PlastiCircle: *Improvement of the plastic packaging waste chain from a circular economy approach*

Grant Agreement No 730292

PlastiCircle
TOO VALUABLE TO WASTE

PlastiCircle Deliverable

D5.1: Specifications required by end users and comparison with sorted material [DRAFT]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730292.

PlastiCircle
TOO VALUABLE TO WASTE

Factsheet

Document name: D5.1: Specifications required by end users and comparison with sorted material

Responsible partner: Axion

Work package: WP5

Deliverable number: D5.1

Version: 1

Version date: 09/08/2018

Date due: M15

Dissemination level	
X	PU = Public
	PP = Restricted to other programme participants (including the EC)
	RE = Restricted to a group specified by the consortium (including the EC)
	CO = Confidential, only for members of the consortium (including the EC)

Author: Richard McKinlay

Reviewers: All partners

Abstract

This deliverable compares the requirements of the manufacturing partners with recycled material that is available on the market today.

Partners

1. ITENE: INSTITUTO TECNOLÓGICO DEL EMBALAJE, TRANSPORTE Y LOGÍSTICA
2. SINTEF: STIFTELSEN SINTEF
3. RTT: RTT STEINERT GMBH
4. AXION : AXION RECYCLING
5. CRF : CENTRO RICERCHE FIAT
6. UTRECHT : GEMEENTE UTRECHT
7. INNDEA : FUNDACION DE LA COMUNITAT VALENCIANA PARA LA PROMOCION ESTRATEGICA EL DESARROLLO Y LA INNOVACION URBANA
8. ALBA: PRIMARIA MUNICIPIULUI ALBA IULIA
9. MOV: MESTNA OBCINA VELENJE
10. SAV: SOCIEDAD ANONIMA AGRICULTORES DE LAVEGA DE VALENCIA Spain
11. POLARIS: POLARIS M HOLDING
12. INTERVAL: INDUSTRIAS TERMOPLÁSTICAS VALENCIANAS
13. ARMACELL : ARMACELL Benelux S.C.S.
14. DERBIGUM : DERBIGUM N.V.
15. PROPLAST : CONSORZIO PER LA PROMOZIONE DELLA CULTURA PLASTICA PROPLAST
16. HAHN : HAHN PLASTICS Ltd.
17. ECOEMBES : ECOEMBALAJES ESPAÑA S.A.
18. KIMbcn : FUNDACIÓ KNOWLEDGE INNOVATION MARKET BARCELONA
19. PLAST-EU: PLASTICS EUROPE
20. ICLEI: ICLEI EUROPASEKRETARIAT GMBH

Table of contents

Publishable summary

PlastiCircle aims to develop and implement a holistic process to increase recycling rates of packaging waste in Europe. This will allow to reprocess again plastic waste in the same value chain (i.e. Circular economy; closure of plastic loop). This process is based on four axes: collection (to increase quantity of packaging collected), transport (to reduce costs of recovered plastic), sorting (to increase quality of recovered plastic), and valorisation in value-added products (i.e. foam boards, automotive parts like engine covers/bumpers/dashboards, bituminous roofing membranes, garbage bags, asphalt sheets/roofing felts and urban furniture like fences/benches/protection walls).

This short report details the requirements of the manufacturers who will be using the recycled materials, and identification of the challenges they have found through the assessment of materials available on the market today. The Plasticircle project partners, products and polymers that are used in the products are given below in Table 1Table 2.

Table 1 Plasticircle partners and products investigated in study

Partner	Product	Polymer
Armacell	Foamed boards	Polyethylene Terephthalate (PET)
Centro Ricerche Fiat (CRF)	Automotive parts	Polypropylene (PP) PET
Derbigum	Bitumen roofing	PP
Hahn Plastics	Outdoor furniture and retention products	Low Density Polyethylene (LDPE) High Density Polyethylene (HDPE) PP
Interval	Refuse sacks bags	LDPE

Analysis by Armacell has shown that PET bottle flake is suitable for their product, however the PET from thermoforms is more challenging. More work is required to understand if the PET from thermoforms can be used.

CRF in collaboration with Proplast are developing formulations for using recycled PP and PET in automotive parts. There are challenges with the PET to ensure the material does not degrade during injection moulding, but it is an exciting potential market.

