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Re-Vert

Redesigning products with recycled plastic feedstock

Business support – case study Re-Vert

Redesigning products with recycled plastic feedstock

As part of the TRANSFORM-CE project, several case studies will be done to assess the conditions that foster the uptake of recycled plastic feedstock in (new) products. This document covers the results of the case study at Re-Vert, based in France. A total of 20 case studies will be done, each representing one product to be (re)designed with recycled plastic. In depth support will be given to five cases per country (The Netherlands, Germany, Belgium and the United Kingdom).

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1. Introduction and method

1.1 Goal of case study

TRANSFORM-CE is an international research project about the uptake of recycled single use plastic (SUP) feedstock. A core part of this project is to provide in-depth business support to businesses willing to use recycled plastic materials in (new) products. The uptake of SUPs implies that companies in the plastic industry must make a major transformation. In order to gain a better understanding of the support required for the wider uptake of recycled plastics (such as SUP) by companies, 20 different case studies will be completed, documenting the conditions that foster the uptake of recycled feedstock. In line with the technologies of the pilot plants from the TRANSFORM-CE project, cases will represent either IEM[1] technology or AM[2] technology.

Thus, the aim of these case studies is twofold; 1) to support the case study company with their specific request to help foster the uptake of recycled plastic feedstock into one of the company's products, and 2) to gather insights into the conditions necessary to support the wider uptake of recycled plastics by using IEM and AM technologies. The case studies also present a unique opportunity to study the technical requirements for (re)designing products with IEM and AM. The learnings of the various cases and (re)designed products could serve as a proof of concept that provides the entire value chain with the insight and confidence to uptake recycled feedstock, creating circular economy opportunities for all stakeholders.

1.2 Case study process

The case studies are being carried out between September 2021 and December 2022. The case study process is structured in four steps[3], with an iterative approach at the end of each step. The first step (*initial diagnostic*) aims to establish a starting point and describes the challenge to be addressed. The second step (*circular product development*) captures basic information about the

[1] IEM: Intrusion-Extrusion Moulding (for low(er) value recycled material), a combination of two techniques to produce plastic products/components. With extrusion the polymer is being melted, thereafter the polymer is being forced into a shape (by using a mould).

[2] AM: Additive Manufacturing (for high(er) value recycled material), method of creating objects layer by layer according to a digital design.

[3] This work uses insights derived from other activities of TRANSFORM-CE, in particular the case study method of WPT3 D2.1: *Case study methodology - Researching good practices of circular economy business models.*

product (re)design and describes prototyping and testing leveraging IEM and/or AM technologies. The third step (*circular product management*) covers how to commercialise the new (or redesigned) product and describes the product's relevance for business and environment, creating a successful circular business model. The last step involves a wrap-up of the results and concludes with strengths of the redefined business model, an overview of the barriers and enablers for circularity, and learned lessons from the case study. The final result is a case study report, covering the previously established information.

The total case study can be seen as a package of business support (all steps). Yet, a specific type of 'in-depth support', chosen from the menu-card[4], will be done for each case study. This support differs from company to company and will be selected based on a first analysis of the case. Examples of in-depth support include: material testing, prototyping and production trials, implementation of technology and use of recycled filament.

An overview of the case study analysis process is shown in figure 1 on the next page. In order to obtain the results, a 'collaborative/participative' assessment is used to collect further information, which gives insights in the overall innovation process. At the end of the case study, an iteration will be done to validate the results. The reported results will be sent to the contact person by email, so this person can validate the results and check if something is still missing or if information has been misinterpreted. Any comments will be processed and the results will be adjusted accordingly.

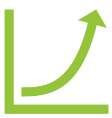
[4] An extensive list of the support possibilities is presented in a separate document '*Transform-CE support Summary*', describing the menu-card.

