-PE/PET and r-PE (agricultural) multi-layer films

Post-industrial r-PE/PA, r-PE/EVOH and r-PE/PET multi-layer films

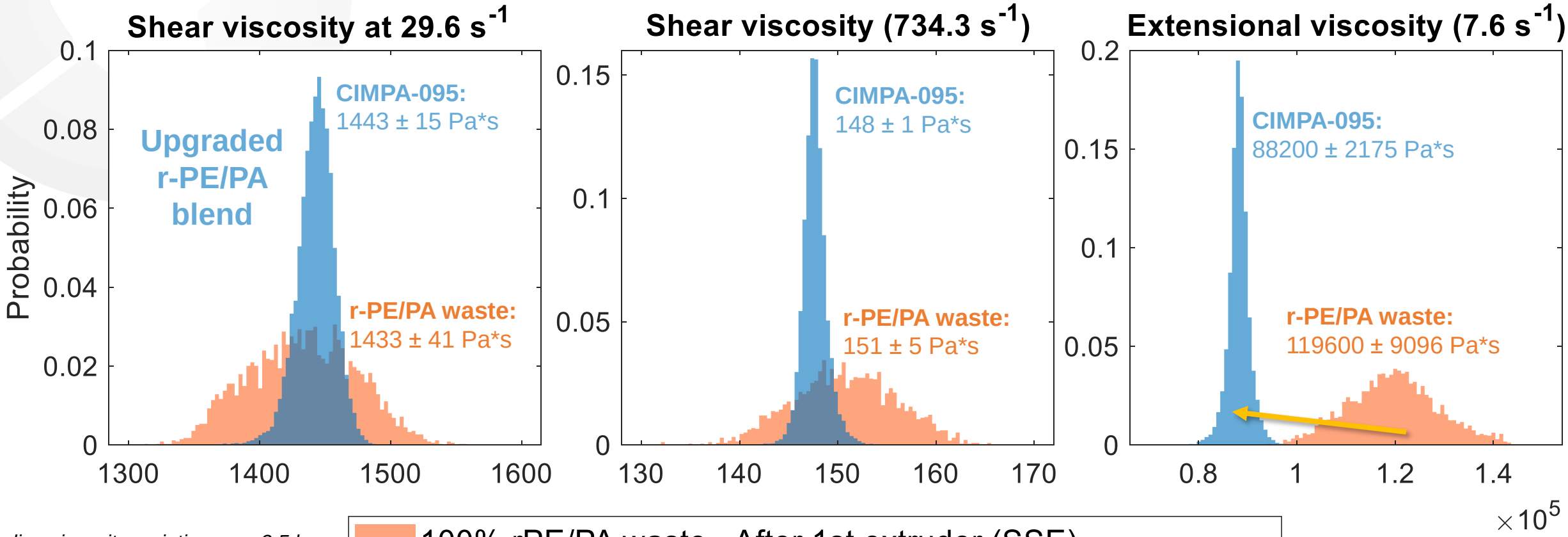
Physically recycled polyolefins from complex multi-layers

Virgin-material-based model compounds
(L-/LDPE, PA6-66, EVOH, PP, PET etc.)



In-line viscosity profiles during mechanical recycling & upgrading of CIMPA PE/PA multi-nanolayer prototype.

Melt flow stabilization of recycled PE/PA waste



In-line viscosity variation over 3.5 h production trial at 25 kg/h throughput.

- ✓ Stabilization of rheological properties of mechanically recycled r-PE/PA multi-layer waste during VAREX process (100+ kg scale).
- ✓ **The upgraded blend shows improvement in viscosity profile homogeneity.**