Derbigum have analysed PP and PE samples from the market, and the key for their process is to investigate how to transform crystalline PP into amorphous PP, so that more recycled content can be incorporated into the product.

Hahn already recycle large quantities of post-consumer waste in Germany and the UK, and are ideally placed in this project to ensure maximum recycling rates The key factor for Hahn is ensuing low PVC and PET levels.

Current LDPE film products are not likely to be fully suitable for Interval, who need high purity to ensure the quality of their end product. The developments in Plasticircle should lead to higher quality material which they could use.

Introduction

The Plasticircle project aims to develop additional end markets for recycled polymers derived from post-consumer household packaging waste.

Already there is successful recycling of post-consumer packaging, however in order to create more demand for recycled products, and therefore stimulate the industry further, research has been conducted in this project focused on five different products.

The Plasticircle project partners, products and polymers that are used in the products are given below in Table 2.

Table 2 Plasticircle partners and products investigated in study

Partner	Product	Polymer
Armacell	Foamed boards	Polyethylene Terephthalate (PET)
Centro Ricerche Fiat (CRF)	Automotive parts	Polypropylene (PP) PET
Derbigum	Bitumen roofing	PP
Hahn Plastics	Outdoor furniture and retention products	Low Density Polyethylene (LDPE) High Density Polyethylene (HDPE) PP
Interval	Refuse sacks bags	LDPE

Work has so far focused on existing recyclate on the market, as the Plasticircle pilots have not yet been carried out. This document is a draft, with the final report to be completed after the pilot trials have taken place.

1. Foamed PET boards

Armacell produce foamed PET boards that can be used as insulation or core boards for composite parts. Currently Armacell use washed PET flakes from PET bottles. Armacell use both clear PET and coloured PET, as the product is not usually visible to the consumer.

The aim of Plasticircle is to ensure Armacell can use the PET generated from the project in the engineered foams. More specifically, the challenge is to determine whether PET from thermoforms can be used as well as PET from bottles.

Product requirements

The main requirement for the recycled material is to produce a stable, even foamed structure.

There are certain characteristics of recycled PET that can affect the foam and therefore quality of the end product. These are:

- Intrinsic viscosity of the PET (0.73 average)
- Level of polyethylene or polypropylene (<0.5% polyolefin)
- PVC (<100 ppm)
- Polyamide (<500 ppm)

These contaminants can effect the reactivity of the foaming process and prevent an acceptable product from being made.

Preliminary test results

Five different samples were sent to Armacell for testing:

Sample	Bottle or thermoform	Post consumer (PC) or post-industrial (PI)	Notes
1	Thermoform	PI	Extruded and IV upgraded
2	Thermoform	PC	Extruded and IV upgraded
3	Bottle	PC	Hot washed flake
4	Thermoform	PI	Granulated PET thermoform made from sample 2
5	Thermoform	PI	Black cPET tray

Armacell analysed the materials according to internal testing standards for primary materials.

The flakes were tested for Intrinsic Viscosity (IV) and Carboxylic End Groups (CEG). Both the IV and CEG give an indication of the polymer chain length (low IV and high CEG denote short chains). Shorter chains, like those used in PET thermoforms, reduce the reactivity of the material, not allowing a stable foaming process.

Armacell add a Chain Extender (CE) which can rebuild the chains, thus in theory decrease the CEG an increase the viscosity.

The effect of the chain extender is measured by monitoring the viscosity of the melt over time. In the test method used by Armacell, a torque is measured as a value which is proportional to the viscosity at a fixed shear rate and temperture.

Samples were analysed and compared to a reference sample of Armacell's standard recycled PET from bottle flake.

Sample	CEG (mmol/kg)	IV	Max torque (Nm)
Reference	28 ±3	0.75	13 ±3
1	44.9	0.735	1.4
2	39.5	0.619	4.7
2 - Double CE	N/A	N/A	4.4
3	28.7	0.748	8.9
3 – Double CE	N/A	N/A	3.4
4	51.6	0.648	0.8
5	(awaiting result)	(awaiting result)	3.1

The analysis showed that only sample 3 (hot washed bottle flake) was suitable for use in the process, although the max torque was lower than the reference sample.

All other samples exhibited a very high level of CEG, and very low max torques, meaning the polymer chains were too short and the reactivity too low. Even doubling the concentration of chain extender had no effect.