Step 1. Initial Diagnostic

- First assessment of company
- Establish starting point
- Describe challenge to be addressed
- State project goal

Step 2. Circular Product Development

- Describe product to be (re)designed
- Assess context in which product will be produced, used and marketed
- Design product
- Describe product's relevance for business and environment
- Create successful circular business model
- Prototyping and testing leveraging IEM and/or AM technologies



Step 3. Conclusion

- Wrap-up of results
- Strengths of redefined business model
- Summarise barriers and enablers for circularity
- Describe learned lessons

Report

- Succinct, yet informative case study report
- Excellent exposure opportunities for business

Figure 1: *Overview of case study process*

2. Step 1 – Initial diagnostic

The first step focusses on an initial diagnostic of the case study, which includes outlining the company profile, its wishes and the project goal.

2.1 Company profile

Re-vert, founded by Emilie François-Diehl and Julie Potier, supports local authorities, associations and companies in the management and reduction of their waste, by promoting local circular economy, re-use and social link. By organizing workshops and making a diagnosis of the needs through a life cycle perspective, it connects the different stakeholders so that resources have several lives.

Table 1: *Overview of company*

Topic	Information
Company name	Re-Vert
Website	https://www.re-vert.io/
Country	France
Size of company (0-10, 10-200, 200-500, 500+ employees)	0-10
Mission/vision	With Re-vert, you will change your perspective and thus: decrease your environmental impact, save time, make savings, have a responsible behaviour and image, be a player in the local ecosystem.
Value proposition	Re-Vert connects waste flows and transformers to provide circular solutions.

2.2 Current situation & challenge

Show-room glass lenses are single-use technical products that are not specifically collected nor recycled, though, being made of thermoplastic polymers, they could enter a loop of recyclability and become a new flow of resource. The challenge was to investigate the possibility for this waste flows to be used as a raw material for preparing 3D-printing filament for fused deposition modelling, that would have printability and functional performance comparable to those of commercially available filaments.

3. Step 2 – Circular product development

After creating a first analysis of the company and project, a more detailed assessment of the (re)designed product is made. This includes basic information about the product and an assessment of the context in which the product will be produced and used, as well as an analysis of the circularity of the product. Moreover, a more detailed design of the product is created, which goes hand in hand with prototyping & testing.

3.1 Circular product canvas

The new (or redesigned) product is investigated by using a circular product canvas (CPC). This model is created for the purpose of this study and covers the main aspects to consider in circular product design. The CPC of Re-Vert is visible in figure 2 and a description of each element is given below.