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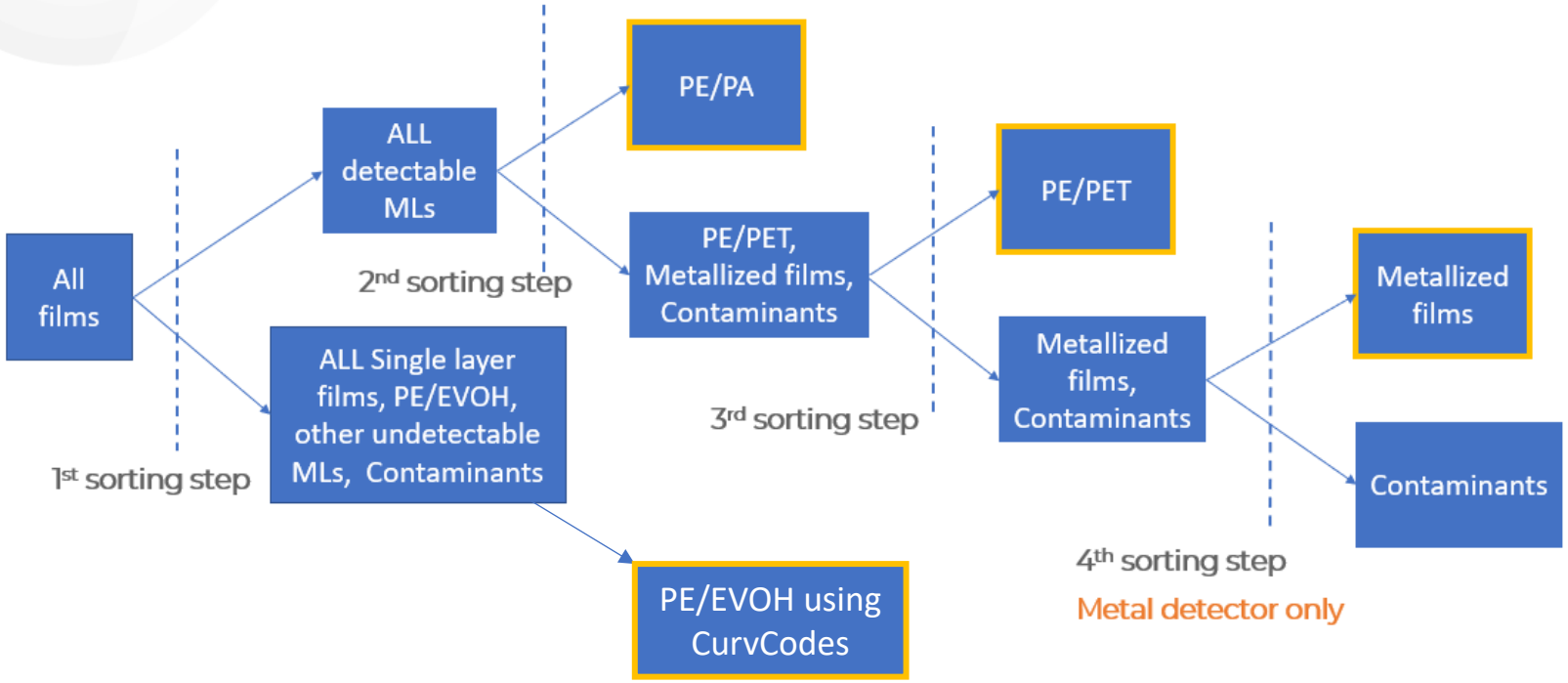
Recycling technologies : mechanical and physical recycling

CIMPA project, Grant Agreement N° 101003864

Post-Consumer Recyclates Families after sorting



4 families :
PE/EVOH, PE/PA and PE/PET : **mechanical recycling**
Metallized films : **physical recycling**

Physical recycling of multi-layer films

In CIMPA, the **physical recycling** route focusses on dissolution and precipitation of the polyolefin (PO) contained in those multilayer films where mechanical recycling leads to a low-quality product.

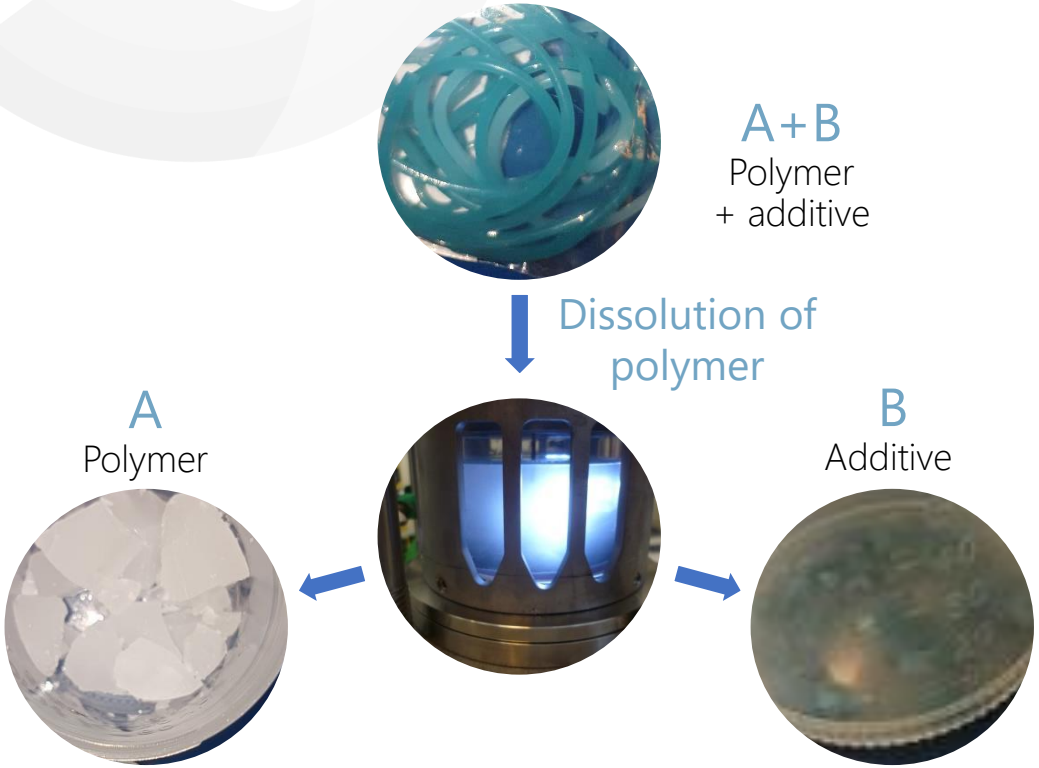
Advantages for multi-layer recycling:

