Business support – case study
Bel Albatros

Redesigning products with recycled plastic feedstock
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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 Bel Albatros, based in Belgium. 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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Deliverable WPT3 D3.4 Redesigned products with AM
WPT3 D3.5 Redesigned products with IEM
WPT3 D3.7 Redefining Circular Economy business models
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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

\(^1\) 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.
the 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 focuses on an initial diagnostic of the case study, which includes outlining the company profile, its wishes and the project goal.

2.1 **Company profile**

Bel Albatros manufactures semi-finished products in the shape of large sheets with recycled PE from post-industrial plastic waste for multiple applications (worktop, table, pavement, etc.), with an artistic vision. Waste is collected in the Brussels region, then sorted out by type and colours, before being shredded and finally compression moulded. Most of the time, the product must be adapted, by milling or thermoforming, according to client or designers’ requirements and is sold afterwards as a recycled and recyclable alternative. A short overview of Bel Albatros is given in table 1. A deeper insight of the business model and products of Bel Albatros is provided in the Best Practice Case Study report also available for the TRANSFORM-CE website (https://bit.ly/3IIx237).

<table>
<thead>
<tr>
<th>Topic</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company name</td>
<td>Bel Albatros</td>
</tr>
<tr>
<td>Website</td>
<td><a href="https://belalbatros.com/">https://belalbatros.com/</a></td>
</tr>
<tr>
<td>Country</td>
<td>Belgium</td>
</tr>
<tr>
<td>Size of company</td>
<td>0-10</td>
</tr>
<tr>
<td>Mission/vision</td>
<td>“Make beauty with your waste” or “Nothing is lost, everything is recycled”</td>
</tr>
<tr>
<td>Value proposition</td>
<td>Giving a second life to post-industrial waste as useful items</td>
</tr>
<tr>
<td>Main activity</td>
<td>Collection, sorting, shredding and compression moulding of recycled polyethylene</td>
</tr>
</tbody>
</table>

2.2 **Current situation & challenge**

Bel Albatros suffers from a relative lack of knowledge about the properties of the secondary raw material they use, about the reproducibility of these properties depending on the sourcing, and about some final functional properties of their products. This may lead to an excess of non-compliant products and therefore of production waste. The challenge is to provide by selected characterisation methods a better understanding of the properties of the materials to enable designing process optimisation to lower the production waste rate and/or be able to enhance the production yield.
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 Bel Albatros is visible in figure 2 and a description of each element is given below.

![CPC of recycled polyethylene products for Bel Albatros](image)

*Figure 2: CPC of recycled polyethylene products for Bel Albatros*
Resources & materials
Bel Albatros collects post-industrial polyethylene waste directly from industrials or in partnership with Bruxelles Propreté.

Tools & technology
The tools and technologies used by Bel Albatros can be divided in two categories: pre-treatment and manufacture. First, the waste is sorted out depending on the type of plastic and the colour. Second, they are shredded when needed into small flakes or pellets in order to be transformable. Eventually, these flakes are heated and hot-pressed into 2.7 to 5.8 m long plastic sheets of different thicknesses with a hydraulic press. These large products are ideal for credenzas or worktops. For smaller items like tables or garden furniture, the sheet must be milled at the adapted size. Thermoforming is possible when specific shapes (e.g. curved back of a chair) are needed.

Product
Bel Albatros sells panels as intermediate products to designers but can also make finished products. produces functional objects,

Figure 3: Recycled HDPE sheet on the left, tables manufactured from the raw material on the right
Requirements
Bel Albatros manufactures and sells recycled products. Therefore, even if the product has an artistic dimension, with the colours, in addition to its sustainability aspect, it must show good mechanical properties as a virgin material would. The requirements may vary depending on the specific applications, but in many cases good flexural resistance and surface hardness are targeted. Warping issues also have to be controlled to limit the rate of non-compliant products.