The preliminary results therefore show that Armacell should be able to use clear and coloured PET bottles to manufacture foams, as is already done. The focus for Plasticircle should therefore be to determine what level of PET thermoforms could be used, and whether a mixed thermoform and bottle product could be viable.

2. Automotive parts

Centro Ricerche Fiat (CRF) is a research institute for Fiat, the automotive company. CRF investigate how to develop parts from new materials. In the automotive industry there is a significant usage of Polypropylene (PP) and Polyamide (PA).

Recycled PP is available from post-consumer packaging waste, but the usage back into automotive parts can be limited due to the levels of R&D that must be put into using this material. For recyclers alone they may not be able to justify the cost of R&D, and will therefore target lower value add products such as drainage piping.

Polyamine is not used in consumer household packaging in significant quantities, and so to investigate alternative feedstocks, CRF will be investigating using PET in place of nylon.

Product requirements

CRF have selected three parts to focus on in the Plasticircle project:

- Interior cap made currently using PA but will be made with PET in Plasticircle
- Dashboard air duct made using PP
- Bumper bracket made using PP

These products do not contain recycled material as standard, so the Plasticircle project will focus on incorporating recycled content.

The technical requirements of these parts are provided in the confidential technical appendix.

Preliminary test results

CRF have worked closely with Proplast to obtain and test samples of PET and PP for post-consumer household waste. A sample of coloured PET and coloured PP has been supplied by recyclers in Italy.

For the PP material, Proplast have investigated three parameters:

- Level of filtration – 1 mm and 200 µm used
- Influence of Polyethylene (PE) – 10% and 20% PE blends looked at
- Fillers – different levels of mineral and glass fillers

Results have been for the different blends and the results are provided in the confidential technical appendix.

The results are promising and shows that the finer filtration gives improved physical properties. Filling the PP with minerals and glass improved some properties, but recued the impact strength as expected. Proplast will be fine tuning the PP blend to improve impact properties.

The PET is a more challenging material to use in injection moulding applications. Because PET is unstable when molten (will absorb moisture and

degrade), the key to processing is to have the shortest possible cycle time in the injection moulder.

There are several additives that can be incorporated into the PET to improve the properties:

- Nucleating agent
- Processing aid
- High reinforcing filler
- Chain extender
- Stabilizers

Proplast have developed a comprehensive test schedule and are testing PET from bottles and thermoforms. Detailed results are available in the confidential technical appendix.

The initial results highlight the challenges with using PET in injection moulded applications, and Proplast will continue to formulate and optimise the injection moulding parameters.

3. Bitumen roofing membrane

Derbigum produce polymer modified bitumen roofing membranes. The polymer used to modify the bitumen is Polypropylene (PP). The polymer prevents the bitumen from becoming too soft in high temperatures or too brittle in low temperatures.

Product requirements

Derbigum use a mixture of amorphous (or Atactic) PP (aPP) and crystalline (or Isotactic) PP (iPP). The amount of polymer used in the bitumen blend is approximately 20%. In the blend aPP is the predominant component.

Amorphous polymer means the structure is less ordered, and polymer is more flexible and blends more easily with the bitumen. Crystalline PP is more rigid and brittle and has a higher melting point.

Derbigum ideally require amorphous PP in order to use a large quantity of recycled polymer.

Aside from the crystallinity, the level of PE must be very low as this can act as a nucleating agent and cause the polymer to become more crystalline. A melt flow index of 15 g/10 minutes is also needed.

Derbigum are also interested in using pure PE instead of PP, but the quality of the end product can be much lower, and as a result Derbigum do not use PE. The possibility of using PE will be investigated in the Plasticircle project.

Preliminary test results

Axion supplied Derbigum with a range of samples of PE and PP from post-consumer and post-industrial sources. The samples supplied are given in

Sample	Polymer	Post consumer (PC) or post-industrial (PI)	Notes
1	PP	PC	Material from Spain
2	HDPE	PC	Material from Spain
3	PP/PE	PC	R&D material from recycling of flexible packaging in the UK
4	PP	PI	PI metallised film
5	PP	PC	Recyclate from Netherlands
6	PE	PC	Recyclate from Netherlands

The preliminary testing showed that sample 4 could be used to replace the existing iPP without issue. However as this material is post-industrial the quality was higher as there was no PE. It is encouraging however that as this material was from flexible packaging, in theory PP from flexibles can be used by Derbigum.