- ✓ Selective recovery of PO while all non-PO materials, colorants and impurities are removed.
- ✓ High quality product for high-value applications.
- ✓ Enhance the circularity of plastic packaging with value retention of end-of-life multilayer films, especially the non-mechanically recyclable streams.

Physical recycling in CIMPA:

1. Recovery of PO from “non-mechanically” recyclable foils, e.g. metallised foils
2. Dissolution technology scale-up from TRL4 (100g scale) to TRL5 (kg scale)
3. r-PO will be recompounded with aim at food contact applications

Physical recycling by employing TNO Möbius dissolution technology

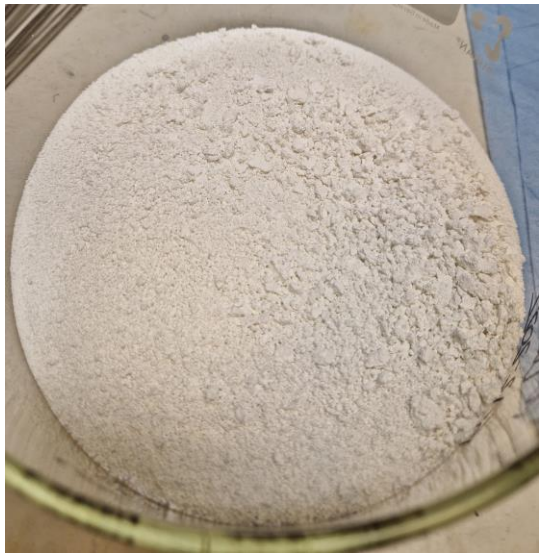


- **Characteristics**:
  - Feedstock: sorted & cleaned waste plastics
  - Use of single superheated solvent to dissolve polymer
  - Low viscosity solution enables filtration and sorption for additive/impurity removal and recovery
  - Polymer precipitation and evaporation of solvent
  - Energy efficient solvent recovery
  - To be developed as continuous process (small hold-up) 10-20 kta

Physical recycling results in CIMPA

- The feasibility of PO separation from other non-PO materials in the 'complex'/non-mechanically recyclable multilayers was demonstrated by using TNO Möbius dissolution technology at TRL4 and scaled-up to TRL5.
- A high quality white product recovered with a high process yield at TRL4 (up to 90% of PO present in the film); yield to be optimized at TRL5.
- Product analysis showed that all non-PO materials were removed, including the majority of stabilizers.
- Therefore, the recovered PO should be recompounded with re-addition of stabilizers.