Circularity of the product
Products are made from post-industrial waste and are therefore recycled. All products are mono material, without any additive incorporated, to ensure further recyclability. However, because of the durability of the product (supposed to last several decades), no re-looping tests have been performed yet to assess after how many cycles the material would lose its processing and functional properties.

Business and product value
From waste to useful and sustainable objects with moreover an artistic dimension, products are upcycled by the process of Bel Albatros and therefore have gained more value after the process than before.

3.2 Support provided
The aim of the support was to provide Bel Albatros, with selected characterisation tests, a better knowledge of the properties of their products and of the processability of their materials. Two types of products from recycled HDPE were studied (figure 4): natural recycled HDPE (nrHDPE) and red-coloured recycled HDPE (rrHDPE). The results were collected in datasheets sent to Bel Albatros and were discussed in a restitution meeting where process optimisations possibilities were also considered, based on the observed properties.
Evaluation of the thermal behaviour of the products

Differential Scanning Calorimetry (DSC) tests were performed on both products. The transition temperatures and transformation enthalpies are reported in Table 2. It appears that both materials have a very similar thermal behaviour. The melting peaks observed on the thermograms (not shown in this report) are monomodal, suggesting a good purity and homogeneity of the material. An exothermal peak around 230-250 °C may indicate a possible oxidation, suggesting processing the polymers under these temperatures (usually 190 °C for HDPE).

Table 2: DSC data of Bel Albatros HDPE panels

<table>
<thead>
<tr>
<th>Property</th>
<th>rrHDPE</th>
<th>nrHDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting temperature (°C)</td>
<td>133</td>
<td>134</td>
</tr>
<tr>
<td>Melting enthalpy (J/g)</td>
<td>170</td>
<td>170</td>
</tr>
<tr>
<td>Crystallization temperature (°C)</td>
<td>113</td>
<td>113</td>
</tr>
<tr>
<td>Crystallization enthalpy (J/g)</td>
<td>161</td>
<td>165</td>
</tr>
<tr>
<td>Theoretical melting enthalpy of 100 % crystalline HDPE$^5$ (J/g)</td>
<td>293</td>
<td>293</td>
</tr>
<tr>
<td>Crystallinity rate (%)</td>
<td>58</td>
<td>58</td>
</tr>
</tbody>
</table>

Evaluation of the mechanical properties of the products

Several mechanical tests were led to have an overall overview of the mechanical properties of the samples and particularly the tensile and flexural behaviour as well as the impact resistance.

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$^5$ Based on https://bit.ly/3moFwQI
**Tensile properties**

Tensile tests give information about the resistance of a material to uniaxial stress and its maximum elongation before break. Tensile specimens (ISO 527-1B) in both nrHDPE and rrHDPE were provided by Bel Albatros, milled from compression moulded panels. Four specimens of each were tested with a Lloyd LR10K tensile bench, at 5 mm/min. Results are presented in table 3.

<table>
<thead>
<tr>
<th>Property</th>
<th>rrHDPE</th>
<th>nrHDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young's Modulus (MPa)</td>
<td>1320 +/- 70</td>
<td>1250 +/- 100</td>
</tr>
<tr>
<td>Stress at yield (MPa)</td>
<td>21 +/- 3</td>
<td>23 +/- 2</td>
</tr>
<tr>
<td>Strain at yield (%)</td>
<td>8 +/- 2</td>
<td>8 +/- 0.5</td>
</tr>
</tbody>
</table>

The determined tensile properties are, again, similar, and close to those obtained for a virgin HDPE. Beyond the elastic zone, very high deformation were observed, especially for the case of nrHDPE as shown in figure 5. Though this behaviour at high deformation is of no use for the applications, it reveals a rather good homogeneity of the material in the panel, since defects such as air inclusions would have generated anticipated break of the samples.