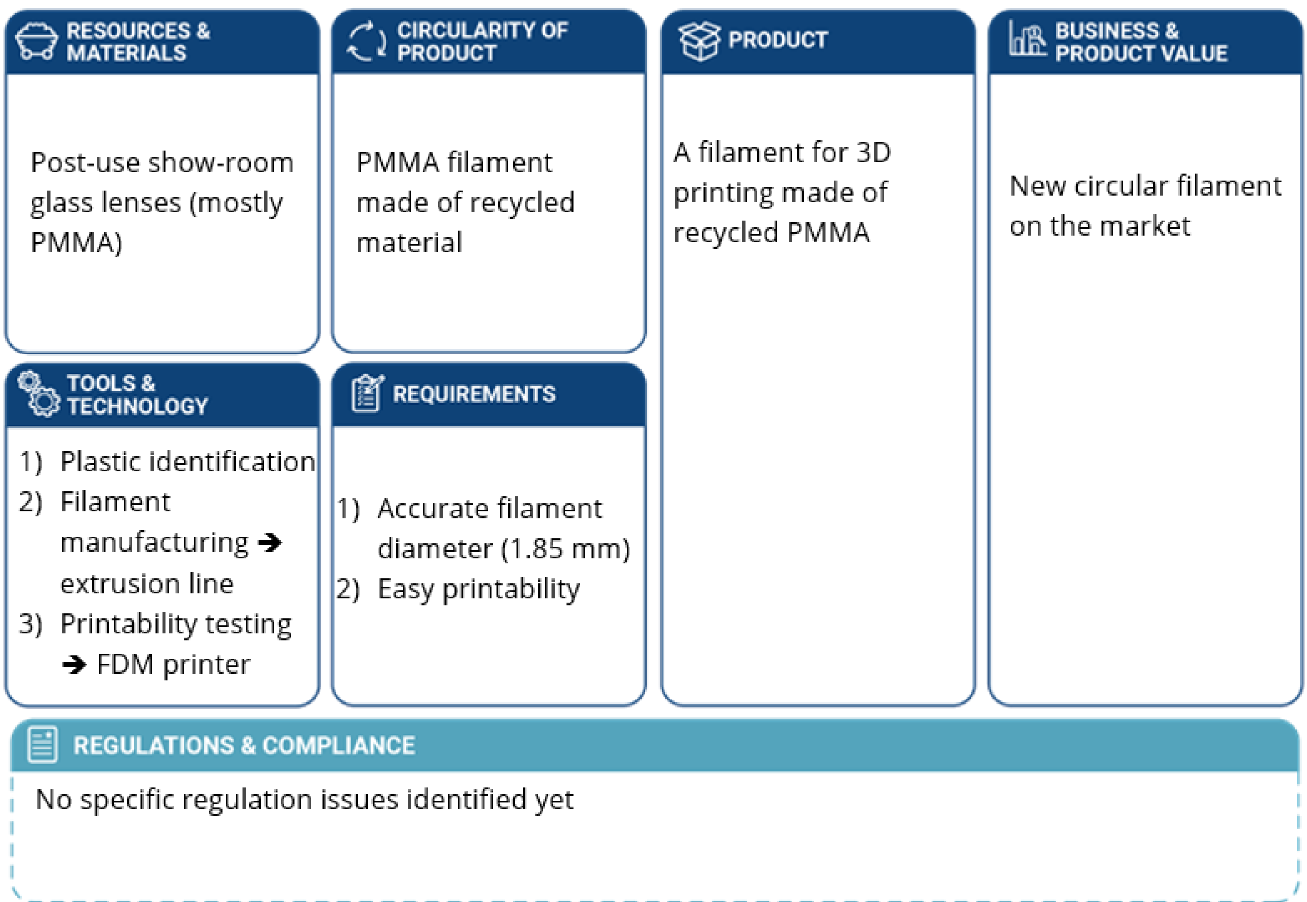


Figure 2: *CPC of rPMMA filaments for Re-Vert*

Product

The final product is a filament of recycled PMMA for 3D printing (figure 3). Re-Vert as such does not plan to produce and commercialise the filament but needs to ensure the feasibility of the recycling process to connect waste suppliers (optical shops…) with transformers and develop a circular initiative.

Figure 3: *rPMMA filament from show-room glass lenses*

Resources & materials

Re-Vert collected plastic show-room glass lenses from several optical shops with a view to find a way to valorise them by recycling. Though knowing that the majority of the lenses would be made of PMMA, there was a need to investigate the exact composition of the lenses batch, because it was known that some glass producers may use different materials. Both transparent and dark lenses were sent to Materia Nova to be treated (figure 4).

Figure 4: *Transparent and dark show-room glass lenses in thermoplastic collected by Re-Vert*

Tools & technology

For filament manufacturing from lenses, those have to first be shredded then processed in an extruder equipped with a cooling bath, a diameter control and a spool winder.

Circularity of the product

The filament could be fully made from recycled PMMA, from a waste resource that is currently not valorised though it is easily selectively collectible.

Requirements

The tolerance of the filament diameter must not be too wide around 1.75 mm or it will not work with the printer. If the filament is too brittle, it will break during the printing, that is the reason why it must be kept in a drying box. In order to keep the polymer melt flow constant, no bubbles must be imprisoned in the filament or they will explode at the exit of the nozzle leading to printing defaults.

Business and product value

No filament from recycled PMMA seems to be available on the market for the moment.