Metallised multilayers

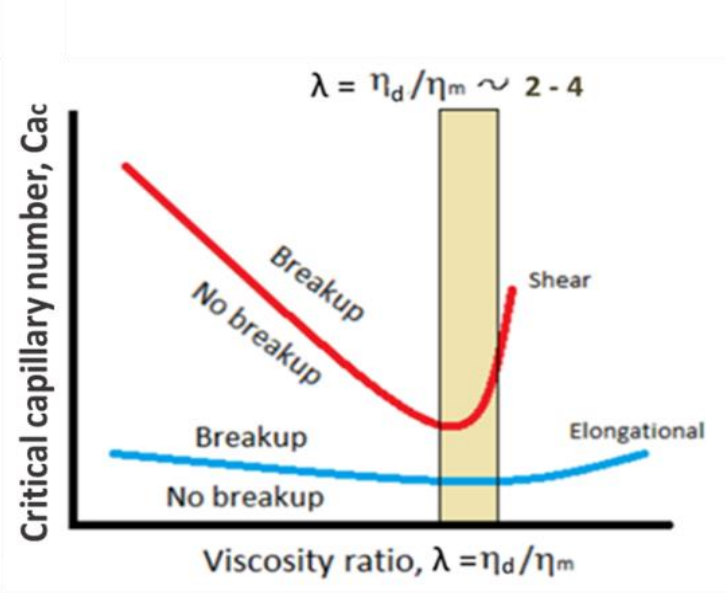


Recovered polyolefins

PO recovery with TNO Möbius technology successfully demonstrated at TRL4 and scaled-up to TRL5 (kg scale).

METEOR® : The Concept

Capillary number : describe a dispersive mixing quality or efficiency



Higher efficiency of elongational flow fields to sustain dispersive mixing in comparison to shear flow, especially when $\lambda > 2$

Grace, H. P. (1982). Dispersion phenomena in high viscosity immiscible fluid systems and application of static mixers as dispersion devices in such systems. Chem. Eng. Commun., 14, 225-277.

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Mechanical recycling: The METEOR® Pilot line

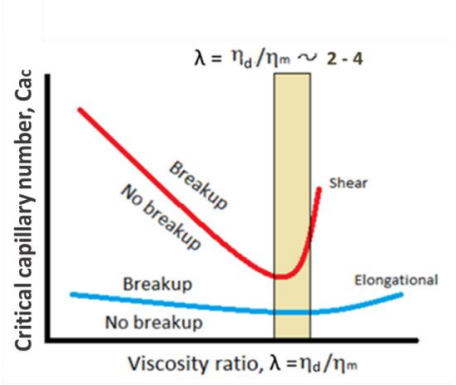
Continuous Extensional Flow Mixer METEOR®

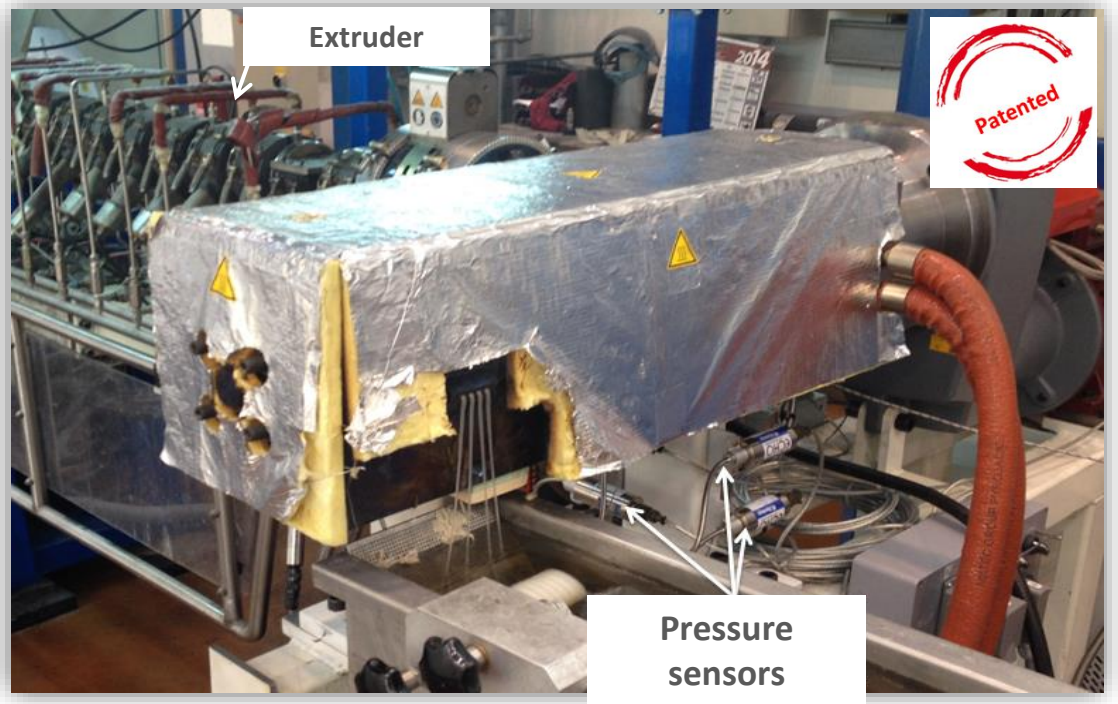
Patent n°1656930 (B1), 23/11/2018, *S. Mani, L. Pivard, H. Duthel*

