

# The path forward for PP mechanical recycling streams in Europe

# **FLEXIBLES TO RIGID**

A demonstration of recycling PP Mono-Material flexible packaging into rigid injection molded applications with industrial partners















### **Purpose & Objective**

The objective of this cooperation was to document in small but industrial scale (1 Ton per variable) the mechanical recycling of fully converted PP mono-material barrier laminates into rigid applications using an injection molding process with no impact of dilution of the PP recyclates (i.e. 100% r-PP). The aim of this work was to help the recycling industry increase their focus on sizable opportunities that exist in Europe to recycle flexible packaging into non-food contact rigid end-use markets.

#### **Key Findings**

INJECTION MOLDED CAPS WERE SUCCESFULLY PROCESSED WITHOUT ENCOUNTERING MOLDING DIFFICULTIES WHEN USING THREE PP-BASED RECYCLATES PRODUCED WITH BOTH BARRIER\* AND NON-BARRIER FULLY CONVERTED 3-PLY LAMINATES. MECHANICAL PROPERTIES WERE NOT SIGNIFICANTLY IMPACTED TO ADVERSELY AFFECT GOOD CAP FUNCTIONAL USE, IMPLYING ADEQUATE USE IN CAPS & CLOSURES NON-FOOD CONTACT END MARKETS.

#### Background

Jindal Films previously conducted a small scale (5kg per variable) demonstration of recycling PP-based barrier\* films and barrier laminates into injection molded shampoo bottle caps, thereby documenting the impact of select inks, adhesives, barrier and heat-seal layers. **The outcome of this work confirmed a good adequacy of PP-mono-material adhesive barrier laminates (OPP + print + adhesive + barrier-OPP\* + adhesive + PP sealant) for injection molding applications in non-food contact segments.** The injection molding assessment identified limited impact in most key properties, predominantly affected by printing inks and polyurethane adhesives commonly used in flexible packaging applications. All molded parts - primarily shampoo bottle caps - were injected with 100% of r-PP produced by Axion Consulting derived from shredded laminates provided by Jindal Films' applications laboratories.

In this scale-up work, **TOTALENERGIES** brought their expertise in Polypropylene (PP) resins, recycling of PP and injection molding. **JINDAL FIMS** provided their commercial printable OPP outer web and several barrier OPP webs for conversion. **PROFOL** provided a commercial heat sealable cast PP films used in flexible packaging markets. **EMSUR** printed the OPP film by flexography in their SPO plant in France and further solvent base laminated the various PP films to replicate industrial every day flexible packaging conversion. Formed packs were not produced - nor were they sorted - as these two steps are not considered to be critical for the demonstration or to affect the injection molding assessment.

Polypropylene resin grades for film applications are typically with high molecular weight (MW) or high viscosities (low MFI). As PP is re-extruded multiple times in the processing and mechanical recycling operations, the MW is reduced by chain-scission and moving in the direction of lower viscosities (MFI) required by injection molding processes. As PP does not cross-link - unlike several other polymers - the key properties are typically maintained in use and less likely to generate gels or unmolten particles.



# **Flexible Packaging**

Three PP films were used for printing and laminating 3-ply barrier PP-mono material laminates to replicate commercial packs in Europe for demanding barrier market applications. These laminates were printed by solvent based flexography in 3 colors using commercial PU inks and further solvent-free laminated using conventional PU adhesives. Three different middle-web OPP grades were inserted to document the impact of barrier technologies on the recycling of barrier flexible packaging streams for large volume end-use target primarily injection molding for future PP-recycling streams across Europe.

Commercial OPP grades were selected to represent commercial solutions currently used in the replacement of non-mechanically recyclable barrier structures, such as PET/ALU/PE, PET/Met-PET/PE, PET/PET-SiOx/PE or PET/PE-EVOH-PE. High barrier vacuum metallized (Metallyte<sup>™</sup>) and clear vacuum coated (Alox-Lyte<sup>™</sup>) films were used as the middle ply. A commercial low SIT cast PP from Profol GmbH was used as the inner web of the laminates.

Variable	Outer web	Print	Glue	Middle web	Glue	Seal web	% PP
Full PP benchmark	20 Coex OPP	3-color Flexo	SF adhesive	20 Coex OPP	SF adhesive	60 Cast PP	92.3%
Met-OPP variable	20 Coex OPP	3-color Flexo	SF adhesive	15Met-OPP	SF adhesive	60 Cast PP	91.9%
AIOx-OPP variable	20 Coex OPP	3-color Flexo	SF adhesive	16AIOx-OPP	SF adhesive	60 Cast PP	91.5%

Legend	Grades	Description and composition information
Adhesive	Solvent free PU	PU SB inks with 2g/m <sup>2</sup> per lamination step
Printing inks	Solvent based Flexo	PU based inks - 100% coverage White (1.6g/m²) + Yellow (1g/m²) + Magenta (1g/m²)
Coex OPP film	Bicor 20MB400	20µm BOPP sealant coex film - coextruded slip formulated grade
Met-OP film	Metallyte 15MM288	$15\mu m$ BOPP film vacuum coated with Aluminum on 1 side with high optical density
AlOx OPP film	Alox-Lyte 16A0893	$16\mu m$ BOPP film vaccum coated with Aluminum Oxide on 1 side
Cast PP film	Profol PL01SC cast PP	60µm cast PP sealant coex film - coextruded slip formulated grade



Mono-material compositions are described in the table and non-PP composition ranged between 7 and 9%, well within the CEFLEX design guidelines for circular economy **(www.guidelines.ceflex.eu)**.