3.2 Support provided

Identification of the incoming waste feedstock

The raw material was received as a batch of transparent and dark show-room glass lenses. Some of them were engraved with the brand or label name (40 different brands). First, every lens was identified thanks to an infra-red scanning equipment (figure 5) and the mass proportions of each type of plastic is reported in table 3.

Figure 5: *Portable infrared scanning analyser used for identification of the material of the lenses*

Several different types of plastics were identified: poly(methylmethacrylate) as expected (PMMA), but also polycarbonate (PC), polystyrene (PS), poly(lactic acid) (PLA), polyamide (PA) and cellulose acetate (CA). PMMA is the most present of polymer in the glass lenses, both transparent and dark, with a higher proportion in the transparent ones. It was then decided to investigate further only with the transparent PMMA, to transform it into a recycled filament.

Table 2: *Plastic composition of the show-room glass lenses collected by Revert*

Type of plastic	% mass (transparent lenses)	% mass (coloured lenses)	comment
PMMA	91.5	80.6	
PC	1.44	8.4	
PS	0.54	/	
PA	1.05	/	only Lindberg brand
PLA	5.32	/	only Tom Ford brand
CA	0.15	3.05	
Not identified	/	7.93	

Pre-treatment of raw material

To be transformed, PMMA lenses were shredded in little pieces with a rotative grinder (figure 6). Ink stains (from marking in the optical shop for precise shaping of the definitive lenses) were previously removed with isopropanol. Some coloured spots remain however visible because of the coloured engravings for some brands. Before further transformation, PMMA flakes were dried at 65 °C during at least 12 h to limit degradation during processing.

Figure 6: *Shredded transparent PMMA glass lenses*

Filament manufacturing

Several attempts were necessary to find appropriate conditions for processing the flakes into a compliant filament. A high extrusion temperature (260°C) was needed, and a ventilation system was installed due to the degassing of acrylates vapours during PMMA processing. Use of individual protection equipment such as protective gas mask for the operator is also recommended.

Printability tests

In order to provide relevant information and guidance, printing tests were realised both with a commercially available PMMA filament and the manufactured rPMMA. The mechanical properties of the two were assessed by the impression of standard specimens (ASTM D638 Type I for the tensile properties and ASTM D256 for the impact resistance). Several tests were performed to find the best printing settings like the nozzle temperature for the commercial filament as well as the rPMMA one. Appropriate conditions were collected in a technical datasheet that was provided to Re-Vert. Filaments were kept in a heating desiccant box (50 °C) during printing and because of the emanations, the ventilation system of the printer was on.

The mechanical properties determined with the tests performed on the printed samples are reported in table 3. It it appears that rPMMA filament shows a more brittle behaviour than the commercial PMMA, with a higher Young modulus. This cannot be supposed to be a consequence of recycling as the grades are different. Indeed, many types of PMMA exist leading to different properties. It is not possible to know the virgin material properties, as mechanical specimens cannot be cut in the lenses, except by tracing up to the supplier material datasheet. If all lenses are made of the same grade PMMA, it would be useful, but if the sources are different, then the properties would depend on the blend.

However, rPMMA appears to be printable with an acceptable quality. The fact that the nozzle temperature must be lower than for the commercial filament and the brittleness of the printed products suggest that the polymer chains length (molar mass) is lower, which could be confirmed by complementary characterisations.

Table 3: *Comparison of the properties of rPMMA and commercial PMMA printed samples*

Properties	**commercial PMMA**	**rPMMA**
Impact resistance (kJ/m²)	7.6 +/- 0.8	2.1 +/- 0.4
Young Modulus (MPa)	1650 +/- 40	2820 +/-180
Stress at yield (MPa)	38 +/- 1	50 +/- 13
Strain at yield (%)	4.2 +/- 0.1	2.5 +/- 0.8
Stress at break (MPa)	33.6 +/- 0.8	50 +/- 13
Strain at break (%)	13 +/- 4	2.5 +/- 0.8

4. Step 3 – Conclusion and recommendations

After going through the previously described steps, a wrap-up is presented in this chapter. This includes identifying the strengths of the redefined business model in regards to circularity, describing the learned lessons from the case study project and providing recommendations for the next steps.