Original design of screw and barrel → **Strong extensional strain** → **Recombination of the flow**

High quality of dispersive and distributive mixing, with…

- Modular screw and barrel design for **flexibility**
- Real-time **process data** supervision





Meteor® mixing technology bring together all the benefits of recycling and successful compounding in one process

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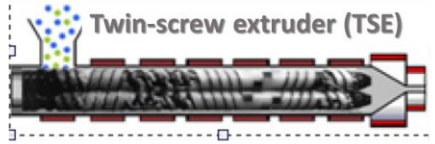
Mechanical recycling: The METEOR® Pilot line

METEOR® as valorization tool in the scope of CIMPA

Films based on representative model blends → **Films based on industrial and post-consumption wastes**

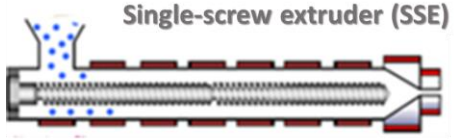
1



LDPE/EVOH with and without compatibilizers

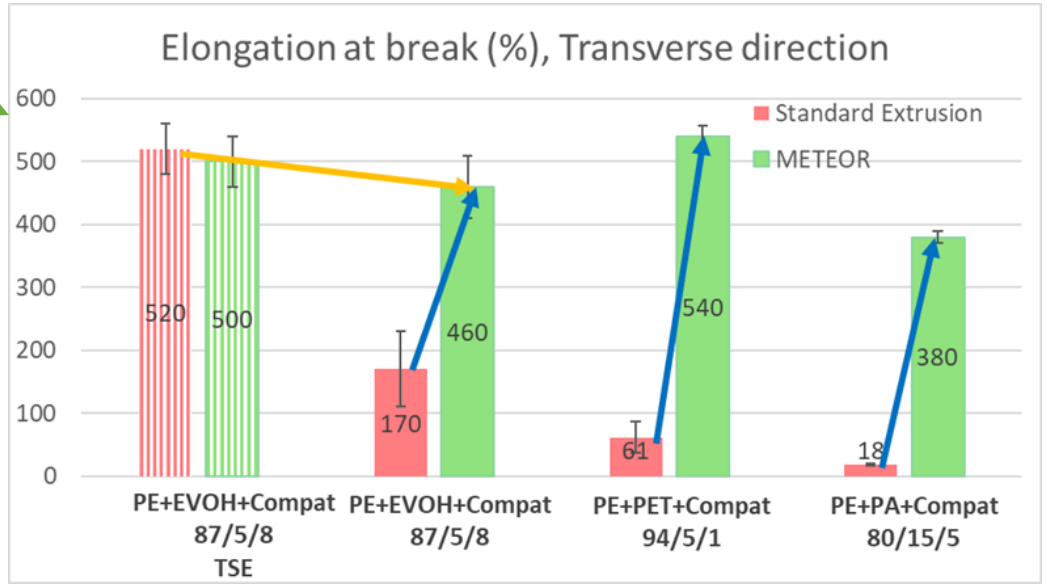
+

2



LDPE/EVOH, LDPE/PA and LDPE/PET with and without compatibilizers

METEOR/Cast film line

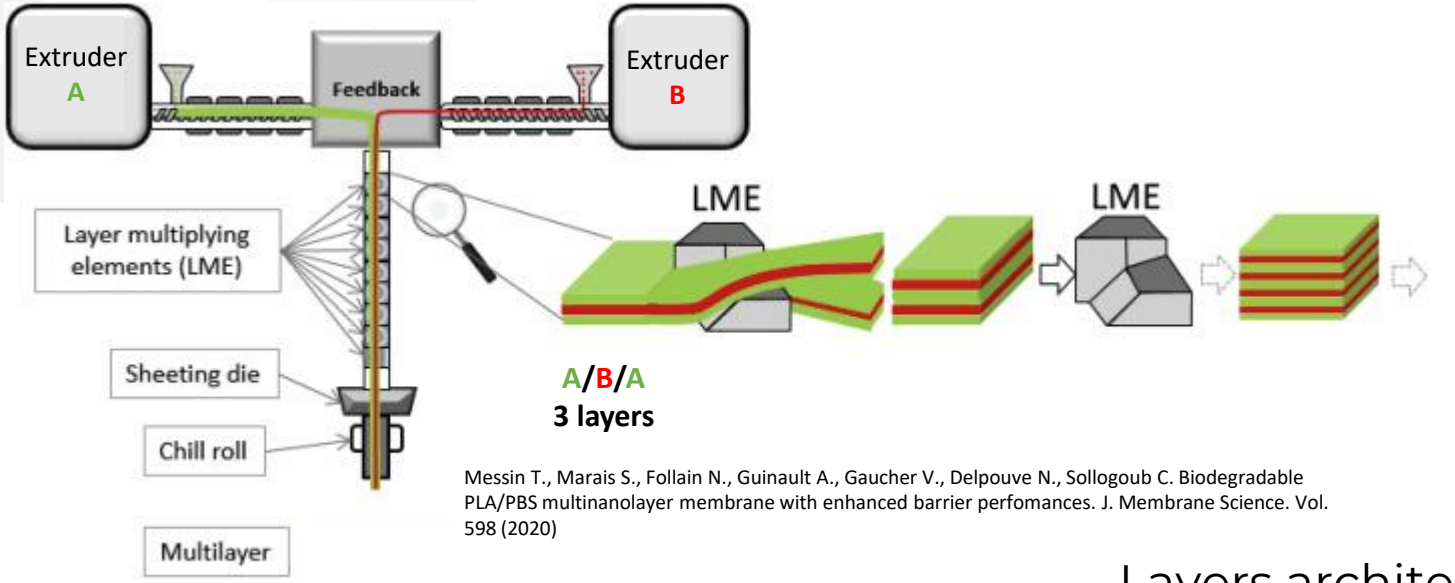


Tremendously high elongation at break (TD) when employing METEOR®+SSE

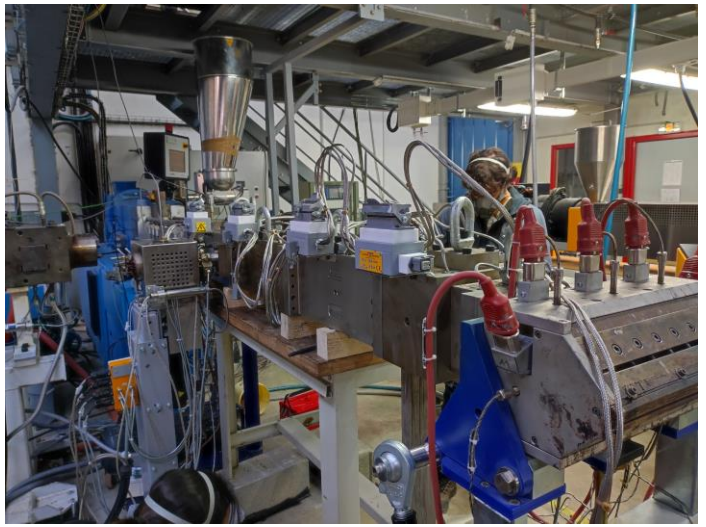
In this context, METEOR®+SSE is pretty much equivalent to that of TSE

Mechanical recycling: MNL (Multinanolayering) process

Principle



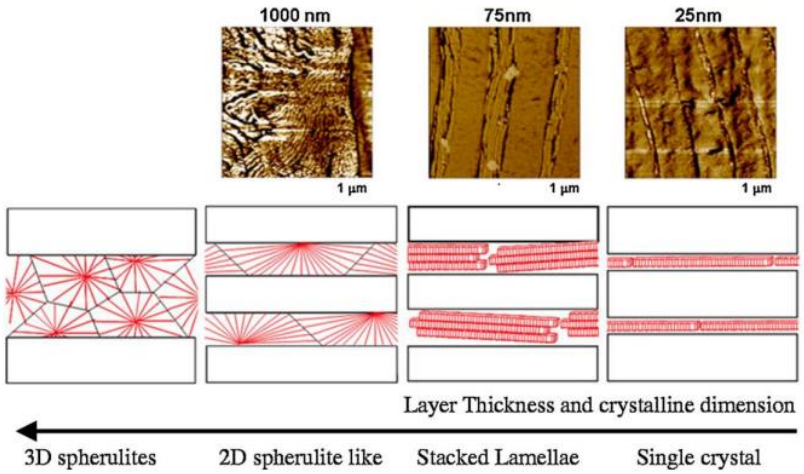
Messin T., Marais S., Follain N., Guinault A., Gaucher V., Delpouve N., Sollogoub C. Biodegradable PLA/PBS multinanolayer membrane with enhanced barrier perfomances. J. Membrane Science. Vol. 598 (2020)