The non-PP elements primarily consisted of polyurethanes, either as inks or adhesives layers.



More information can be obtained from the various partners.

## Recyclate (r-PP) Assessment

The laminates provided by **EMSUR** were shredded, densified and re-pelletized via an extrusion process as is commonly performed with recycling of flexibles. Extra antioxidants were added during the extrusion step, but no peroxide cracking was performed to adjust viscosity. **TotalEnergies** characterized the quality of the 3 recyclates (r-PP) in terms of injection molding key requirements, such as viscosity and thermal properties as well as ash content, which are higher mostly due to the pigment contained in the inks.

Key Resin Property	Units	r-PP with OPP laminate	r-PP with Met-OPP laminate	r-PP with AIOx-OPP laminate	PPH injection molded grade
MFI (2 measurements)	(g/10′)	10.7	13.8	12.8	~ 12
Ash content	(wt%)	1.4	1.9	1.5	0
DSC (20°C/min)					
Tm main peak	°C	159	161	160	~ 160
Тс	°C	116	119	116	~ 115
Melting enthalpy	J/g	74	72	70	

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More detailed information can be obtained from TotalEnergies.



Var. #2: OPP/ink/adh/met-OPP/adh/CPP

Var. #3: OPP/ink/adh/AlOx-OPP/adh/CPP

## **Injection Molding Assessment**

The three recyclates (r-PP) based on the 3-ply PP mono-material laminates from **Emsur** were used to perform an injection molding assessment, primarily in the segment of caps and closures with an aim to assess compatibility for non-food contact applications. Two different types of hinged caps were molded and resulted in relatively homogenous end-products at 100% load of the r-PP resins. The effect of dilution with virgin PP resin was not performed, but the mechanical properties were measured on classic injection bars and had slight deviations from pure PP results. **The color differences were not noted as impactful as in practice pigments will be added to most recycled resins.** 

Key Injection Molding Property	Units	r-PP with OPP laminate	r-PP with Met- OPP laminate	r-PP with AlOx- OPP laminate	PPH injection molded grade
Vicat A50	°C	137	138	137	152
Vicat B50	°C	61	61	60	84
Bending test on injected bar (ISO 178 A)					
Flexural modulus	MPa	1,291	1,300	1,292	1,450
Modulus at 1% elongation	MPa	1,173	1,180	1,174	
Tensile test on injected bar (ISO 527-1A)					
Tensile elastic modulus	MPa	1,104	1,124	1,114	1,550
Strength at yield	MPa	25.9	25.7	26.0	32.0
Elongation at break	%	147	460	122	
Izod notched impact at 23°C (ISO 180)					
Impact strength	kJ/m²	8.7	9.5	10.1	3.5



Var. #1: OPP/ink/adh/OPP/adh/CPP



Var. #2: OPP/ink/adh/met-OPP/adh/CPP



Var. #3: OPP/ink/adh/AlOx-OPP/adh/CPP

### Conclusions

The work performed with key industrial partners confirmed the conclusions from previous work performed with AXION, namely that fully converted flexible packaging with **various barrier\* technologies** can be used at a high loading in injection molding applications for end market segments like **caps & closures** but likely also numerous other non-food segments. The high MW/low MFI resins used for PP films are allowing the recyclates (r-PP) to be in the range required by most injection molding processes which can optionally be further adjusted by peroxide cracking.



#### **About Our Partners**



#### www.totalenergies.com

TotalEnergies develops, produces and commercializes polymers – polyethylene, polypropylene, polystyrene, their recycled equivalents and biopolymers – that can be incorporated in the plastics manufacturing process. Lighter than many alternative materials, they help reduce the carbon footprint of end-use applications through enhanced energy efficiency. TotalEnergies' polymers experts in Europe, Asia and the United States of America are working alongside all the professionals in the value chain, including plastic manufacturers, research centers, waste collection and sorting companies, and their customers to accelerate in the circular economy. The Company is developing different plastic recycling processes and using renewable raw materials, with the ambition to commercialize 30% circular polymers by 2030.



#### www.profol.de

Profol, was founded in 1980 in Halfing, Germany. At 7 locations on 3 continents, we develop cast PP films for a wide range of applications, such as packaging, furniture surfaces, flooring, office supplies, automotive and many more. Product solutions individually adapted to the respective requirements are one of our greatest strengths



#### www.emsur.com

Emsur is the division of the Grupo Lantero dedicated to the manufacture of flexible packaging solutions primarily designed for the food and dairy sectors, with both rotogravure and flexographic printing. Emsur currently has 8 production plants in 7 different countries with a workforce of over 1000 employees. Thanks to its global approach and dedicated customer service, Emsur sells flexible packaging solutions to companies in more than 60 countries in the Americas, Europe, Africa, the Middle East and Asia, with a distribution close to 1,000 million square meters.

#### PLEASE CONTACT US FOR MORE DETAILS.



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