![Figure 5: Ductility of the natural recycled HDPE beyond the limits of the tensile bench](image-url)
**Flexural properties**

3 points bending tests give information about the resistance of a material to stress when a perpendicularly strain is applied. The resistance of the panel in flexural tests is important for some potential applications where the panel could bear a load, such as tables or cupboards for example. Bending specimens milled from both panels were provided by Bel Albatros. Four specimens of each were tested with a Lloyd LR10K tensile bench, at 2 mm/min, up to 5 ‰ strain or break if it happens earlier (ASTM 790). Results are presented in table 4.

<table>
<thead>
<tr>
<th>Property</th>
<th>rrHDPE</th>
<th>nrHDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chord modulus (MPa)</td>
<td>1280 +/- 50</td>
<td>1290 +/- 100</td>
</tr>
<tr>
<td>Maximum stress (MPa)</td>
<td>26.2 +/- 0.2</td>
<td>26.6 +/- 0.6</td>
</tr>
</tbody>
</table>

No break occurred before the limit of 5 ‰ strain, which means that maximum stress corresponds to the stress at 5 ‰ strain. Both samples behave very similarly with a high resistance to bending and the reproducibility of the curves and low standard deviation suggest again a good homogeneity material. Chord modulus was determined between 0.25 and 0.50 ‰ strain, as an approximation of the flexural modulus.

**Impact properties**

Izod tests give information about the resistance of a material submitted to a collision by measuring the necessary energy to break a notched specimen, at a set speed with a calibrated hammer. Impact specimens (ASTM D256) of both nrHDPE and rrHDPE were provided by Bel Albatros. Four specimens of each were tested with a Ray-Ran pendulum bench, at 3.5 m/s, with a hammer of 0.653 kg. Results are presented in table 5.

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6 The same limits are used for the calculation of Young's modulus in tensile tests.
Unlike what was observed for the other properties, the two materials exhibit a different behaviour in terms of impact resistance: nrHDPE is very resilient, whereas rrHDPE presents a much lower impact strength, that remains however high enough for the applications, and rrHDPE can not be qualified as a fragile material. All the samples broke only partially, as shown in figure 6.

![Partial break of nrHDPE after impact test](image)

**Table 5: Impact resistance of Bel Albatros recycled HDPE’s**

<table>
<thead>
<tr>
<th>Impact strength (kJ/m²)</th>
<th>rrHDPE</th>
<th>nrHDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>7.4</td>
<td>19.6</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.7</td>
<td>3.5</td>
</tr>
</tbody>
</table>

**Hardness**

Shore D (ISO 868) measures give information about the hardness of a material to categorize it among other materials on a hardness scale. Four squares (30 x 30 x 4 mm³) of each recycled HDPE were tested (up and down) with an indenter, after 15 seconds of applying. Reproducible and similar values were obtained for both materials, that are consistent with those observed for a virgin HDPE (61 for rrHDPE, 62 for nrHDPE).
4. Step 3 – Conclusion and recommendations
Regarding the results of the different characterization tests, it appears that both natural and red-coloured recycled HDPE are competitive material for many applications, as a promising alternative to virgin material. Better homogeneity is noticed with the natural one and further investigation may be led to understand this phenomenon for the red-coloured one.

4.1 Strengths of the redefined business model

Circularity of the product
The circularity of the business model is not modified by the technical support that was provided here.

Product (re)design, testing and/or prototyping
The technical characterisations performed as a support for Bel Albatros enable the company to be confident in the mechanical properties of its products. Furthermore, Bel Albatros now owns enough information to provide technical datasheet in addition to its products, increasing the trust of its clients in the quality of its manufactured items. Process optimisations, especially regarding the processing temperatures, were discussed based on the determined thermal properties, that are likely to lead to a better stability of the panels and reduce warping issues.

4.2 What’s next
Further analyses may be performed to explore other properties, either on the semi-finished product or on the raw material as a processing optimization guide. Tests for process optimisations based on the results have to be performed. More systematic characterisations of incoming material, in particular regarding thermal and processing properties, should be considered for enhancing the reliability of the production process.
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