Layers architecture:
A/B
A/B/A
A/B/C/B/A

Number of layers
$= 2^{N+1}$
$= 2^{N+1} + 1$
$= 2 * 2^{N+1} + 1$

N= number of multiplier elements



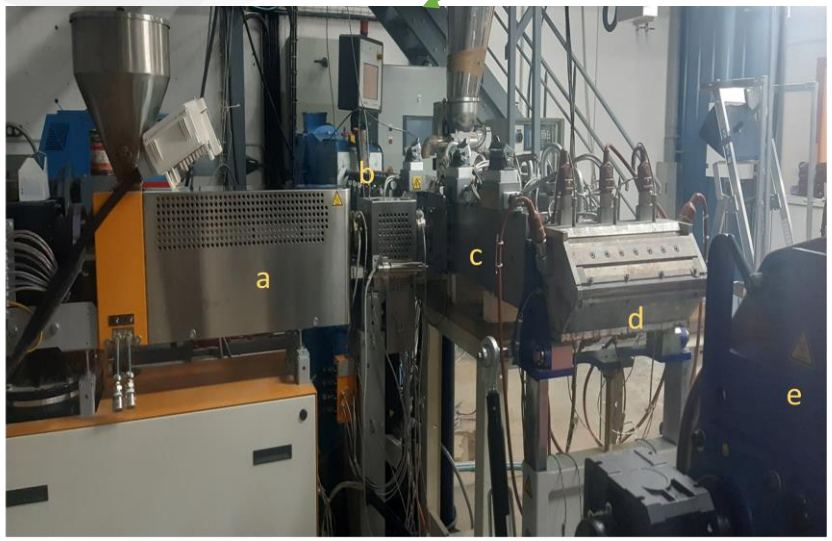
Carr J.M. Langhe D.S. Ponting M.T. Hiltner A. Baer E. Confined crystallization in polymer nanolayered films: A review. J. Mater. Res. Vol. 27 No. 10 p. 1326-1350 (2012)

- Maximum multiplier element: **10**
- Maximum number of layers : **4097**
- Possibility to add external layer before the exit (=**encapsulation**)

Mechanical recycling: MNL (Multinanolayering) process

MNL as valorization tool in the scope of CIMPA

Films based on representative model blends → **Films based on industrial and post-consumption wastes**

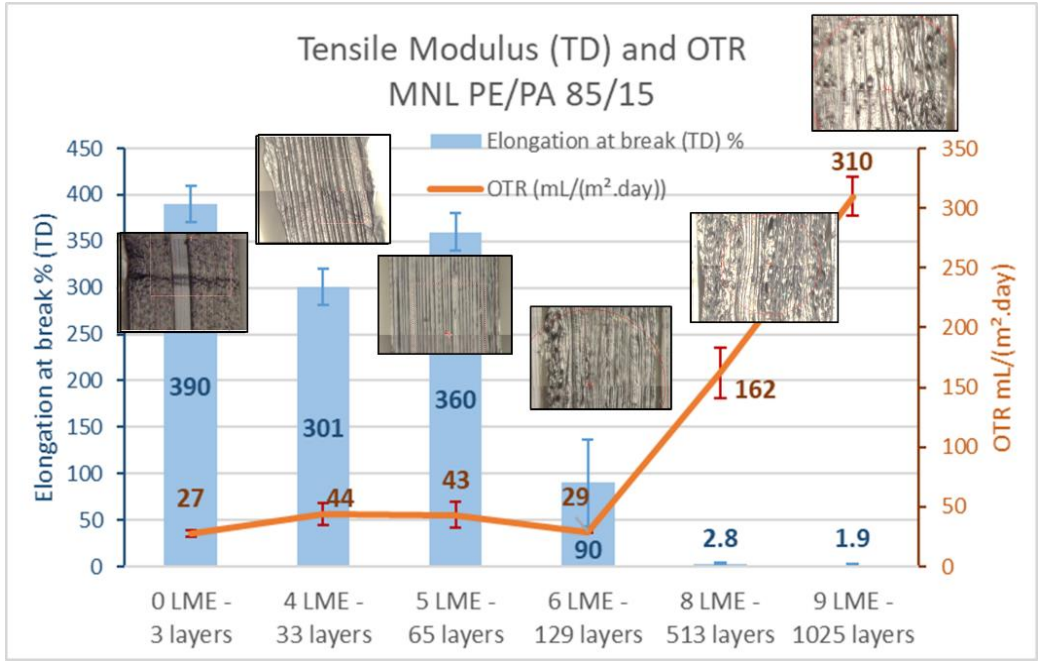


a. *Single-screw extruder*
b. *Twin-screw extruder*
c. *MNL unit*
d. *Cast film die*
e. *Chill roll → winding system*