4.1 Strengths of the redefined business model

Circularity of the product

The feasibility study revealed that a 3D printing filament of good quality could indeed be prepared from transparent PMMA show-room glass lenses. This offers a way for valorisation of an easily collectible waste flow of single-use technic plastics, that is for the moment only collected as residual domestic waste and therefore not valorised. Such a recycled filament could be the first of its kind on the market.

4.2 Lessons learned

It appears that though more of 80% of show-room lenses are made of PMMA, a large variety of plastics is used for the rest of the flow. This would mean that if a recycling value chain is put in place based on this system, the recycler would have to invest in an equipment for sorting the lenses. Another option would be to raise awareness of show-room lenses producers and glasses brands that a standardisation of the products would be an asset to help developing this circular approach they could all benefit from.

As in other business supports aiming at developing 3D printing filaments from waste flows, it appeared that finding appropriate extrusion conditions may require time, and that a specific equipment may be needed for each kind of flow. In that case, a degassing system adapted to the extruder would be of interest.

4.3 What's next

This preliminary study was only conducted on the transparent lenses. The recyclability of coloured lenses should also be investigated.

It could also be interesting to investigate whether the pollution of the PMMA with a limited amount of the other materials currently used for this application would really prevent to obtain a printable filament, or if some contamination can still be tolerated.

Finally, since the r-PMMA filament obtained seems to be more brittle than commercially available PMMA filaments, it has to be investigated whether end-users would or not have interest in sing filament with such properties. In case there would be no market for such a material, further development work would be needed to improve the properties, for example by mixing with other grades of PMMA or other plastics that may lead to miscible blends such as PLA.

About the project

The problems associated with plastic waste and in particular its adverse impacts on the environment are gaining importance and attention in politics, economics, science and the media. Although plastic is widely used and millions of plastic products are manufactured each year, only 30% of total plastic waste is collected for recycling. Since demand for plastic is expected to increase in the coming years, whilst resources are further depleted, it is important to utilise plastic waste in a resourceful way.

TRANSFORM-CE aims to convert single-use plastic waste into valuable new products. The project intends to divert an estimated 2,580 tonnes of plastic between 2020 and 2023. Two innovative technologies – intrusion-extrusion moulding (IEM) and additive manufacturing (AM) – will be used to turn plastic waste into recycled feedstock and new products. To support this, an R&D Centre (UK) and Prototyping Unit (BE) have been set up to develop and scale the production of recycled filaments for AM, whilst an Intrusion-Extrusion Moulding Facility, the Green Plastic Factory, has been established in the NL to expand the range of products manufactured using IEM.

Moreover, the project will help to increase the adoption of technology and uptake of recycled feedstock by businesses. This will be promoted through research into the current and future supply of single-use plastic waste from municipal sources, technical information on the materials and recycling processes, and circular business models. In-depth support will also be provided to a range of businesses across North-West Europe, whilst the insights generated through TRANSFORM-CE will be consolidated into an EU Plastic Circular Economy Roadmap to provide wider businesses with the 'know-how' necessary to replicate and up-scale the developed solutions.

Lead partner organisation
Manchester Metropolitan University

Partner organisations
Materia Nova
Social Environmental and Economic Solutions (SOENECS) Ltd
Gemeente Almere
Save Plastics
Technische Universiteit Delft
Hogeschool Utrecht
Hochschule Trier Umwelt-Campus Birkenfeld Institut für angewandtes Stoffstrommanagement (IfaS)
bCircular GmbH

Countries
UK | BE | NL | DE

Timeline
2019-2023

www.nweurope.eu/transform-ce