Sample 5 was a high quality recycled PP from post-consumer household packaging. This had a small level of PE which is very difficult to eliminate from post-consumer material. With the existing quality, it could be used to replace a proportion of the iPP.

All other samples were not suitable for replacement in the existing product range. Derbigum will continue work to develop a product that can use PE rather than PP.

Unfortunately, none of the samples were useable to replace the larger aPP proportion of the blend. This is not surprising as the post-consumer waste stream is a mix of various grades of PP, and it is not possible to separate the amorphous from crystalline polymer.

A decision has therefore been made to investigate how the post-consumer recycled iPP can be transformed into aPP. Derbigum have researched this in the past, but with the growing cost of aPP and the lack of any recycled material available, it is now more viable to investigate.

4. Outdoor furniture

Hahn plastics are a leading manufacturer of outdoor furniture, such as benches and tables, as well as retention and ground work products.

Hahn use an intrusion moulding process to create plastic boards and planks, which can then be used to create a wide range of end products. The intrusion moulding process is less sensitive to contamination and so the process is ideal for recycled content.

Hahn operate a large recycling facility in Germany which takes in material collected from the kerbside of households through the DSD system. They also have a plant in the UK which takes in post-industrial material for recycling.

Product requirements

The requirements for Hahn are relatively low in comparison to the other partners, which is why their placement in the project is so vital as it means a mixed waste stream can be used.

Hahn's recycling facility in Germany can accept dirty waste straight from a Materials Recovery Facility (MRF). The main requirement for Hahn is for the material to be predominantly polyolefin (either PE or PP). Providing Hahn know what the material is, they can tailor the product blend to ensure a high-quality product can be created.

PVC is unacceptable, and PET is not desirable. PP, HDPE and LDPE are the target materials.

Preliminary test results

Since Hahn are already recycling this type of material, additional tests have not yet been carried out. Testing is being planned for later in the project.

Feedback from Hahn is that the specification of the LDPE produced by Ecoembes would be suitable for their recycling facility in Germany. The specification of this film is given in Table 3 below.

Table 3 Ecoembes film specification

Material	Specification
Flexibles (LDPE, HDPE, PP)	>82.00%
Contamination	<18.00%
PET	<1.00%
Metals	<1.50%
Rubber	<0.05%
Paper/carton	<2.50%
Other impurities	<9.00%
Moisture	<5.00%

5. Refuse sacks

Interval operate a recycling and production facility in Valencia. They recycle predominantly post-industrial LDPE films, and some agricultural LDPE films. A wet process is used to carry out a basic clean on the material, which is then extruded into pellet. The pellet is then blown into film products such as refuse sacks.

Product requirements

Interval produce a wide range of products. The most important criteria for the raw material used to produce the blown film are:

- No odour: Recycled LDPE film from post-consumer, household sources often has an odour once recycled. The odour can be minimised
- Maximum 5% PP: Typically, recycled film applications can handle up to 5% PP in the LDPE. Above this it is not possible to form a bubble during extrusion
- No PVC: PVC will degrade during extrusion and release gas
- Low levels of solid contamination: The recycled polymer will be put though a melt filter, but any contamination such as metal or glass could seriously impact the quality of the end product.

The level of moisture and contamination such as paper and organics that is acceptable for Interval is still being defined. Since their plant was designed for agricultural plastics the required process to recycle this material may be different from that which is currently in place.

Preliminary test results

Interval have inspected the film produced from MRF in Spain (as per the specification in Table 3). This film would not be suitable for the interval plant as the levels of contamination are far too high.

Materials from countries such as Germany with higher quality standards on the LDPE products from MRFs may be more suitable. The DSD standard for the film fraction is >92% film. Testing plans are being developed to test this type of material at the Interval facility, but obtaining a reference sample outside of the pilots is difficult.

6. Conclusions

Work in WP5 is onging and there are still technical challenges to overcome. There is however a very clear idea of what the issues are and the requirements of each of the manufacturing partners.

There is still likely to be a significant challenge surrounding PET thermoforms. This is a known issue in the industry, however a new facility has recently opened in the Netherlands which could provide further insight into how this material can be recycled.

The Plasticircle project will unlock new markets for recyclate from post-consumer household packaging, complimenting the existing end markets.