Polymer systems:
- *LDPE/EVOH*
- *LDPE/PET*
- *LDPE/PA*

Starting layer arrangement: A/B/A
- *LDPE/EVOH/LDPE*
- *LDPE/PET/LDPE*
- *LDPE/PA/LDPE*

Effect of the layers' number on the barrier properties against oxygene for a LDPE/PA pair at fixed LME configuration and winding speed



Effect of the number and the localization of multiplying element on the mechanical and barrier properties

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a circular
multilayer plastic approach
for value retention of end-of-life
multilayer films

Do you have any questions? Follow the project updates https://cimpa-h2020.eu/

This project has received funding from
the European Union's Horizon 2020 research and innovation programme
under grant agreement N° 101003864.

CIMPA FINAL EVENT

Advancing the circularity of complex plastic films

Circular Plastics Cluster: joining efforts towards the circularity of plastic packaging

CIRCULAR PLASTICS

MERLIN

buddie pack

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Hosted by EuR1O

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Funded by the European Union

European Commission

THE EU RESEARCH & INNOVATION PROGRAMME

2021 – 2027

Research and Innovation

EU R&I Projects: Synergies for Better Impact

Keti Medarova-Bergstrom,
Research Programme Manager,
European Research Executive Agency
(REA / EC)

CIMPA Final event, 20 November 2024, Brussels

European Commission

REA'S CENTRAL ROLE IN HORIZON EUROPE

Pillar I
Excellent science

- European Research Council
- **Marie Skłodowska-Curie Actions**
- **Research Infrastructures**

Pillar II
Global challenges & European industrial competitiveness

- Health
- **Culture, Creativity & Inclusive Society**
- **Civil Security for Society**

CLUSTERS

- Digital, Industry & Space
- Climate, Energy & Mobility
- **Food, Bioeconomy, Natural Resources, Agriculture & Environment**

- Joint Research Centre

Pillar III
Innovative Europe

- European Innovation Council
- European Innovation Ecosystems
- European Institute of Innovation & Technology

Widening participation and strengthening the European Research Area

- **Widening participation & spreading excellence**
- **Reforming & Enhancing the European R&I system**

European Commission

REA B3 - Biodiversity, Circular Economy and Environment

- Coordinating evaluations of submitted proposals
- Preparing Grant Agreements for projects delegated to REA
- Monitoring project implementation and dealing with contractual issues
- Facilitating project clustering and synergies
- Reporting on project management and results to policy Directorate Generals of the European Commission (feedback to policy)

European Commission

EU R&I plastics projects – from packaging to pollution prevention ~ 75 million euro EU contr.

Research and Innovation

Delivering project clustering - how?

Joint activities	•Collaboration on technical tasks / case studies / demonstration activities and knowledge exchange •Collaboration in engaging stakeholders along the value chain •Organising joint communication, dissemination and exploitation activities
Joint outputs	•Joint policy briefs and/or policy recommendations •Summary / conclusions of joint events •Joint contributions to public consultations •Joint reports synthesizing main scientific results
Reporting	•Report on collaborative activities in relevant deliverables, as well as in periodic reports and publishable summary for your EU grant •Inform your project/policy officer for any major dissemination/policy contributions activities

Looking ahead – EU priorities for R&I

Strategic Plan 2025-2027

- **Work Programme 2025**
- **Work Programme 2026-2027**

- Strong alignment to EU strategies and policies
- Product eco-design for reuse, repurpose, and remanufacture to unlock all possible paths to circularity going beyond recycling
- Chemicals and materials in line with Safe and Sustainable by Design framework (SSbD)
- Digital tools for value chain transformation
- New business models to enable circular and sustainable use of products and services
- Mobilising capital investments into circular and sustainable solutions

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- Horizon Results Platform

REA on LinkedIn

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#HorizonEU
#EUGreenDeal
#CircularEconomy
#ZeroPollution

Research and Innovation

CIMPA FINAL EVENT

Advancing the circularity of complex plastic films

Circular Plastics Cluster: joining efforts towards the circularity of plastic packaging

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CIMPA FINAL EVENT

Advancing the circularity of complex plastic films

20 November 2024
14:00-18:00
BluePoint Brussels

Policy Discussion: Challenges and opportunities for plastic films circularity

Wolfgang Trunk

Team Leader,
DG ENV, European Commission

Judit Guerra-Falcon

Senior Manager Technical Affairs and Circular Economy,
Plastics Europe

Lauriane Veillard

Policy Officer,
Zero Waste Europe

Alexandra De Schonen

Head of EU Affairs,
SUEZ

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